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Bread and Brain, Education and Poverty

The Proceedings of the Working Group
4-6 November 2013

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Bread and Brain, Education and Poverty

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The Proceedings
of the Working Group on

Bread and Brain, Education and Poverty

4-6 November 2013

Edited by

Antonio M. Battro
Ingo Potrykus
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The opinions expressed with absolute freedom during the presentation of the papers of this meeting, although published by the Academy, represent only the points of view of the participants and not those of the Academy.

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PONTIFICIA ACADEMIA SCIENTIARVM • VATICAN CITY

If the persons they encounter are living in poverty – said the Holy Father – it is necessary to help them, as the first Christian communities did, by practicing solidarity and making them feel truly loved. The poor living in the outskirts of the cities or the countryside need to feel that the Church is close to them, providing for their most urgent needs, defending their rights and working together with them to build a society founded on justice and peace. The Gospel is addressed in a special way to the poor, and the Bishop, modelled on the Good Shepherd, must be particularly concerned with offering them the divine consolation of the faith, without overlooking their need for "material bread".

Aparecida Document, 550, Fifth General Conference of the Latin American and Caribbean Bishops' Conferences, 13-31 May 2007
www.celam.org/aparecida/Ingles.pdf


R. VICUÑA
M. SANCHEZ SORONDO
P. TURKSON
W. ARBER


R. VICUÑA

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Preface

The Pontifical Academy of Sciences has a rich history of transdisciplinary meetings. Given the nature of the urgent and dramatic challenges regarding education and poverty and the broad spectrum of disciplines involved, this time we have decided to focus on some aspects that have been undergoing substantial improvements and may bring hope and practical solutions to the current situation. The pairing of "Bread and Brain" in the title of our Working Group refers to the new technologies to improve food and nutrition on the one hand and to the effects of poverty and malnutrition on neurocognitive development and education and how to overcome them, on the other. We have reached on both sides a high level of expertise that can guide policy makers in their decisions to bring solutions to the global emergency of millions of children of the new generations still deprived of food and nutrients and excluded from a most needed education, two conditions essential for human dignity.

In this spirit we have divided our meeting into four sessions to profit from the discussions of experts on brain development and education, food security and nutrition security that may converge towards integrated solutions to improve the quality of human life. We fully agree with Blessed John Paul II who, already in 1982, in his address to the Study Week of the Pontifical Academy of Sciences on Modern Biological Experimentation, organized by Professor Jérôme Lejeune, had stated the following: "I wish to recall ... the important advantages that come from the increase of food products and from the formation of new edible plant species for the benefit of all, especially people most in need". It's clear that this moral challenge also applies to the best use of the new technologies in the field of neurocognitive development and education today.

Those of us who are Christian ask "our" Lord for "our" daily bread, to give it to us, not to me only, but to others in common with me, to my brothers and sisters, which means providing them with sustainable nutrition, healthy brain development, good education and, finally, the supersubstantial bread of Jesus Christ.

Antonio M. Battro, Ingo Potrikus,
Marcelo Sánchez Sorondo

Programme

Monday 4 November 2013
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Chairperson: Antonio M. Battro
16:00 *Word of Welcome*
H.Em. Card. Peter Kodwo Appiah Turkson
Werner Arber
16:10 *Introduction*
Antonio M. Battro and Ingo Potrykus

neurocognitive development and poverty
16:15 **Martha Farah**
Brain Development in Poverty
16:45 Discussion
17:05 Coffee break
17:35 **Juan Llach**
Long-Term Effects of Early Childhood Education
18:05 Discussion
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Biological and Sociocultural Determinants of Neurocognitive Development: Central Aspects of the Current Scientific Agenda
18:55 Discussion
19:15 Dinner at the Casina Pio IV

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Chairperson: Ingo Potrykus
the effects of nutrient deficiencies, especially micro-nutrient deficiency on human development
9:00 **Joachim von Braun**
Food and Nutrition Security – The Concept and its Realization
9:30 Discussion
9:50 **Robert Zeigler**
The Continued Need for More Food – Contributions from the CGIAR
10:20 Discussion

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11:10 **Konrad Biesalski**
The Tragedy of Hidden Hunger – Man Can Not Live on Bread Alone
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The Importance of Micronutrients for Economic Development
12:30 Discussion
12:50 Lunch at the Casina Pio IV

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SCHOOLING AND POVERTY: HOW EDUCATION CAN ENHANCE QUALITY OF LIFE AND EQUITY IN POOR POPULATIONS
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Educating the Children of Immigrants for the 21th Century
15:30 Discussion
15:50 **Daniel P. Cardinali**
Sleep and Quality of Life in Urban Poverty
16:20 Discussion
16:40 Coffee break
17:10 **Maryanne Wolf**
The Reading Brain, Global Literacy, and Fighting Poverty. Child by Child
17:40 Discussion
18:00 **Antonio M. Battro**
A Digital Educational Environment in Poor Populations
18:30 Discussion
18:50 **Abel Albino**
Investing in Intelligence
19:20 Discussion
19:40 Dinner at the Casina Pio IV

WEDNESDAY 6 NOVEMBER 2013
MORNING SESSION IV
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INTERVENTIONS TO ACHIEVE NUTRITION SECURITY
8:30 **Howarth Bouis**
Biofortification

9:00 Discussion
9:15 Departure by bus to the Domus Sanctae Marthae
9:30 Group photo with Pope Francis
10:00 **Klaus Kraemer**
Supplementation
10:30 Discussion
10:45 Coffee break
11:00 **C.S. Prakash**
Biotechnology for Developing Countries
11:30 Discussion
11:50 **Robert Paarlberg**
The Consequences of the Anti-GMO Campaigns
12:20 Discussion
12:40 **Ingo Potrykus**
Lessons from Golden Rice
13:10 Discussion
13:30 General discussion and Final Statement
14:20 Lunch at the Casina Pio IV

List of Participants

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Scientific Papers

Neurocognitive Development and Poverty

Socioeconomic Approaches to Long Lasting Effects of Early Childhood Education

Juan J. Llach

Most of the academicians and professionals that study from different perspectives the effects of early childhood education coincide that it has a key and long lasting role on educational attainments and on life's opportunities and quality as well. However, evidences on this relationship are much less conclusive than convictions about it, perhaps because of the intrinsic difficulties to test social hypotheses. This is problematic both for the advancement of science and at the time of giving advice to educational practitioners either in schools or in governments. This paper aims to shed some light on this difficult question analyzing the contributions that arise from recent socioeconomic literature.

1. The social gradient and its mysteries

It is very clearly established in the literature the existence of a positive sloped social gradient in most of the relationships between socioeconomic status (SES) and, on the other hand, education and health outcomes. This means that at the time of analyzing the access of different human populations to most of the scarce goods the lower the children' SES, the lower will be, for instance, the quality of nutrition and stimulation received at early ages, the lesser their attendance to kindergarten and the lower the educational outcomes at early ages. Figures 1 and 2 show two clear examples referred to standardized test scores in primary school. The first one is from the U.S. and shows, additionally, that socioeconomic differences widen from 6 to 12 years old. Figure 2 is from Argentinean census-based standardized test scores at the age of twelve. The social gradient is very clear there but, at the same time, it's evident that the dispersion of the points resulting in a R^2 of just 0.50 is high enough to pose as many questions as answers. Figures 3 and 4 add some international perspective, the first one showing the countries' SES as determinants of the PISA standardized test scores and the second one reminds us that another kind of social gradient, although weaker, also exists and it is the one that positively associates educational outcomes and equity.

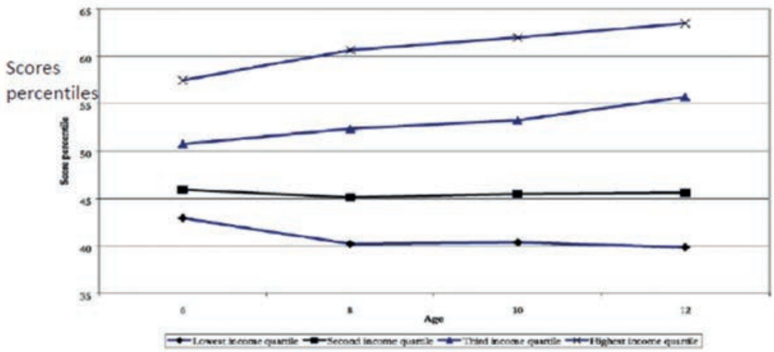

Figure 1. PIAT Math score by income quartile. Source: F. Cunha, J.J. Heckman, L.I. Lochner and D. V. Masterov (2006).

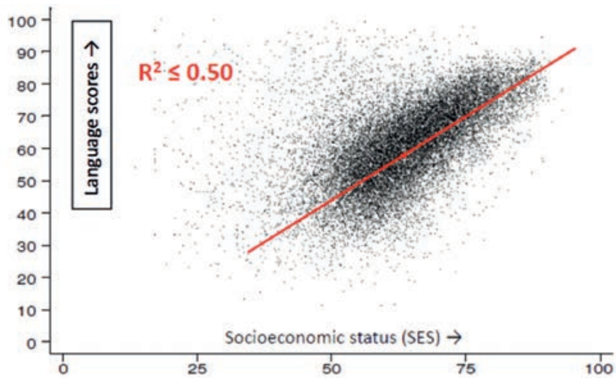

Figure 2. The gradient (I). Language scores and SES, 6th year primary school, Argentina. Source: J.J. Llach *et al*. (2006).

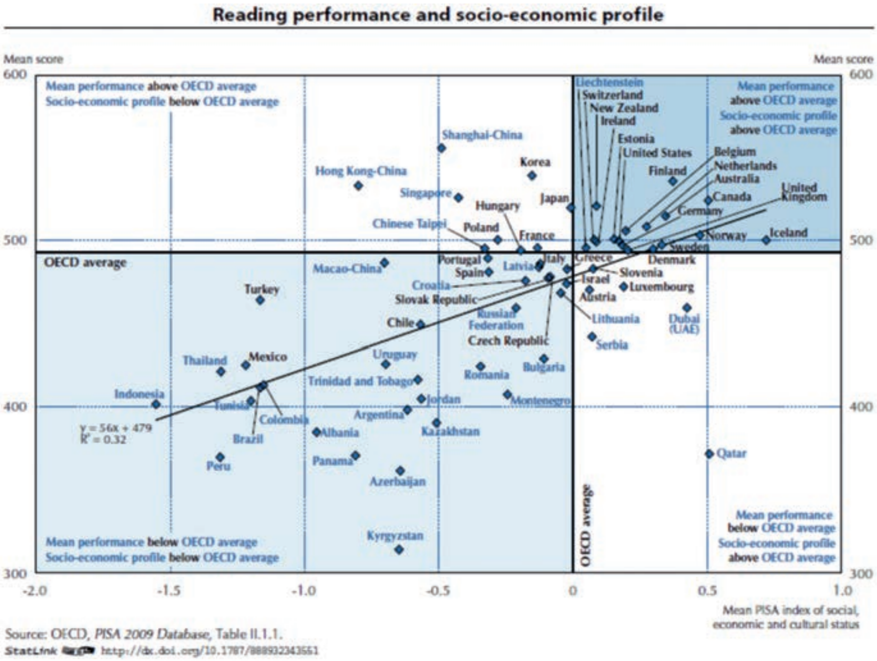

Figure 3. The gradient (II). PISA math performance and national averages of students' SES.

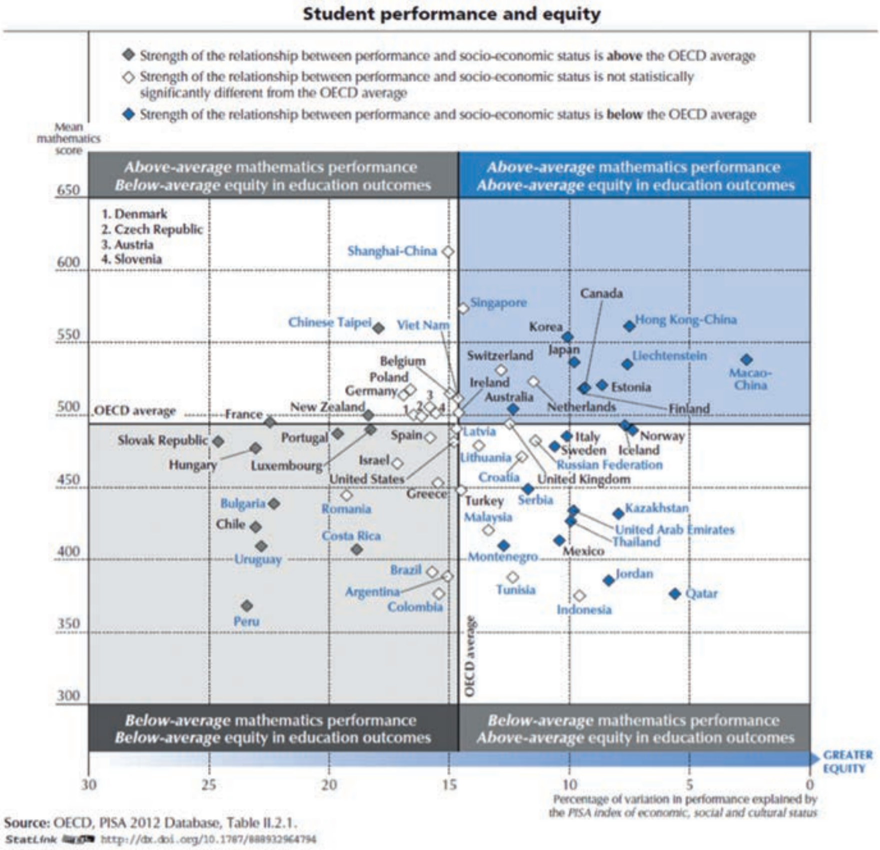

Figure 4. Equity and high performance are not mutually exclusive.

2. Economists' approaches

2.1. Heckman's neuroscience aware research program

James J. Heckman (Nobel Prize in economics) and his team are perhaps the social scientists that in the last ten years have given the most valuable and permanent contributions to the knowledge of the long-lasting effects of early childhood interventions and education.[1] Synthesizing the outcomes in the middle of the road Heckman presents the following stylized facts.

Nine stylized facts[2]

1) Abilities matter. Cognitive ability is a powerful determinant of wages, schooling, low crime participation and success in many aspects of social and economic life including health.

2) Abilities are multiple. Non-cognitive abilities like perseverance, motivation, time preference, risk aversion, self-esteem, self-control have direct effects on wages (controlling for schooling), schooling, teenage pregnancy, smoking, crime and achievement tests.

3) The nature versus nurture distinction is obsolete. Modern literature teaches that the sharp distinction between acquired skills and ability is not tenable. Behaviors and abilities have both a genetic and an acquired character.

4) Cognitive and non-cognitive ability gaps between individuals and across socioeconomic groups open up at early ages (Figure 1).

5) There is compelling evidence of critical periods in child development. Different types of abilities appear to be susceptible to manipulation at different ages. While IQ scores become stable by age 10, adolescent interventions can affect non-cognitive skills. The later remediation is given to a disadvantaged child, the less effective it is and, for many skills and human capabilities, later intervention for disadvantage may be possible, but it is much more costly than early remediation to achieve a given level of adult performance.

6) Interventions targeted toward disadvantaged adolescents have low returns but the contrary is true for remedial investments in young disadvantaged children, because of the dynamic complementarity and self-productivity mentioned below.

7) If early investment in disadvantaged children is not followed by later investment, its effect at later ages is lessened. Investments at different stages of the life cycle are complementary and require follow up to be effective.

8) The effects of resource/credit constraints on a child's adult outcomes depend on the age at which they bind for the child's family.

[1] See https://www.heckmanequation.org/ and http://heckman.uchicago.edu/
[2] J.J. Heckman (2007).

9) Socio-emotional (non-cognitive) skills foster cognitive skills and are an important product of successful families and successful interventions in disadvantaged families.

Capabilities formation model[3]

These stylized facts come from an analysis framed in the main methodological approach of economists to early childhood and human development, i.e., the human capital (HC) model in which wages are a function of investments in HC that increase capabilities (C) and productivity. Both HC and innate abilities are inputs to human capital production function but the model has tended up to now to concentrate only on cognitive abilities. Cognitive (C) and non-cognitive (NC) capabilities plus the health stock are functions of nature, nurture and investments in HC. The technology to produce HC is multi-stage and flexible in such a way that inputs can vary. There are critical stages for interventions such as nutrition, stimulation or formal education. There are three other relevant traits of children' development technology.

1. *Self-productivity*: Ct = (g) C_{t-1}, meaning that current (time t) capabilities depend on capabilities acquired in the previous state (t-1). For instance, emotional assurance in t-1 can influence eagerness to explore and cognitive development in t.

2. *Dynamic complementarity*: current (t) capabilities can influence the productivity of investments I in HC performed in the following state (t+1), so I_{t+1} = (j) C_t.

3. *Multiplier effects*: meaning that self-productivity and dynamic complementarity interact in such a way that capabilities at time t-1 could influence productivity of investment performed at t+1 through their influence in capabilities at time t.

In other words, both HC accumulation and C development are dynamic processes in which skills got in t-1 affect initial conditions and learning technology at the following stage t. It is unfortunate that these dynamics give place to early and many times persistent abilities' gaps between individuals and between SES groups (gradients)

Non-cognitive or socio-emotional capabilities

> Hence to value schools, by length instead of quality, is a matchless absurdity. Arithmetic, grammar, and the other rudiments, as they are called, comprise but a small part of the teachings in a school. The rudiments of feeling are taught not less than the rudiments of thinking.

[3] F. Cunha, J.J. Heckman, L.I. Lochner and D.V. Masterov (2006).

> The sentiments and passions get more lessons than the intellect. Though their open recitations may be less, their secret rehearsals are more.
> Horace Mann (1867)

Although parents and educators have known since long ago the role of non-cognitive or socio-emotional capabilities they have also been frequently forgotten.[4] Some social scientists, including Heckman and his team, have been recently "rediscovering" their critical role for personal development. NC capabilities include among others self-esteem, perseverance, planning ability, motivation, pro-activity and ability to socialize. Heckman and his team emphasize that NCCs are negatively associated to behaviors like alcohol and smoking addictions, adolescent pregnancy, crime, dependence on subsidies, drop outs and unemployment or low-quality employment. They also find that some current educational policies inspired by a biased idea of accountability could lead to perverse incentives like educating for the tests. In addition, NCCs are frequently omitted in research and much more in educational policies because of difficulties in measuring and dealing with them and also because of the belief that they only depend on parents. However, Figure 5 shows that college graduation increases students' stock of NCCs while those with GED certificates have the same NCC stock as dropouts.

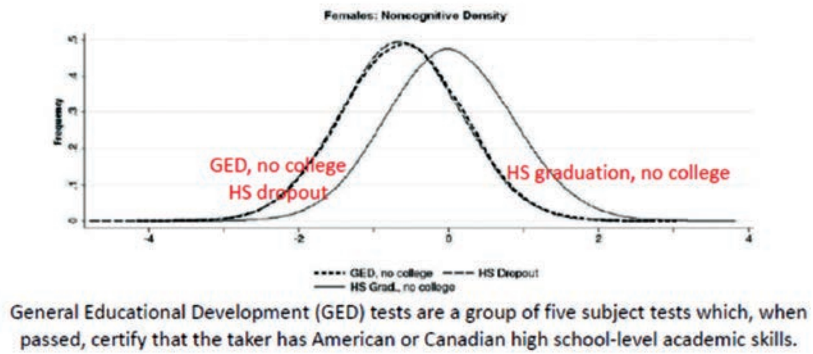

Figure 5. Non-cognitive capabilities by educational status. No college sample, all ethnic groups. Source: J. J. Heckman, J. E. Humphries and N. Mader (2010).

[4] One of the reasons of the oblivion could be the sometimes unilateral insistence on standardized tests that are not easily applicable to the study or non-cognitive capabilities.

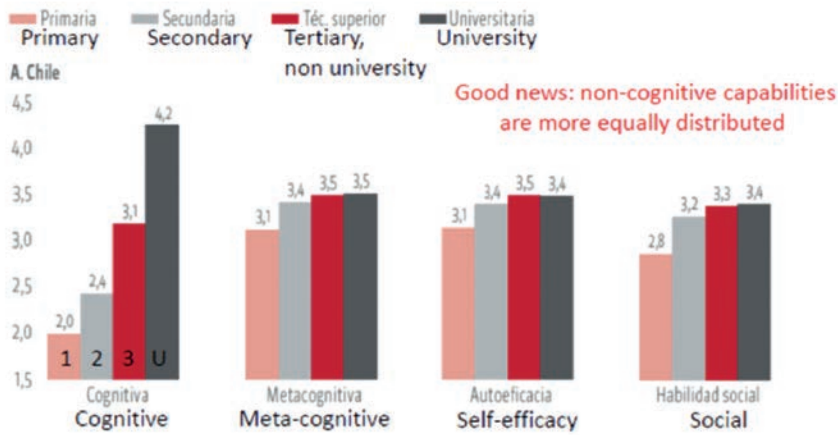

Figure 6. NC capabilities in Chile according to education levels. Source: IDB (2012).

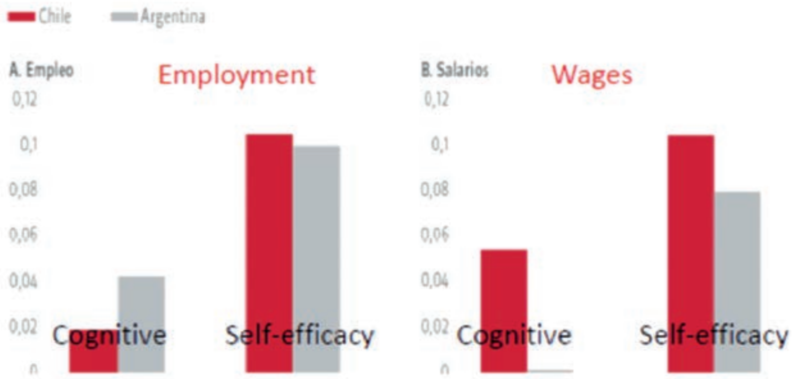

Figure 7. NC capabilities and labor market outcomes in Argentina and Chile. Source: IDB (2012).

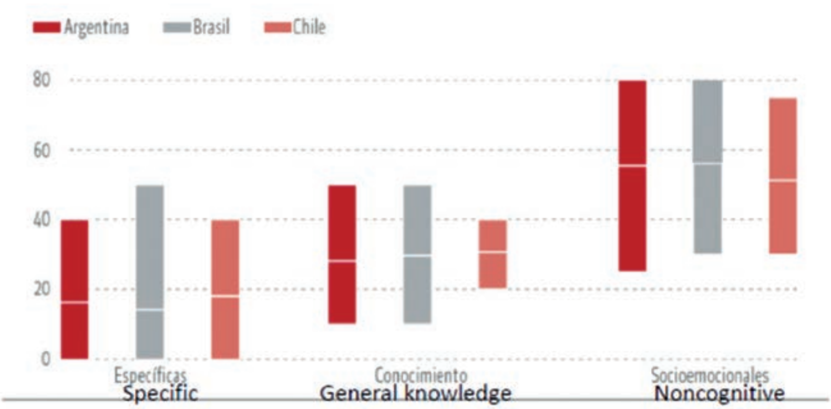

Figure 8. C and NC capabilities in Argentina, Brazil and Chile as valued by employers. Source: IDB (2012).

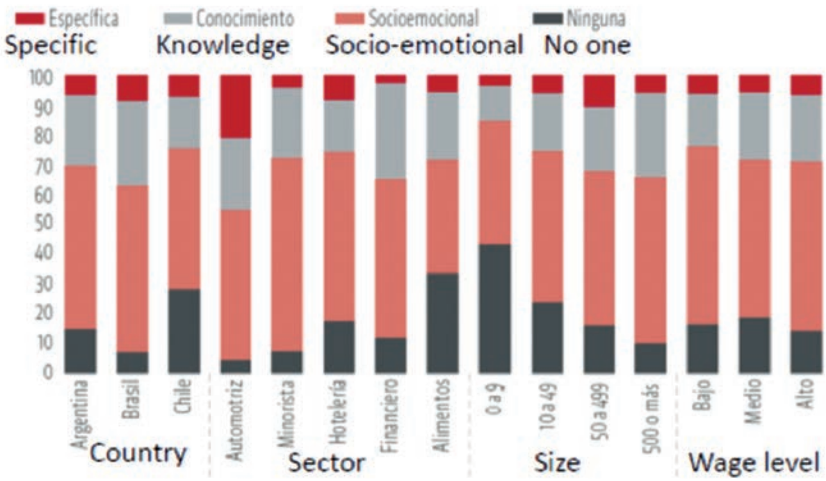

Figure 9. Perceived scarcity of C and NC capabilities in Argentina, Brazil and Chile. Source: IDB (2012).

The good news shown in Figure 6 is that NCCs are more evenly distributed than cognitive ones. This is even more relevant if we take into account the relevant role of NCCs in labor market success (Figures 7 and 8). Figure 9 reminds us they are scarcer than CCs and, together with the previous ones, it conveys to us the message of the importance of incorporating the teaching of NCCs in the curriculums.

2.2. Empirical results of human capital theory and the education production function

The empirical evidence of human capital theory is solid as regards, first, the positive association between more years and degrees in education and, on the other hand, better employment, more income and more non pecuniary benefits. Secondly, there is also good evidence showing that more education leads to more economic growth, and vice versa.

Unfortunately, empirical results are less clear-cut as regards learning quality. Emerging countries have significantly increased investments in education and this has had positive effects on enrolments and graduation rates, but not many of them have increased learning quality too. At the time of explaining educational outcomes economists have mostly used the approach called "education production function" in which the outcome = f (SES, schools, teachers, peers, geography... and error). When the approach is applied to assess which factors are associated to learning levels, results can explain at most 50% of the variance. P.W. Glewwe *et al.* (2011) analyzed more than 9000 papers published between 1990 and 2010, in both education and economics literature, to investigate which specific school and teacher characteristics, if any, appear to have strong positive impacts on learning and time in school in developing countries. They finally choose the most methodologically accurate (first 79, then 43, including 13 random experiments) and found that most of the schools' and teachers' traits were not statistically significant as regards learning. Additionally, most of the variables that showed significant effects were self-evident and, for that reason, not very relevant as guidelines of renewed educational policies. Among those variables were the physical capital of schools and its maintenance – which frequently also captures the quality of school's management – teachers with greater knowledge of the subjects they teach, longer school days and tutoring, while the absence of teachers showed a clear negative effect on learning.

Figure 10 adds new information to Figure 2 as it emphasizes that there is not a sort of "gravity law" relating SES and educational outcomes but rather a big dispersion of results. Classrooms whose students have the same SES can get either 90 or 20 points in the test scores. This can be called "the

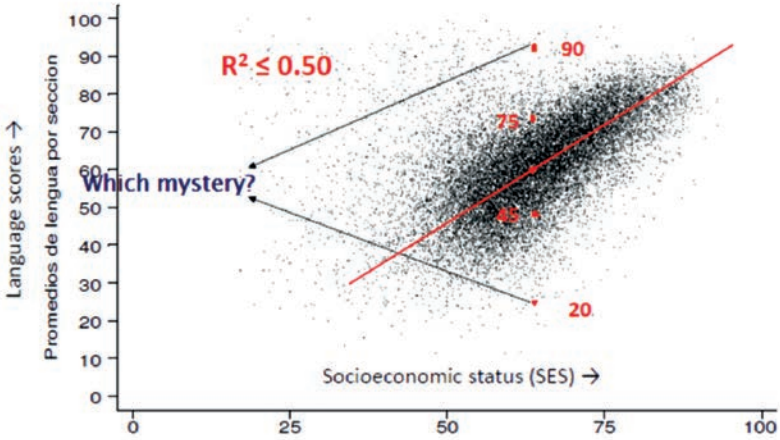

Figure 10. The gradient (III). Language scores and SES, 6th year primary school, Argentina. Source: Juan J. Llach *et al.* (2006).

classroom mystery" because in spite of the enormous quantity of studies our knowledge of the effects of educational practices or policies on student learning is poor. But the mystery is per se a very good piece of news because it gives room to the effectiveness of those practices and policies. Among them, some of the most explored in the very recent years have been school organization, incentives and accountability but no conclusive evidence has been obtained up to now. Of course, educational practices and policies compete with many other "candidates" aspiring to explain the mystery, such as non-cognitive capabilities or family and peer qualities other than the SES.

2.2.1. Natural and random experiments on early childhood [5]

In spite of the absence of conclusive evidence coming from the aforementioned studies it is useful to know the results obtained by the most rigorous studies.

2.2.1.1. Perry Preschool Project

An intensive preschool program applied to 53 Afro-American children from low-income families and IQs between 75 and 85 in five waves, between 1962 and 1967 (Ypsilanti, Michigan). The control group had 68 children

[5] In J.J. Llach *et al.* (2009) there can be found both a revision of part of this literature and a large bibliography.

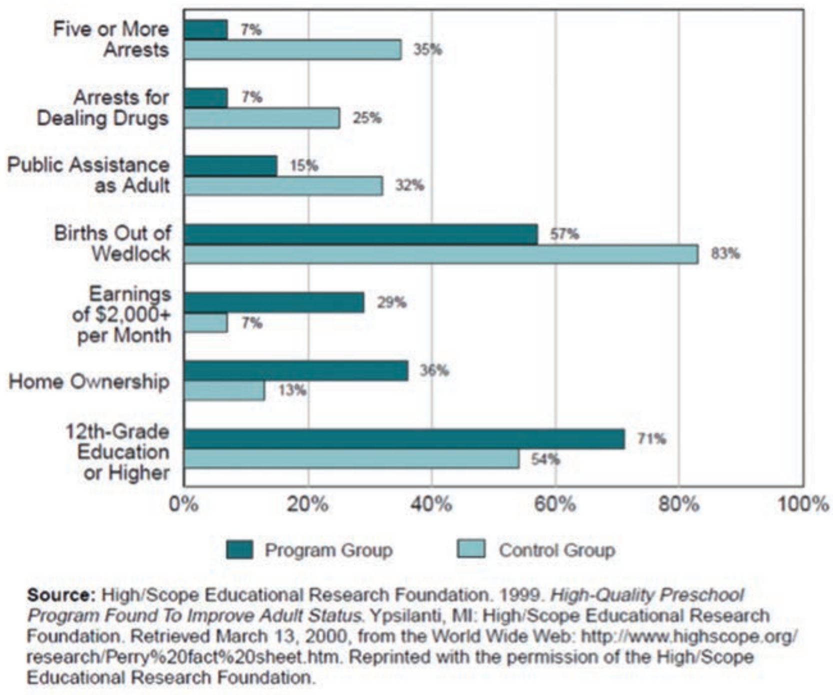

Figure 11. Major findings: Perry Preschool project's participants at 27 years.

and the treatment included extra classes plus ninety-minute visits to children's homes to include the mother in the process.

Measurements were taken up to when the children were 40 years old. In addition to the results shown in Figure 11 the policy had substantive impacts on intellectual development (not necessarily IQ), a 28% increase in HS graduation rate and employment quality. The economic benefit/cost analysis of the policy was also very positive, with a ratio of almost 5:1 and most of the benefits came from lower crime. Other sources were more fiscal income because of better employment, and lower court costs, losses of crime victims and costs of special education. Finally, the parents also improved both their education and labor status, which implies that the Perry Preschool Project had long-term effects on household welfare.

2.2.1.2. Other studies

Lowering the children/teachers ratios plus some parents' participation, the Chicago Child Parent Center (since 1967) found after twenty years similar outcomes to those of Perry.The Abecedarian project (since 1972) was applied in primary schools to high-risk kids, also lowering pupil/teacher ratios and increasing parents' participation. At 21 years old it found a non-permanent IQ increase, permanent improvements in math and language, more youngsters studying in university and an increase in mothers' educational and income levels. J. Colombo and S. Lipina (2005) applied special preschool training to basic and non-basic needs kids, 3-5 years old, and leveled both groups' outcomes by the end of the experiment. S. Berlinski, S. Galiani and P. Gertrel (2006) found that one additional kindergarten year produced better learning performance and non-cognitive capabilities. Finally, the Lobería Project (Province of Buenos Aires, Argentina, 2002) performed local community training on child development that increased kids' intellectual and emotional abilities.

2.2.1.3. Synthesis of other natural experiments

As regards dependent variables, positive but modest[6] outcomes can be found from different educational policies – with some relevant exceptions. Results are stronger in "quantitative" variables like attendance, enrolment or graduation than in "qualitative" or labor variables like standardized test scores, income or wages. Regarding independent variables, i.e. those that include educational practices of policies, the strongest results have been found with better preschool quality and classroom size measured by pupil/student ratios, particularly in low SES students. Effects of other policies like conditional scholarships or cash transfers, work-oriented training, longer school days and some meals provision in the case of kindergarten are positive but weaker. At a third level of effectiveness appear more school buildings effect on attendance, provision of school uniforms, also on attendance and longer school years on tests and promotion. At the lowest level of effectiveness, although positive, appear the few studies performed on peer effects, schooling support and free delivery of learning materials. Finally, wholesome experiments like those applied to charter schools and integral reforms are up to now mostly inconclusive because of serious problems in statistically identifying independent variables.

3. Conclusions: Beginning with the youngest and the poorest, the safest way to educational justice

In spite of the advancement of research in educational practices and policies in the last couple of decades we are yet far from being sure which

[6] Modest means improvement of less than 0.3 standard deviations, less than 0.5 educational years or less than a 10% increase in others dependent variables.

is the best advice to give to education practitioners and policymakers. To help them improve the academy has prior duties to perform. The most important of them is to get involved much more than in the past in interdisciplinary and applied studies. Literature coming from the neurosciences, educational sciences, sociology, psychology or economics is most of the time completely unconnected and tends to dodge applied approaches. A more collaborative and, in a way, closer to reality stance would probably have positive effects on enlightening the advice to give to practitioners in schools, governments and NGOs. An example of the cost of this isolation is that the new hope coming from the neurosciences is almost mostly unknown to practitioners, and educational systems are thus almost immune to the possibilities that the knowledge of brain plasticity has opened to educational outcomes in disadvantaged contexts, including the enhanced power to compensate up to around the age of 10 deficiencies in children that have not been appropriately stimulated or even nurtured.

Notwithstanding so many uncertainties on these issues broad consensus exists on some simple truths than can be summarized by saying that *beginning with the youngest and the poorest is the safest way to educational justice*. This could avoid or at least temper realities like the one told to the author by a director of a primary school in a very poor neighborhood of Rafael Calzada, in the Metropolitan Area of Buenos Aires: "Many kids sitting in first grade classrooms (at age 6) are really in the 4th year kindergarten room."

Walking the same pathways will also help reduce the persistent segregation or discrimination suffered by the poor regarding both school access and quality. Many laws mandate the allocation of resources giving priority to poor districts, but many if not most of the time it does not happen. And there is neither enough basic formation nor training to directors and teachers on how to attend children's special needs in disadvantaged socio-geographic contexts. These are very widespread problems, mostly in developing countries but also in some developed countries. Figure 14 reminds us that differences between schools explain an important proportion of the variance of math test results, in this case in PISA 2012. In practice, this means that if you are wealthy enough you or your children will have more chances – or many more, depending on the country in which you live – to attend a good school and, on the contrary, that it you are poor you will have the same chances only if you are lucky and very lucky.

A third truth that also sometimes comes from academic studies but much more frequently from educator practice can be learned from the sayings of Héctor Robles, former director of schools sited in places like "Ciudad Oculta" ("Hidden City") in Villa Lugano, Buenos Aires City, Argentina

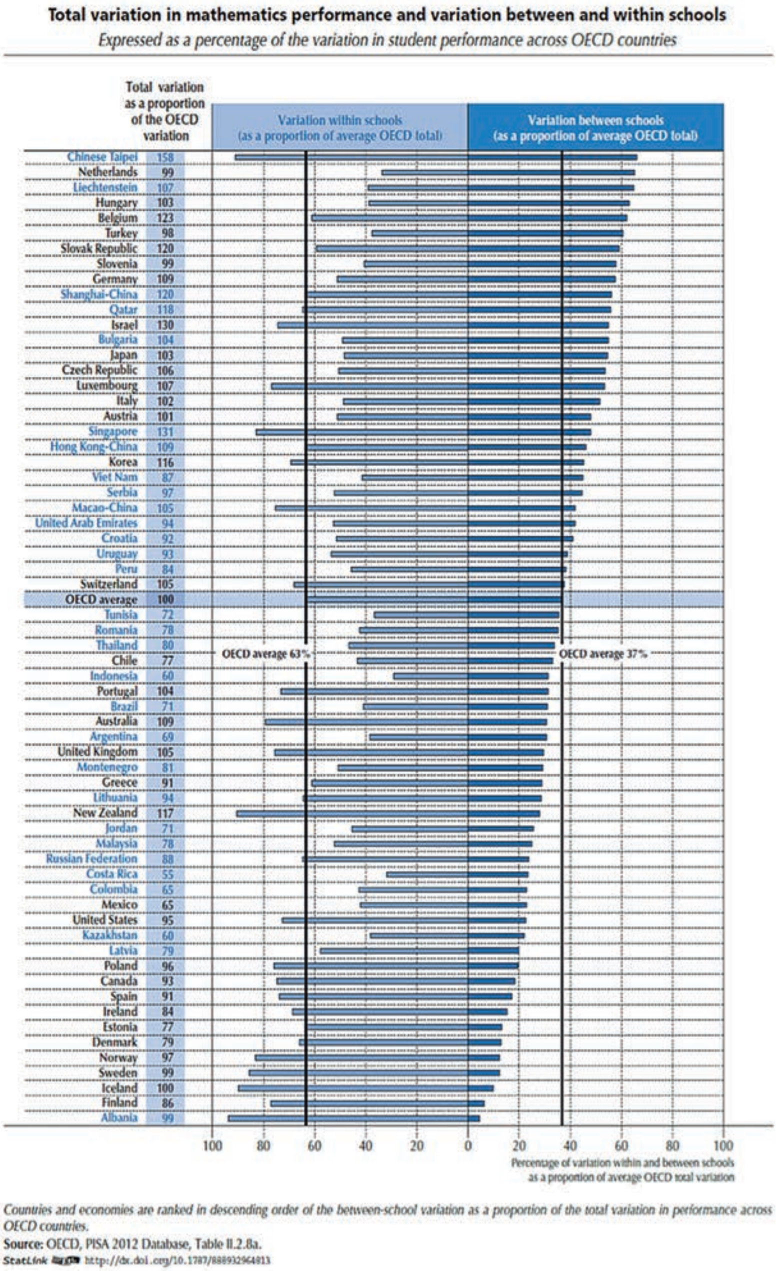

Figure 14. The other gradient (I): The worst schools, for the poor. Within and between schools explanation of test variance.

(Figure 12): "Our main goal is to demonstrate that this school's kids are intellectually able to perform as well as those of other social sectors… We demand from them maximum dedication to study, the best behavior and a careful look, and we get all that". It is worth knowing that Robles' sayings were not just words. In spite of being at the bottom of the social pyramid Robles' students were in the middle of the rankings in the test results of the city of Buenos Aires. His not so frequent sort of "Pygmalion approach" (R. Rosenthal and L. Jacobson, 1968) completely omitted self-fulfilling prophecies based on the wrong idea that children from marginalized contexts are less educable than their peers from other social strata.

It is very difficult to understand why these three simple and evident ideas of beginning with the youngest and the poorest and approaching them without stigmatizing prejudices about their incapacities to learn are however so seldom applied to the everyday practices in many, if not the majority, of the schools in developing countries and also in developed countries in schools, for instance, attended by children of immigrant origin. Perhaps one of the explanations of this sort of paradox is that the long-term nature of the effects of educational policies carries serious incentive problems for politicians. Educational and school reforms are many times problematic and even conflictive at the beginning while eventual positive results come after several years. But this is not an unavoidable conflict. It is the role of politicians to find the way out but it is the role of educational scientists to devote more effort to interdisciplinary and applied studies trying to shed lights brilliant enough as to convince and motivate politicians.

Figures 12. Images of Ciudad Oculta (Hidden City), Buenos Aires, Argentina.

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Biological and Sociocultural Determinants of Neurocognitive Development: Central Aspects of the Current Scientific Agenda

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1. Introduction

The study of the influences of material and social deprivation on the central nervous system (CNS) has been an issue of interest in the agenda of neuroscience since the first half of the twentieth century. Early neuroscientific studies have begun to analyse how the exposure to complex, standard or deprived environments modifies the brain in the context of experimental animal models. At present, the same approach still applies to the analysis of how different rearing environments modulate the brain structure and function at molecular, genetic, cellular, network, individual and social behaviour levels (Mohammed *et al.*, 2002; Pang & Hannan, 2013; Sale *et al.*, 2009; Simpson & Kelly, 2011). Moreover, the study of stress regulation, which also has an extensive history in the neuroscience agenda, has addressed the impact of different threatening experiences on the hypothalamic-pituitary-adrenal axis (HPA axis) functioning (Feder *et al.*, 2009; Joëls & Baram, 2009; Karatoreos & McEwen, 2013; Lupien *et al.*, 2009). More recently, stress regulation analysis began to be applied to the study of poverty and cognitive development through different perspectives, such as vulnerability and environmental susceptibility (Ellis & Boyce, 2011; Sheridan *et al.*, 2013; Theall *et al.*, 2013), executive functions performance (Blair *et al.*, 2011; Evans & Fuller-Rowell, 2013), and child development policy (Shonkoff & Bales, 2011). During the twentieth century research programs emerged to analyse the influences of malnutrition (Antonov-Schlorke *et al.*, 2011; Georgieff, 2007) and the exposure to different types of pollutants (Hubbs-Tait *et al.*, 2005; Jacobson & Jacobson, 2004) and drugs (Thompson, 2009) at pre- and postnatal brain development stages, with significant implications for the neuroscientific study of social inequities. The neuroscientific study of human poverty, particularly child poverty, is an issue that has recently emerged (Gi-

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anaros & Hackman, 2013; Hackman *et al.*, 2009, 2010; Lipina & Colombo, 2009). Since the mid-nineties different researchers have begun to apply neurocognitive behavioural paradigms to compare the performance of children with disparate socioeconomic status (SES) (e.g., Farah *et al.*, 2006; Lipina *et al.*, 2004, 2005, 2013; Lawson *et al.*, 2013; Mata *et al.*, 2103; Mezzacappa, 2004; Noble *et al.*, 2005). Technological advances in neuroimaging allowed the incorporation of neural network analysis (e.g., D'Angiulli *et al.*, 2008, 2012b; Jednoróg *et al.*, 2012; Krishnadas *et al.*, 2013; Monzalvo *et al.*, 2012; Noble *et al.*, 2006, 2012, 2013; Raizada *et al.*, 2008; Rao *et al.*, 2010; Sheridan *et al.*, 2012, 2013; Stevens *et al.*, 2009).

Taking into consideration all these research efforts, the study of how different environmental conditions (e.g., disparate SES or poverty) influence brain organization and reorganization during development includes different approaches, such as neural plasticity, epigenetics, influence of environmental toxins, nutrition, stress regulation, poverty modulation of cognitive and emotional processing, and poverty perception of adults with a history of poverty at childhood (Hackman *et al.*, 2009, 2010; Lipina & Colombo, 2009). Some of the main questions currently included in this neuroscientific agenda focus on some topics already analysed in the fields of developmental psychology, cognitive psychology and health sciences, especially regarding the effects and mechanisms of mediation at the behavioural level of analysis (Bradley & Corwyn, 2002; Brooks-Gunn & Duncan, 1997; Evans *et al.*, 2013; Lipina & Colombo, 2009; McLoyd, 1998; Moffitt *et al.*, 2011; Reiss, 2013; Schreier & Chen, 2013; Yoshikawa *et al.*, 2012). Nonetheless, the intrinsically innovative aspect of the neuroscientific agenda is that neuroscience allowed the beginning of these explorations in terms of basic mental operations considering different levels of analysis (i.e., genetics, networks, behaviour). In this sense, during the last decade different researchers began to produce evidences regarding how disparate socioeconomic status or deprivations modulate different aspects of neural processing and neurocognitive performance in tasks with language and cognitive control demands – the two neurocognitive systems in which poverty modulation appears to be most frequent (Gianaros & Hackman, 2013; Hackman *et al.*, 2009, 2010; Lipina & Colombo, 2009; Lipina & Posner, 2012; Raizada & Kishiyama, 2010).

Addressing the mechanisms of mediation of the impact of child poverty on cognitive development is also a recent issue of interest and study in the context of neuroscience (Hackman *et al.*, 2010). In other related disciplines, such as the study of pollutant or toxic agent neurotoxicity and malnutrition, these issues began to be explored earlier. However, even in the latter case (i.e., nutrition) only recently have researchers begun to include current neuroimaging technologies, which would eventually allow improving its comprehension (e.g., Jackson & Kennedy, 2013; Sheinkopf *et al.*, 2009).

To generate changes in neurocognitive development, interventions have been recently implemented for the study of attentional disorders (e.g., Thorell *et al.*, 2009), dyslexia (McCandliss *et al.*, 2003; Shaywitz *et al.*, 2004; Temple *et al.*, 2003), dyscalculia (Wilson *et al.*, 2006), attentional development in healthy children (Rueda *et al.*, 2005), executive functions (Colombo & Lipina, 2005; Lipina *et al.*, 2012; Neville *et al.*, 2013b), and arithmetic performance (Wilson *et al.*, 2009) in samples of children from different SES backgrounds. In all these studies, the behavioural levels of analysis have been emphasized, and neuroimaging techniques (Rueda *et al.*, 2005; Shaywitz *et al.*, 2004; Temple *et al.*, 2003) and behavioural genetics (Espinet *et al.*, 2012; Neville *et al.*, 2013b; Rueda *et al.*, 2005, 2012) have been included in some cases.

Further research is required in terms of (1) the theoretical and methodological integration of developmental psychology and cognitive psychology hypotheses to the neuroimaging studies devoted to explore neurocognitive development, and intervention studies focused on better cognitive and emotional performances, both in disparate SES samples of infants, children and adolescents (Crone and Ridderinkhof, 2011; Gianaros & Hackman, 2013); and (2) the inclusion in this agenda of the exploration of how improve the comprehension of effects and mediation mechanisms beyond the most univariate approach proposed by neuroimaging techniques (e.g., Lipina & Posner, 2012; Noble *et al.*, 2013).

This chapter proposes a brief review of findings, conceptual and methodological contributions and challenges about the present neuroscientific approach of childhood poverty. The aim of this effort is to visualize target areas, which could potentially help to build a research agenda for the coming years. In this context of discussion, it would be wise to determine which is or would be the specific contribution of neuroscience that differs from that made by other disciplines.

2. Effects and mediators of material and social deprivation

Neural plasticity

The brain adapts to its environment based on experience (Hebb, 1949). In experimental settings, rodents and non-human primates exposed to motor, sensory and social stimulation in complex environments show several structural and functional changes in different neuronal and non-neuronal components, compared with those subjects exposed to deprived environments (Mohammed *et al.*, 2002; Pang & Hannan, 2013; Sale *et al.*, 2009; Simpson & Kelly, 2011). Specifically, exposure of different species to complex, standard or deprived environments has been associated with several structural changes such as synaptic number and morphology, dendritic arborisation, cell morphology; number of astrocytes and glial-synaptic contacts, myelination, glial cell morphology; brain vasculature; brain cortex weight and thickness; rate of hippocampal neurogenesis; availability and metabolism of both neurotrophic factors and neurotransmitters in different brain areas; and neurotrophic and neurotransmitter gene expression as well. In turn, these multiple changes in neural structure have been repeatedly correlated with functional changes in motor, cognitive, and emotional outcomes at the behavioural level of analysis (i.e., learning, motor, self-regulation and attachment paradigms) (Mohammed *et al.*, 2002). Thus, development and learning would continue to exist, with each endpoint receiving inputs from experience-expectant (which would share common developmental time points across individuals of the same species) and experience-dependent mechanisms (which are more fluid in timing, as experiences and learning opportunities differ in developmental times among individuals) (Galván, 2010).

Neural plasticity in humans may also lead to use-dependent structural adaptation in cortical grey matter, in response to environmental demands (Bavelier & Neville, 2002). At the level of imaging studies, evidence exists that the brain may adapt dynamically to reflect environmental cognitive demands. For instance, neuroimaging studies evidence structural changes in specific areas after training in difficult motor tasks, such as the increased activation of motor, auditory and visual-spatial brain areas and white matter tracts as well, in professional musicians (Gaser & Schlaug, 2003; Imfeld *et al.*, 2009); or selective increases in grey matter volume in posterior hippocampus and concomitant spatial memory performance in licensed taxi drivers from London (Woollett and Maguire, 2011). During the last decade, the studies of developmental cognitive neuroscience aimed at analyzing the influence of poverty or SES on neural organization have been integrated into the research agenda of plasticity. These studies have made a specific contribution through the integrated analysis of different levels of analysis. Examples of such an integration are the study by Rao and colleagues (2010), which analyses the prediction of parent nurturing on memory demanding tasks and hippocampus volume; and the study by Sheridan and colleagues, which analyses the links among hippocampal function, HPA axis function and maternal SES (2013) or prefrontal function, HPA and home complexity language (2012).

Regarding white matter plasticity, and apart from the above studies of musicians, different mental and developmental disorders began to be described in terms of their impact on cortical connectivity, using the diffusion-tensor imaging (DTI) technique and functional connectivity analysis. In this sense, the experience of a stressful event cannot be localized to single brain regions (Hermans *et al.*, 2011), but to a distributed system involving cortical and subcortical areas, and the neuroendocrine system as well. Thus, the stressing experience would depend upon sociocultural history and how it shapes the resting networks (Allen & Williams, 2011). In the specific context of poverty studies, Noble and colleagues (2013) have recently assessed to what degree white matter microstructure mediates the relationship between education attainment and performance in a cognitive control task.

Conceptually, current theoretical approaches propose that neural development often depends on neural activity, which in turn is mediated by experience. It is therefore assumed that cognitive and emotional processing and learning shape the neural networks responsible for this processing. In turn, this activity would change the nature of neural representations and their processing, which leads to new experiences and further changes in the neural systems. Therefore, in terms of neuroscience, this neuroconstructivist approach proposes that the basis of cognitive, emotional and learning development may be characterized by mutually induced changes between neural, cognitive, emotional and learning levels, in a complex ecological context involving social interactions with cultural specificities (Westermann *et al.*, 2007). Therefore, this complexity must be considered when trying to study each one of these dimensions in isolation or at a unique level of analysis.

Sensitive periods and epigenetics

One of the most promising areas to be faced by the field of poverty and neuroscience over the next years is that of the sensitive periods, which characterizes the structural and functional organization of those brain networks most affected by socioeconomic deprivation. Sensitive period refers not only to a time when human brain is especially sensitive to particular classes of external stimuli, but to a time window temporarily opened, during which the brain is particularly receptive to experience that contributes to its organization.

Neural networks are shaped by experience also during critical periods of early postnatal stages of development in different species. Timing, duration and closure of these plastic processes have been experimentally addressed by the analysis of the visual system. It has been hypothesized that these processes are run by the following principles: diversity of molecular mechanisms in different brain areas, role of structural consolidation, inhibitory and excitatory balance, functional competition between inputs, regulation by experience and age, influence of motivation and cognitive control, and potential for reactivation of organizational processes in adulthood (Bavelier *et al.*, 2010; Hensch, 2004).

Recent behavioural studies have disclosed that critical periods are not necessarily fixed in terms of timing and object specificity. For example, the period of organization for the imprinting of any domestic bird – usually conceptualized as a critical period rather than sensitive – could be extended in time, should the appropriate stimulus be missing. Alternatively, imprinting can be reversed under certain learning conditions. This suggests that closure of this period is likely to constitute the natural consequence of a given learning process (Michel & Tayler, 2005).

At a neurocognitive level of analysis, several studies performed in humans show the expression of multiple sensitive periods in sensory systems, several aspects of speech development and face recognition (Peretz & Zatorre, 2005). A very important feature in the development of these sensory systems is that sensitive periods are not synchronized among sensory modalities. In spite of such differences in developmental timing, basic plastic mechanisms appear to be similar. The end of a sensitive period is often associated with the age at which a set of neural circuits subserving a given neural processing becomes specialized. For instance, between the 6th and 12th months of age, electrophysiological patterns associated with face recognition processes become specific for a given stimulus. In addition, and approximately at the same age, the number of cortical areas activated by the viewing of faces seems to decrease. This suggests that the end of the sensitive period of a neural substrate for a given modality processing coincides with specialization attainment (Johnson, 2005).

In the case of neural circuits involved in complex behaviours, the closure of sensitive periods seems to depend on their association or not with circuits performing either fundamental or high level computations. For instance, the sensitive period for circuits combining visual inputs from both eyes ends a long time before circuits responsible for recognizing biologically significant objects do so (Pascalis *et al.*, 2005). According to Knudsen and colleagues (2006), experience-dependent plasticity of high-level circuits – i.e. those related to language, cognitive and emotional processes – would depend on the type of information provided by those circuits, while experience-dependent plasticity is unable to attain completion until such circuits become stable.

Thus, time-scale and integration of different forms of plasticity would be targets for a neuroscientific agenda in the field of poverty and brain development aimed at exploring windows of intervention opportunities. This analysis is time-consuming and requires methodological innovations for the exploration of molecular, system and behavioural events and phenomena at the same time, and throughout different stages of development. For example, in experiments with infants different tools are usually introduced to facilitate motor skills before the age at which these behaviours are typically observed. These studies provide behavioural information about how experience-expectant processes can be manipulated to happen before it is expected. Therefore, associated measures of neural activity could allow a better understanding of the emergence of the mechanisms responsible for these behaviours (e.g., Needham *et al.*, 2002; Rao *et al.*, 2010).

Current studies in the developmental neuroscience field continue to advance in the understanding of the mechanisms through which experience and environmental influences interact with genes, especially with DNA biochemical markers and histone proteins that regulate gene activity, which could be modified by early experience. Post-translational modifications of histones and DNA methylation are the most frequently analysed mechanisms, which are involved in interactions between gene activity changes and environmental factors, such as neurotoxin, nutrition and regulation of stress (Roth & Sweat, 2011; Zhang & Meany, 2010).

Preliminary studies of maternal care, caregiver maltreatment, mother-infant separation and prenatal stress in experimental animal models hypothesize that early environmental influences could produce lasting epigenetic modifications, stable changes in the CNS gene activity and behavior. For instance, in experimental models with rodents phenotypes of adult offspring raised by mothers providing high level of pup licking and grooming were attributable to molecular changes, such as hippocampal glucocorticoid receptor, transcription of the NGFI-A factor, corticotrophin releasing factor expressions, and glucocorticoid feedback sensitivity (Roth & Sweat, 2011; Zhang & Meany, 2010).

Different studies reported significant associations between childhood maltreatment and developmental disorders later in adolescence and adulthood. Neurocognitive approaches to adults with histories of childhood maltreatment suggest the modulation of this experience on different nodes of the HPA axis (Lupien *et al.*, 2009). In epigenetic animal models, Roth and colleagues (2009) found a significant methylation of the brain-derived neurotrophic factor (BDNF) in the prefrontal cortex, and a DNA hypermethylation paralleled a lasting deficit in expression of the gene as well. Moreover, pharmacological treatment with a DNA methylation inhibitor in adults that had experienced maltreatment resulted in the rescue of the aberrant DNA methylation and gene expression patterns incited by adversity. These preliminary results suggest that experiences with an abusive caregiver during the very first stages of postnatal development can modify DNA methylation and gene expression.

Regarding mother-infant separation, recent evidence also supports the hypothesis that this experience can also modify DNA methylation and gene expression. In this sense, Murgatroyd and colleagues (2009) found that periodic mother-infant separations during a sensitive period of development modulate the methylation of the arginine vasopressin gene – a hypothalamic inductor of synthesis and release of adrenocorticotropin from the pituitary.

In other series of experiments, different studies have shown that prenatal experiences should be recognized for their profound effects on brain development, hypothesizing that glucocorticoids could be the mediator of such modulation. For example, Mueller and colleagues (2008) found that prenatal stress on adult HPA axis responsiveness and behaviour might be mediated by changes in hippocampal glucocorticoid receptor and hypothalamic corticotropin releasing factor genes expressions.

Learning and memory processes also evoke alteration of epigenetic markers in the adult CNS, as shown by animal models. For instance, Miller and Sweatt (2007) have used the contextual-fear conditioning paradigm to analyse epigenetic modulation of hippocampal genes. They found that following fear conditioning and during a period of fear memory formation, adult rats have a demethylation and transcriptional activation of the memory-enhancing gene reelin, and an increase in methylation and transcriptional silencing of the memory suppressor gene Protein Phosphatase 1.

The epigenetic analysis of the early experiences on brain development in humans is at its first stages, as many of the issues in the study of childhood poverty and brain development. McGowan and colleagues (2009) recently examined the gene expression and DNA methylation of the human glucocorticoid receptor (Nr3c1) gene in hippocampal samples from suicide victims with a history of childhood maltreatment. They found decreasing levels of mRNA hippocampal glucocorticoid receptor gene, correlated with increases in cytosine methylation of the Nr3c1 promoter, which suggests that human caregiver experiences may program genes through epigenetic modifications. In another study, Oberlander and colleagues (2008) found that infants of mothers with high levels of depression and anxiety during the third trimester of pregnancy had increased methylation of the Nr3c1 gene promoter in cord blood cells. Evidences of the modulation of epigenetic mechanisms during early development in different rearing conditions (e.g., disparate SES, stress exposure) have been recently incorporated into this research agenda. For instance, Essex and colleagues (2013) examined differences in adolescent DNA methylation in relation to parent reports of adversity during childhood. They found that maternal stressors in infancy and parental stressors in preschool periods predicted differential methylation and gender differences. In addition, recent cumulative evidences have suggested differential susceptibility to rearing environment depending on dopamine-related genes (Bakermans-Kranenburg & Van Ijzendoorn, 2011). More recently, these frameworks have begun to be applied to analyse the association between dopaminergic polymorphisms and educational achievement (Beaver *et al.*, 2012).

Although many conceptual and methodological issues should be explored, the epigenetic approach supports the notion that epigenetic changes underlie at least partially the long-term impact of early experiences, and that epigenetic alterations are potentially reversible or modifiable through pharmacological and behavioural ways. This means that the understanding of the role of the epigenome in behavioural modifications driven by early experiences could contribute to the field of childhood poverty and brain development. However, the genetic polymorphisms in humans should be cautiously analysed because similar experiences could produce different outcomes in different people, which adds another level of complexity to the study of how behaviour is modulated by early experiences.

Poverty influences on self-regulation and language development

Regarding cognitive development, the most commonly described impacts of poverty were first associated with Developmental Psychology and Education, which are lower Developmental Quotients, children's verbal and achievement Intelligence Quotients (IQ) – verbal and executive, completed school years; and higher incidence of learning disorders and rates of school absence (Bradley & Corwyn, 2002; Brooks-Gunn & Duncan, 1997; Evans *et al.*, 2012; Yoshikawa *et al.*, 2012). With respect to language, in the same disciplines, current language development studies also show different patterns of socioeconomic modulation on several outcomes, such as vocabulary, spontaneous speech, grammatical development, and communication styles and skills (Hoff, 2006).

Viewing cognition as consisting of component codes, computed in different ways and programmed to perform complex tasks, leads to new ways of thinking about how the brain might organize thought and emotional processes (Posner & Raichle, 1994). Specifically, basic processes involved in early cognitive control and language development, such as the different subsystems of attention, working memory, and flexibility, are the cornerstone of all forms of cognitive activity and social behaviour throughout the lifespan in most cultural systems worldwide (Sperber & Hirschfeld, 2004). The main assumption from this neurocognitive point of view is that given the multiplicity of factors that influence and modulate brain development, it is most likely that the impact of poverty on cognition would have a neurocognitive basis, and that those more basic cognitive functions would be modulated by socioeconomic backgrounds.

Neuroscientific studies that began to assess associations between different forms of poverty and its impact on basic cognitive processing have been recently reported. Several studies verified the modulation of socioeconomic characteristics on different attentional, inhibitory control, working memory, flexibility, planning, phonological awareness, self-regulatory, decision making, and theory of mind processes related to different neurocognitive systems in infants, preschoolers, and school- and middle school-age children (D'Angiulli *et al.*, 2008, 2012b; Farah *et al.*, 2006; Herrmann & Guadagno, 1997; Jednoróg *et al.*, 2012; Kishiyama *et al.*, 2009; Lawson *et al.*, 2013; Levine *et al.*, 2005; Lipina *et al.*, 2004, 2005, 2013; Mata *et al.*, 2013; Mezzacappa, 2004; Monzalvo *et al.*, 2012; Noble *et al.*, 2005, 2007, 2006, 2012, 2013; Raizada *et al.*, 2008; Rao *et al.*, 2010; Sheridan *et al.*, 2012, 2013; Stevens *et al.*, 2009).

Among the most widely explored neurocognitive systems is the prefrontal/executive system, which includes subsystems such as the lateral prefrontal cortex and the anterior cingulate cortex related to working memory and cognitive control processing, respectively. In behavioural studies of preschoolers, first graders and middle school children, Farah, Noble and colleagues repeatedly found that low SES children had reduced performance on these tasks compared to middle SES children (e.g., Farah *et al.*, 2006; Noble *et al.*, 2005). These findings support the hypothesis that the prefrontal/executive system is one of the primary neurocognitive systems associated with social inequalities in early experience. Similar results have been observed in studies using specific paradigms designed to measure aspects of executive function. For example, Lipina and colleagues (2005) examined the performance of low and middle SES infants using a task of a delayed-response paradigm (i.e., AnotB), which incorporates the evaluation of processes such as working memory and inhibitory control. Findings showed that low SES infants had more errors associated with lower levels of performance in inhibitory control and spatial working memory, and errors associated with attention and search strategies. The effects of socioeconomic disparities on attention have been examined in several studies. For instance, Mezzacappa (2004) used an Attention Network Test (ANT) to investigate the effects of socioeconomic disparity on attentional processes in 6-year-old children. Results showed that low SES children had reduced of both speed and accuracy on measures of alerting and executive attention, indicating that SES modulated response conflict and inhibited distracting information.

The medial temporal/memory system was assessed by Farah and colleagues (2006) using an incidental learning paradigm in which subjects are not aware that memory will be tested during the learning phase of the task and both verbal and non-verbal stimuli can be employed (e.g., pictures and faces). Results showed that low SES first grade and middle school children had reduced performances, which was not initially found in kindergarten children. However, after adding a delay interval, this finding was observed in the older groups.

In some of these studies, researchers have reported that the modulation of SES on performance is neither similar in all the administered measures, nor uniform at all ages (e.g., Farah *et al.*, 2006; Lipina *et al.*, 2004, 2013; Noble *et al.*, 2005). Both aspects are worth considering for different reasons. Conceptually, this implies that poverty does not necessarily generate homogeneous and continuous changes in neurocognitive processing. This is consistent with temporal and regional differences in cortical organization throughout childhood and adolescence (Brain Development Cooperative Group, 2012; Gogtay *et al.*, 2004; Menon, 2013; Zhou *et al.*, 2013). At the same time, these findings are not consistent with the notion of low-SES performance as a deficit (D'Angiulli *et al.*, 2012a). In summary, the findings from the above behavioural studies indicate that SES disparities can adversely affect cognitive processes, such as language, executive function, attention and memory. This further suggests that specific brain regions may be associated with these processes, and that the paradigms used would be more specific than those used to measure general cognitive ability (e.g., scales of intelligence).

However, these evidences are still behavioural in nature and therefore present certain limitations. Thus, researchers can make only indirect inferences about brain function. In addition, many of these tests are multi-factorial and performance could be modulated for reasons other than those resulting from a specific alteration. Moreover, low correlations have been obtained among these tests, which mean that two tasks can engage the same system in different ways. Therefore, a deep examination of the impact of SES on the relationship between cognitive processes and brain function is needed. In this sense, magnetic resonance imaging (MRI), functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) neuroimaging techniques applied to analyse the neural level of analysis would contribute to a better understanding of these relationships.

For instance, Noble and colleagues (2006) hypothesized that SES systematically influences the relationship between phonological awareness skills and brain activity in areas involved in reading. Specifically, researchers have predicted that the strength of the association between phonological awareness and brain activity will be increased in an environment with low exposure to literacy resources, and reduced in the opposite case. To test this hypothesis, researchers have examined fMRI responses during a pseudoword reading task in first- to third-graders from diverse SES backgrounds, who showed an equivalent level of phonological awareness scores from impaired to normal levels. Results suggested a significant phonological awareness-SES interaction in the left fusiform area, indicating that at similar low phonological awareness levels, children from higher SES were more likely to evidence increased responses in the left fusiform cortical gyrus, while children from lower SES were not. In another recent study of normal 5-year-old children performing an auditory rhyme-judgment task, Raizada and colleagues (2008) found that the higher the socioeconomic status, the greater the degree of hemispheric specialization in Broca's area, as measured by the left-minus-right fMRI activation during rhyming tasks. This suggests that the maturation of Broca's area in children may be ruled by the complexity of the linguistic environments in which they grow up. In turn, Monzalvo and colleagues (2012) compared fMRI activity to visual stimuli (i.e., houses, faces, written strings) and to sentences spoken in the native or a foreign language in 10-year-old dyslexic and normal children from disparate SES backgrounds. They found similarities in fMRI activation in both SES groups, which was interpreted by authors as the existence of a core set of activation anomalies in dyslexia, regardless of culture, language and SES. Additionally, Sheridan and colleagues (2012) found that complexity of family language – and salivary cortisol, a biological marker of stress regulation – was associated with both parental SES and prefrontal cortex activation during a stimulus-response mapping task. Finally, the same researchers (Sheridan *et al.*, 2013) verified associations between subjective social status and hippocampal activation in children during a declarative memory task. The latter findings add evidences to those by Gianaros and colleagues in college students and adults regarding the modulation of subjective social status on amygdaline response to angry faces (Gianaros *et al.*, 2008), and perigenual anterior cingulated cortex (Gianaros & Manuck, 2010), respectively.

More recently, different researchers have begun to explore the SES modulation of different structural brain measures using MRI techniques. For instance, Rao and colleagues (2010) examined the effects on later brain morphology of parental nurturance and home stimulation in the context of a longitudinal data set of early experience during childhood (4 and 8 years) and MRI during adolescence. They found that parental nurturance at age 4 predicted the volume of the left hippocampus in adolescence (i.e., better nurturance was associated with smaller hippocampal volume). In contrast, home stimulation did not correlate with hippocampal volume. Importantly, the association between hippocampal volume and parental nurturance disappeared at 8, suggesting the existence of a sensitive period for brain maturation. In addition, Lawson and colleagues (2013) found evidences that parental education is associated with cortical thickness in some subareas of the prefrontal cortex. In turn, Noble and colleagues (2013) showed that educational attainment predicted the performance in an inhibitory control-like task, and that this association accounted for connectivity (i.e., DTI) previously linked to cognitive control. Finally, Jednoróg and colleagues (2012) explored the association between SES and brain anatomy applying MRI in 10-year-old children. Their results showed that low-SES condition was associated with smaller volumes and surfaces of grey matter in hippocampus, middle temporal gyri, left fusiform gyri and right inferior occipito-temporal gyri. In addition, they found local gyrification effects on anterior frontal regions, and no associations between SES and white matter architecture.

Complementary, recent studies of socioeconomic disparities have used electrophysiological techniques to obtain direct measures of brain activity. For example, D'Angiulli and colleagues (2008) examined the influence of socioeconomic disparities on attention using an auditory selective attention task and ERP techniques. In these studies, low and high SES children had to respond to target tones in an attended channel while withholding responses to all other tones in the attended and unattended channels. A negative difference waveform, reflecting selective attention, was observed for high SES but not for low SES children. These results suggest that high SES children selectively attended to relevant information, whereas low SES children attended equally to relevant and irrelevant information. In a similar approach, the effects of SES on attention were investigated by Stevens and colleagues (2009) using an adapted version of the selective auditory attention paradigm. In this case, children were instructed to attend to one of two narratives played simultaneously in speakers located to their left or right. They also observed that low SES children showed reduced ERP measures of selective attention, suggesting that this group has a reduced ability to filter or suppress irrelevant information. In a more recent study, D'Angiulli and colleagues (2012b) showed that frontal brain areas of high- and low-

SES children were differently activated during selective attention tasks. Tomarken and colleagues (2004) also found evidences of SES-related differences in the neural processing of emotion in low-SES adolescents. Specifically, researchers observed lower left-sided brain activity at rest, as measured by resting alpha-asymmetry at frontal sites. Finally, Tomalski and colleagues (2013) found SES disparities in frontal gamma power in infants as young as 6 months old.

In a recent study using a visual novelty oddball paradigm, Kishiyama and colleagues (2009) examined the impact of socioeconomic disparity on prefrontal-dependent ERP components. Interestingly, no behavioural differences were observed in measures of reaction time and accuracy between low and high SES children, and no differences were observed in target ERP responses. The behavioural results indicate that both groups could perform the task with a high degree of accuracy. In addition, group differences were predicted in prefrontal-dependent ERP components. Specifically, researchers found that low SES children had reduced amplitudes for early, attention-sensitive, visual ERP components and novelty ERP responses. These differences in results at distinct level of analysis reveal that environmental influences on neurocognitive performance and development could be differentially modulated. This implies that a complex approach with different methodologies is required in order to examine several levels of analysis (D'Angiulli *et al.*, 2012a; Gianaros & Hackman, 2013; Lipina & Posner, 2012). Although such an approach is methodologically and logistically difficult to implement, some recent examples can be verified (e.g., Neville *et al.*, 2013b; Noble *et al.*, 2012, 2013; Posner *et al.*, 2011; Rueda *et al.*, 2005; Rao *et al.*, 2010; Sheridan *et al.*, 2012, 2013; Voelker *et al.*, 2009).

Finally, there is still an important sort of disconnection between the large amount of behavioural and neural information, which represents not only a quantitative but also a qualitative issue. This means that the mere measurement of the neural correlates of SES disparities would be insufficient to advance in the field (Crone & Ridderinkhopf, 2011; Gianaros & Hackman, 2013; Raizada & Kishiyama, 2010). As Raizada and Kishiyama propose (2010), information from the neural level of analysis may be useful for predicting performance changes – which anyway requires an integration of conceptual and methodological issues of development and plasticity. However, in cross-sectional comparative analysis and in behavioural interventions, the univariate approach of fMRI and ERP must be overcome using integrating alternatives, such as the analysis of its development in conjunction with neural connectivity analysis approaches.

Exposure to environmental toxic agents and drugs

The impact of different environmental toxic agents on children's cognitive development has been recently analysed. Several epidemiological and animal studies have reported the negative impact of different metals, plastics, legal and illegal drugs, and the lack of micro- and macronutrients on pre- and postnatal development of the CNS (Hubbs-Tait *et al.*, 2005; Walker *et al.*, 2011). At present, there is consensus about the negative effects on brain development of different neurotoxic agents such as lead (Magzamen *et al.*, 2013), mercury, manganese and cadmium (Hubbs-Tait *et al.*, 2005) – all of which cross the placenta. Although the documented impacts have been identified by high and low exposure to these neurotoxic agents at the behavioural and cognitive level, cognitive performance levels associated with toxic exposure are highly variable. Thus, further research is required concerning why some children are more susceptible than others are to certain neurotoxic agents. This would help to clarify the effectiveness of treatments and both regulatory and public policy interventions (Hubbs-Tait *et al.*, 2005).

Emphasis has been laid on the impact of alcohol consumption during pregnancy and its serious consequences on neurocognitive development throughout the lifespan, as evidenced by the many studies on foetal alcohol syndrome (Riley *et al.*, 2011). Specifically, prenatal alcohol exposure has been shown to have cognitive, social and emotional long-lasting impacts compared with other substances, which vary with the amount of consumption and the specific time during pregnancy at which exposure occurs (Irner, 2011).

Prenatal exposure to cocaine has been associated with various cognitive disorders. Schroder and colleagues (2004) studied children aged 8 and 9 years that were exposed to cocaine prenatally and found changes in the speed of response and procedural learning skills. In another study, Bennett and colleagues (2008) examined the effects of prenatal cocaine exposure on performance in a test of general intelligence in 231 children aged 4, 6 and 9 years. They found that prenatal cocaine exposure interacted with gender. Thus, boys had the lowest scores – especially in abstract reasoning, visual short-term memory and verbal reasoning tasks. Moreover, higher levels of home stimulation and mother's verbal IQs predicted higher scores. Finally, Sheinkopf and colleagues (2009) analysed prenatal cocaine exposure on performance on a task demanding inhibitory control in combination with fMRI techniques in children aged 8 and 9 years. Results showed no differences at the behavioural level between exposed and unexposed children. However, differences were observed at the level of neural activation during inhibition demands performance. Since these are preliminary findings, it is necessary to be cautious regarding their implications. Nevertheless, results suggest that cocaine exposure during uterine life affects the development of those neurocognitive systems associated with the regulation of attention and inhibitory responses.

Other drugs with impacts on cognitive development are tobacco and marihuana. Fried and colleagues (2003) analysed the cognitive performance of 145 adolescents between 13 and 16 years exposed during prenatal life to both substances. The results showed a significant correlation between exposure to tobacco and general intelligence levels and auditory attention, and exposure to marihuana and performance on memory tasks, and analysis and synthesis processing. Recently, Barros and colleagues (2011) found that exposure to tobacco during pregnancy was associated with higher levels of excitability and emotional regulation difficulties at the neonatal stage. These studies – which also require the consideration of mediation analysis to explore their mechanisms of influence, suggest that prenatal exposure to tobacco and marihuana is associated with neurocognitive impairment during the first two decades of life. Furthermore, prenatal exposure to tobacco has also been associated with an increased risk of obesity, hypertension and gestational diabetes since adolescence (Cupul-Uicab *et al.*, 2011). These impacts could be sometimes reduced through the mediation of adequate parenting and the provision of environmental stimulation, even in the case of children grown up in contexts of poverty (Evans & Kutcher, 2011). Finally, Roussotte and colleagues (2012) studied the associations between prenatal methamphetamine and polydrug exposure and corticostriatal networks. Applying a functional connectivity MRI technique during a working memory task in children aged 7 to 15 years, they found differences in the patterns of activation – the putamen showed increased connectivity with frontal areas, while the caudate showed decreased connectivity with some of the same areas – in both groups of exposed children compared to controls.

According to the current agenda, a better understanding of these phenomena depends on the development and evaluation of models for the analysis of the simultaneous combined or cumulative effect of different neural components on different aspects of motor, cognitive and emotional processing (Evans *et al.*, 2013). Evidence shows that prenatal exposure to different legal and illegal drugs is associated with the development of various changes during the first two decades of life both at the behavioural and neural level of analysis (Mezzacappa *et al.*, 2011; Roussotte *et al.*, 2012). Since social vulnerability is associated with an increase in the use and abuse of these substances (Bradley & Corwyn, 2002; Evans *et al.*, 2013), this area of research significantly contributes to the study of the impact of poverty on brain development. Although most of the studies are based on the application of behavioural methods, neuroimaging techniques have been recently applied for a better understanding of such impacts (e.g., Roussotte *et al.*, 2012).

Nutrition

Epidemiological research has shown that the correlation between nutrition and low SES modulates: (a) physical growth; (b) the potential occurrence of prenatal neural tube defects due to poor folic acid intake before pregnancy; (c) the prevalence of iron deficiency due to poor intake of food rich in this mineral; (d) cognitive process associated with memory demands after long episodes of poor nutrition; and (e) greater likelihood of developing insecure attachments and other emotional disorders due to chronic malnutrition (Bradley & Corwyn, 2002; Georgieff, 2007; Nyaradi *et al.*, 2013).

In neurobiological terms, nutrients and growth factors regulate brain development since the prenatal stage. The rapid brain development during the early stages of growth leads to greater vulnerability to poor nutrition. For example, experimental studies with nonhuman primates have recently demonstrated that moderate nutritional restriction of mothers during pregnancy is associated with various structural and functional disorders of the CNS (Antonov-Schlorke *et al.*, 2011). However, the detection of specific deficiencies depends on how each brain area or neural network is preferentially affected, and on devices to measure such potential impacts at the molecular, systemic or neural, and behavioural networks levels of organization. For example, iron deficiency has been associated with alterations in the synthesis of different neurotransmitters, cognitive speed processing, and performance on tasks with motor, emotional and cognitive demands. In addition, the impact caused by nutrient deficiency depends on the identification of that nutrient. To illustrate, zinc deficiency is associated with alterations in hippocampal development, but also in the cerebellum and autonomic regulation, while deficiencies of certain long-chain fatty acids affect myelin production and further contacts between neurons (Benton, 2008; Georgieff, 2007).

As in the case of other scientific approaches dealing with child poverty, it is difficult to determine the implications of the different nutritional deficit in the typical and atypical development, since children who lack proper nutrition also lack other resources. Specifically, a difficult issue to be determined is whether a condition associated with nutritional deficit occurs as a direct result of this deficit, or of inadequate prenatal care, difficulties to receive adequate medical treatment, or increased exposure to infectious agents (Adler & Newman, 2002). For example, prematurity and low birth weight are also associated with the absence or reduction of prenatal care (Bradley & Corwyn, 2002). Many families living in poverty cannot afford health care services; therefore, they turn to emergency services at advanced stages of disease, thus increasing the risk of morbidity and mortality (Friel *et al.*, 2011).

Recent studies have explored the potential effects of diet on mental health transmitted across generations, and whether diet can influence epigenetic mechanisms. In this respect, a longitudinal study conducted in Sweden with records from 300 families living in relative isolation in the same region over a 100-year period; show that the risk for diabetes and early death was increased if paternal grandparents grew up in times of food abundance (Kaati *et al.*, 2007). Complementary to this finding, the experimental research on animal models also discusses issues such as the influence of diets rich in saturated fats on gene expression of different regulatory mechanisms of the hippocampus (Gomez-Pinilla, 2008).

Current studies of the effects of nutrition on brain function focus on the effects of breakfast on cognitive function and academic performance (Adolphus *et al.*, 2013), the effects of breakfast different components (e.g., rice versus bread) on neural activation (Taki, 2010), the role of insular cortex in food related processes (Frank *et al.*, 2013), and the impacts of long-term nutritional interventions. In this sense, the inclusion of multiple evaluation methodologies has been postulated, such as biological markers in combination with nutritional supplements and performance on cognitive tasks at different stages of development. This would allow the identification of potential sensitive periods during the lifetime (Prentice *et al.*, 2013) and pathways of impacts and interventions (Yousafzai *et al.*, 2013).

Regulation of stress response

Since the mid-twentieth century, many studies have analysed the regulation of stress response in both children and adults, as one of the most important mediating mechanisms of the effect of poverty on emotional, cognitive and social functioning (Fernald & Gunnar, 2009; Lupien *et al.*, 2009). Threats, negative life events, exposure to environmental hazards, family and community violence, change processes and family break-up and moves, job loss or instability and economic deprivation are more likely to occur in poverty conditions (Bradley & Corwyn, 2002; Evans *et al.*, 2013; Maholmes & King, 2012; Yoshikawa *et al.*, 2012).

Neural systems implementing this complex regulation include the hippocampus, amygdala and different areas of the prefrontal cortex (i.e., HPA axis). Together, these systems regulate the physiological and behavioural response to stress, adapting to short- or long-term impacts caused by difficulties in adaptation processes, as in chronic situations of abuse or extreme poverty (Karatoreos & McEwen, 2013; Shonkoff *et al.*, 2012). These regulatory processes arise from communication between the brain and the immune and cardiovascular systems. On the one hand, bidirectional mechanisms regulating the stress response are protective through adjustments in the short term. On the other hand, these mechanisms may be associated with physiological mismatches under conditions of chronic stress, affecting recovery processes and overall health (McEwen & Gianaros, 2010). The stress and uncertainty caused by economic deprivation conditions increase the likelihood of negative emotional states, anxiety, depression and anger. In turn, this may induce more frequent negative parental control strategies, less sensitive emotional neglect and more difficulties in promoting appropriate socio-emotional adjustment in children (Shonkoff *et al.*, 2012). However, some studies show that even in poverty, maintaining proper child rearing can be a protective factor of development (e.g., Brody *et al.*, 2002), highlighting the environmental plasticity levels of these regulatory systems.

The analysis of the mechanisms mediating the stress has generated a number of guiding principles that can contribute to the understanding of child poverty. Ganzel and colleagues (2010) have suggested that the stressor properties (i.e., magnitude, duration and chronicity), and nature (e.g., social exclusion versus physical threat) modulate the type of differential impact on neural networks involved in acute and chronic responses to stress. In this regard, it is necessary to investigate the timing and specificity of the neural developmental sensitive to stress processes (Lupien *et al.*, 2009).

The current neuroscientific agenda in this area has begun to gradually incorporate the concepts and methodologies derived from the advances in epigenetics and the analysis of neural activation in both animal and human models. Three sets of problems have started to feed the agenda: prenatal programming of brain plasticity, reactivity of amygdala areas in threatening situations, and brain embodiment of adverse life experiences (Gianaros & Manuck, 2010).

In the context of child poverty analysis of long-term stressful experiences, Blair and colleagues (2011) found that cortisol levels combined with the quality of parenting contexts functioned as mediators of the effect of family income, maternal education and ethnicity on different cognitive control tasks. In addition, in a recent study including children in rural poverty contexts, Fernald and Gunnar (2009) found that cortisol levels decreased only in those cases where mothers had higher levels of depressive symptoms. This suggests that child poverty and maternal mental health modulate stress regulation: both cortisol and mental health levels are two mechanisms that may improve the understanding of the associations between child poverty and stress.

The impact of moderate to chronic stress has been associated with the release of a diverse set of brain chemical modulators, which have specific temporal and spatial niches that generate complex phenomena not yet clearly identified (Joëls & Baram, 2009). Wismer-Fries and colleagues (2005) have recently found that the absence of opportunities for adequate attachment during the early stages of development is associated with hormonal changes involving neuropeptides vasopressin and oxytocin. These hormones are critical to the development of social bonds and the regulation of emotional behaviour. Specifically, experiences of physical and sexual abuse during early developmental stages have been associated with this complex pattern of stress responses, which are assumed mediators of increased susceptibility to psychiatric disorders in adulthood (Feder *et al.*, 2009). However, vulnerability and susceptibility to chronic moderate situations of stress vary individually according to epigenetic phenomena and the eventual presence of certain potentially protective factors, such as relationships with caring adults, self-regulation and social competences and the pleasantness of children (Evans & Fuller-Rowell, 2013; Luthar *et al.*, 2006).

During the last decade, the first neuroimaging studies were performed to explore how socioeconomic deprivation during childhood influences the stress response at different stages of life. Tottenham and colleagues (2011) evaluated the long-term neural correlates of adverse rearing conditions and performance on an emotional inhibitory control task that demanded the discrimination of threatening faces. The results showed that children raised in orphanages showed increases in amygdala activity, which was associated with emotional processing and decreased eye contact during dyadic interactions between children and adults. Previously, Taylor and colleagues (2006) had found that adults with histories of stressful childhood in families at risk of stress for physical and mental health presented specific patterns of reactivity in amygdala and orbitofrontal areas during observation of threatening faces. More recently, Butterworth and colleagues (2011) applying structural MRI found that adults exposed to poverty at childhood had modified the volumes in their hippocampus and amygdala nuclei; and Hanson and colleagues (2011) found the same pattern of results even in populations of school-age children.

3. Concluding remarks

The trajectories of typical and atypical neurocognitive development in disparate socioeconomic contexts generate different degrees of brain plasticity (Gianaros & Manuck, 2010). The consideration of the sensitive periods for many of these plastic processes requires a revision of the agendas of those disciplines addressing child poverty based on the notion that the impacts are permanent and irreversible. Considering the latter as a starting point in the design of new studies and a scientific and public policy, does allow evaluating the opportunities that could enhance human development.

The notion that poverty impacts are irreversible, in contraposition to that postulating that the CNS plasticity promotes opportunities for emotional, cognitive and social optimization contributes to visualize the ethical and moral responsibilities of communities in the generation of those conditions. In this context of discussion, the neuroscientific approach helps to understand more specifically the extent of the impacts of social and material deprivation produced by society (Stephens, Markus & Phillpis, 2014), and the possibilities for preventive interventions to protect human development. Thus, neuroscience should actively participate in the ethical discussion on poverty, and may even enhance discussions about some basic moral rights and facilitate their exercise. Thus, access to adequate nutrition from prenatal stage encourages emotional and intellectual development in different contexts, such as home and school. It further promotes full social and educational inclusion, and comprises different aspects such as basic human rights, which have been considered by different disciplines.

Regarding the research agenda, there is still a trend focused on the effects of poverty on different processes, instead of the analysis of mediation mechanisms, and the use of reductionist conceptions of childhood poverty and development (D'Angiulli *et al.*, 2012a; Neville *et al.*, 2013a; Lipina *et al.*, 2011). These are some issues that require a deeper approach:

(1) Theoretical integration of developmental and cognitive psychology in experiments applying neuroimaging techniques, in order to promote and generate innovative hypotheses and research programs (Crone & Ridderinkhof, 2011; Gianaros & Hackman, 2013).

(2) Analysis of the development of neural connectivity in different socioeconomic rearing contexts (i.e., parenting), given its implications in the study of the impact of poverty, its mediators and intervention efforts (e.g, Jolles *et al.*, 2013; Lipina & Posner, 2012).

(3) Development of innovative research to analyse plasticity of complex affective and cognitive processes and their windows of opportunity (i.e., sensitive periods) in the context of intervention studies (D'Angiulli *et al.*, 2012; Lipina & Colombo, 2009; Lipina & Posner, 2012).

(4) Generation of alternative methodologies aimed at overcoming those obstacles associated with small sample sizes, application of longitu-

dinal designs, and integration of different levels of analysis (Gianaros & Hackman, 2013).

In all these areas – i.e., effects, mediators and interventions – research questions, and therefore the interpretation of data obtained by the applied molecular, behavioural, and neuroimaging techniques, seem to focus on the comparison of performance and degree of activation. In addition, most of the evidence is still based on cross-sectional or short-longitudinal designs, which makes it difficult to integrate and adjust the discussion on neurocognitive developmental phenomena. This sometimes leads to the mistaken notion that poverty is associated with neurocognitive deficits, which must necessarily be studied in a research context comprising neuroscientific approaches in the field of plasticity, development and transfer of interventions.

In particular, a need still arises to consider a proper and specific (neurocognitive) criticism on how to conceptualize the child poverty experience, to include and adjust the implications of poverty impacts and mechanisms according to different aspects of neurocognitive development (Lipina *et al.*, 2011). Although this issue has not yet been developed, the neuroscientific evidence on the impact and its progression during development contributes to an insight into poverty as a phenomenon much more complex and dynamic than the definitions proposed by other social and human scientific disciplines.

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The Effects of Nutrient Deficiencies, Especially Micro-Nutrient Deficiency on Human Development

Food and Nutrition Security The Concept and its Realization

Joachim von Braun[1]

Abstract

This paper reviews the prevailing concept of food and nutrition security and points at needs for concept revisions in order to more comprehensively depict causes and indirect consequences for the food and nutrition insecure, and guide policy actions. The state of realization of food and nutrition security is briefly presented, and the menu of policy actions for enhancing food and nutrition security is discussed, and linkages between "bread and brain", i.e. cognitive and educational issues of nutrition are pointed out. The paper highlights the need for accelerated and revised actions at international and national levels to achieve food and nutrition security for all.

1. The concept of food and nutrition security

The 2009 Declaration of the World Summit on Food Security defines the concept of food security as "Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. The four pillars of food security are availability, access, utilization and stability. The nutritional dimension is integral to the concept of food security" (FAO 2009, p. 1). FAO further states that, based on this definition, "... four food security dimensions can be identified: food availability, economic and physical access to food, food utilization and stability (vulnerability and shocks) over time" FAO 2013, p. 17). Each food security dimension is described by specific indicators by FAO (2013).

Undernourishment is one such important indicator among several. The absolute number of undernourished people in the world decreased from an estimated 1012 million in 1990/92 to about 842 million in 2010/12 according to FAO estimates, a decline by 17 percent (FAO 2013, see table 1). The percentage of undernourished in the developing countries declined from 23.6 to 14.3 percent. If these trends continue, the Millennium Development

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Goal indicator related to under-nutrition in the developing world would be just about one percentage point above the target of cutting the percentage of undernourished in half (FAO 2013). While there is a risk of declining progress in reducing hunger, which needs to be addressed, ending hunger in the coming two decades should be a realistic yet ambitious goal. At the opposite continuum, overweight and obesity are now recognized as drivers of disease in most countries in the world due to obesity-related disorders and increased risk on non-communicable diseases (Davies and Mullan 2014).

Table 1. The Multiple World Food and Nutrition Problems.

Problems	Numbers of people	Consequences
Hunger (Under-Nutrition, calories)	ca. 0,8 Bill. (crude estimate)	acute deficiency, political conflicts
Hidden Hunger (deficiencies of micro-nutrients, vitamines, iron etc).	ca. 2 Bill. (crude estimate)	diseases, reduced productivity
Children's under-nutrition (the first 1000 days)	ca. 165 Mill.	stunting, reduced physical, cognitive development.
Obesity and resulting chronic diseases	ca. 1 Bill.	high costs of public health

Source: derived from data presented in The Lancet, 6/ 2013 and FAO 2013.

1.1 Deficient metrics and data

The food crisis has shed light on the deficient data about the scale and change of food and nutrition problems. The numbers about undernourished people are rough estimates at best, and even less well known is the increase in diet deficiency and related long-term – indeed lifelong – health effects that impair physical and mental capacities. The above-mentioned estimates (table 1) only capture patterns and broad trends and not annual change. They are based on aggregate data, not actual people (household) level food deficiencies. Other relevant indicators of nutrition are child underweight and stunting. They show less progress than the reduction of calorie deficiency (hunger). It is roughly estimated that 2 billion people suffer from micronutrient deficiencies. Moreover, the prices of non-staple foods, such as vegetables and pulses, have risen even more than grains, further adding to deficiencies in healthy diets, especially in South Asia. Part of an appropriate response to the global food crisis needs to be an overhaul of the system of monitoring information on food and nutrition.

The nutrition indicators much in use that are based on bone-length (stunting) and body mass relative to carefully designed reference populations have proven important predictors of health, but may be poor proxies for people's (constrained) cognitive potentials, and actually underestimate the problem of nutritional deficiencies for people's wellbeing. More and better data are needed, but FNS action must not wait for that. Investment in improved food and nutrition related data are – not only on outcomes but also on causes – part of action.

1.2 Critical assessment of the prevailing food and nutrition security concept

In the prevailing concept, food and nutrition security depends upon the availability of food through production and trade, upon access to food due to purchasing power or self-production, upon the utilization of that food for nutrition, and upon the stability of the food system, especially of related markets and prices (Figure 1). These dimensions of the food security concept, however, need to be viewed in a dynamic context, where food and nutrition insecurity undermines the resilience of poor people and low-income countries and thus exacerbates economic insecurity, often eroding societal cohesion.

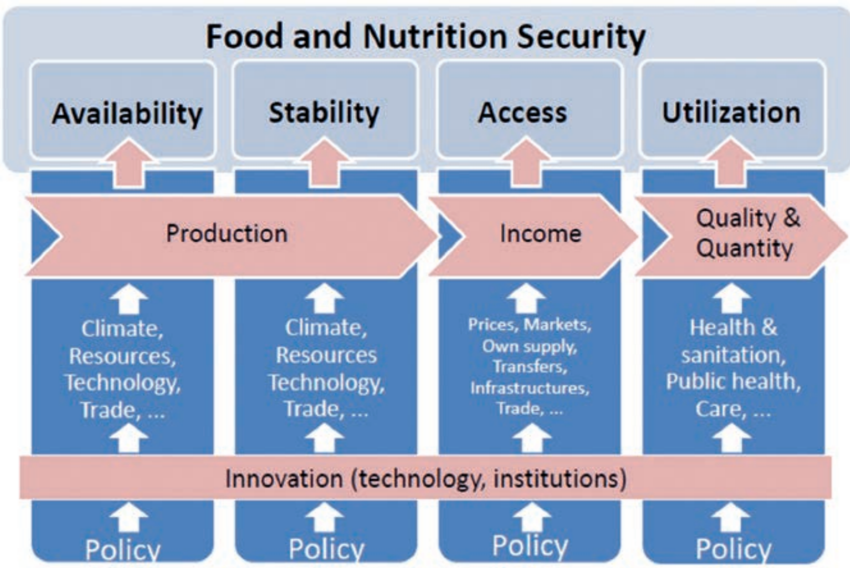

Figure 1. The Prevailing Concept of Food and Nutrition Security. Source: designed by author, based on FAO (2002).

Food and nutrition security goals need to be addressed with comprehensive strategies, beyond the narrowly defined food sector, and be adapted to regional circumstances. Strategies for food and nutrition security need to take note of two fundamental changes that re-position food and nutrition in the global and national economies. For instance, food and agriculture are now embraced by the larger (bio-) economy, and food markets are embraced by financial markets. Each of these inter-linkages poses challenges to the aspects of availability, access and utilization of food by the poor, and food system stability.

The basic framework of food and nutrition security (the 4 pillars of availability, access, nutrition/utilization, stability in figure 1) broadly outlined above has at least four limitations:

1) Lack of depicting causality: lacking a comprehensive theoretical basis, it is of rather limited value in terms of capturing causalities. Especially it lacks linkages between drivers and impacts on nutritional outcomes. Of critical importance is the distinction between drivers that are inside versus outside the food system. Here is where clarity of system boundaries and causalities will have to be defined, including through complex feedbacks such as commodity market volatility; urbanization with "supermarketization"; rural and agricultural growth linkages; consumption and behavioral change. At a more micro-level, more detailed food and nutrition security concepts have been conceptualized, depicting the food, health and care aspects as drivers. While certainly helpful at household level to understand causalities, it is necessary to connect these concepts with the more macro-framework. This raises the matter of conceptualizing food and nutrition security across scales.

2) Lack of depicting synergies: the synergies among enhancement in one pillar for the other pillars are not well captured. For instance, the impacts of technology enhancing production have consequences for stability and income (access). In fact, stability really cuts across the other three pillars. Moreover, productivity (availability) and access are clearly partly endogenous to human capabilities (including nutrition). Ignoring such synergistic linkages has further led to the compartmentalization of food and nutrition security initiatives in each of the four columns. The research communities have thus often chosen to connect to one or the other pillar, rather than exploring options across the whole framework. This led at times to unproductive singular emphasis on food availability, versus food access, versus nutrition actions. A useful way out of this deficiency may be a well-defined nutrition value chain concept. Synergies should be enhanced among complementary sectors such as agriculture, health, water and sanitation, and early child education (Rue *et al.* 2013).

3) Ignoring dynamics: the prevailing food and nutrition concept does not capture dynamics well. Different time subscripts are relevant for different drivers and resulting nutrition problems. The prevailing food and nutrition concept does not capture dynamics well. Different time subscripts are relevant for different drivers and resulting nutritional impacts: impacts can appear in the short or long term, and can result from abrupt shocks or more permanent drivers. Stunting is typically used as a long-term (decades/years) indicator of under- and malnutrition. This is because stunting is not sensitive to short-term FNS shocks, unlike indicators of underweight prevalence. Stunting can however be the result of seasonal food and nutrition insecurity over a sustained period of time. Caloric and nutrient deficiency, as well as weight loss, are medium-term (months) indicators of food and nutrition insecurity. Short-term FNS impacts (weeks/days), especially in early childhood, are often the result of nutrition shocks.

Further, the periodicity of the drivers and their impacts (seasonal and recurrent versus continuous and lasting) also cannot be ignored (Pangaribowo *et al.* 2013), with potential feedback mechanisms across periodicities: for example, recurring short-term shocks leading to long-lasting impacts. Finally, impacts can be more or less irreversible. For instance, sustained undernourishment over a period of time can lead to stunting, which cannot be compensated for subsequently by improved nourishment. On the other hand, the impact of some forms of undernourishment on brain development seems possible to mitigate with improved nourishment later in life. Brain development in humans is remarkably resistant to permanent damage from protein-energy malnutrition. However, specific nutrients have different and crucial roles (de Long 1993). The implications of food deficiencies that last for a certain time for cognitive capacity, and their long run or even intergenerational effects, have been largely neglected until recently in the framework, as have potential opportunities for rehabilitation of cognitive capacities. On the other hand there are complex long run linkages: mothers' *in utero* malnutrition may impact on the second generation's level of schooling (Kim 2014).

4) Ignoring the broader political and ecology context: Capturing political determinants such as discrimination and marginalization impacts on food and nutrition security – which are becoming relatively more important – would require a broader framework to capture these causes, which the stereotype four pillars cannot provide. FNS problems are deeply rooted in institutional and governance deficiencies at international and national levels (von Braun 2013). Achieving FNS without addressing these deficiencies seems hardly feasible. A comprehensive FNS concept thus needs to take the political dimensions of the FNS problem into account explicitly, rather than treating them as exogenous framework conditions.

One of the basic causes of FNS deficiencies is the marginalisation and exclusion of people from rights and political processes. The marginality concept calls for the integration of various concepts of poverty, with those of social exclusion, geography, and ecology. People at the margins are explained by a set of distances (i.e., physical distances such as being located in remote or harsh environments), social distances (being excluded, discriminated against, or not having access to rights), but may also be related to technological and institutional infrastructure deficiencies. Food and nutrition insecurity is often a sub-set of the outcomes of marginality (von Braun and Gatzweiler 2014).

While pointing out these deficiencies of the prevailing food and nutrition security concept, it is recognized that the concept may still be a useful point of departure for the food and nutrition policy action agenda, but its limitations need to be kept in mind. In the following, a broader perspective for food and nutrition security is taken, and new challenges for the world food system are pointed out.

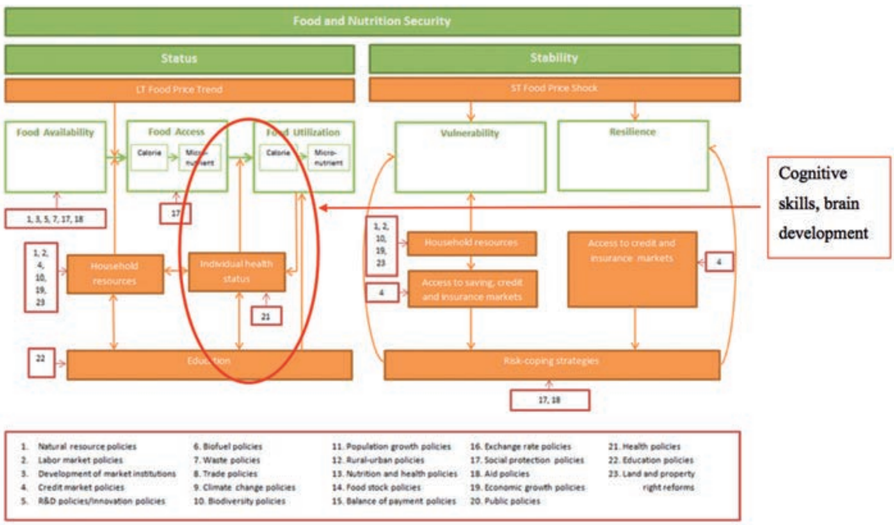

Figure 2. Linkages between macro and micro-level policy interventions and food and nutrition security at the household/individual level. Source: Pieters et al. 2013. Note: the authors define policies 1-16 as macro policies, 17-18 are mixed macro and micro-level policies, 19-23 are micro-level policies.

1.3 Steps toward a more comprehensive concept

As mentioned above, it is important to develop a sound theoretical framework to the analysis of food and nutrition security at the truly meaningful scale: the households and the individuals. These determinants are generically captured in the UNICEF conceptual framework for under-nutrition, which showcases a hierarchy of basic, underlying and immediate drivers (Black *et al*. 2008). As a further step in that direction, Pieters *et al*. (2013) provide a conceptual framework linking macro and micro level policies with FNS at the household and individual levels. Figure 2 is useful in pointing out the complexity and number of linkages and provides for a global overview of the determinants of FNS at the household and individual level. Naturally, specific FNS pathways are at play within the complex web of inter-linkages of Figure 2. For instance, the focus on the inter-linkages between appropriate nutrition and the development of the brain, of the cognitive skills and ultimately the educational achievements and the formation of human capabilities are only implicitly portrayed in this overview. These inter-linkages have traditionally gotten sufficient attention from economists and nutritionists alike. They deserve a closer attention, particularly as they seem to provide more hope for corrective action against the negative impacts of under- and malnutrition for personal and societal development. For instance, more scientific inquiry is needed, if a narrow focus on a certain age segment, such as the currently much advocated first 1000 days in life in nutritional improvement strategies, might not neglect the opportunities to recover from post FNS shocks in older children's age segments, and related chances to mitigate the impact on cognitive capabilities' formation more broadly.

2. Toward realization of food and nutrition security

2.1 Food and agriculture in broader contexts

Producing more food to achieve food security is confronted with challenges arising from the fact that agriculture and the food economy are part of the larger economic and biological systems. Food security partly depends on the availability of food, which is part of biomass production and increasingly determined by new competitive uses of biomass for energy and industrial raw materials. This "bioeconomy" intends to use a bigger part of what we are able to sustainably grow on soils, with seeds, sun and water, and use it a lot more efficiently. It is the aggregate of all industrial and economic sectors and their associated services that produce, process or in other ways use biological resources (plants, animals, micro-organisms). Langeveld *et al*. (2010) define a bio-based economy as the "(...) technological development that leads to a significant replacement of fossil fuels by biomass in the production of pharmaceuticals, chemicals, materials, transportation fuels, electricity and heat (...)". Defined as such, the bioeconomy is interconnected with a large cluster of economic sectors in the wider economy; even in some industrial economies it constitutes the largest sector in terms of GDP and employment, while in many low-income economies it tends to be the largest employer. New technology intervenes in all of the above sectors, to different degrees. The largest sector of the bioeconomy, in terms of total output, employment and so on, is typically food and feed production.

Achieving sustainable development will have to rely on alternative sustainable sources of energy and raw materials, mostly away from fossils, and in that context, biomass is likely to play a key role. The challenge will be to frame reliance on biomass without undermining the long-term productivity of agriculture and other ecosystems. Addressing the challenge will require a systemic approach identifying:

- The consequences of substituting the consumption of finite resources by using biomass and other renewable resources;
- What is needed in order to move towards production systems that rely more on recycling, on more efficient use of limited resources and on an increased employment of renewable resources.

This identification needs to recognize fundamental paradigm shifts. First, in world food consumption, demanding more products that are rather biomass intensive, for example animal products. A comprehensive integration of animal production into efficient value chains is an essential part of the bioeconomy. Second, climate change provides powerful incentives for investment in the bioeconomy in three ways: first, there is the need to establish a different energy base, including Biomass; second, there exists the threat of declining crop productivity and increased production risks; and third, the emerging GHG mitigation markets or related taxation policies are increasing the incentives for biomass production (sequestration).

The new value chain system of the knowledge-based bioeconomy is much more a system than a chain; actually, it is a set of interlinked chains, i.e. a "value web". For food security it is essential to increase efficiency in the whole value web. Until now the technological options have for the most part been pursued in a traditional manner, and hence in isolation: that is to say, by enhancing outputs per unit of individual inputs in production, say yield per hectare or per animal and without consideration for the opportunity costs within the value web. For addressing the necessary yield increases, however, plant breeding is essential to meet these challenges.

2.2 Development strategy for food and nutrition security addressing the set of risks

In 2000, the member states of the United Nations committed themselves to creating a "more peaceful, prosperous and just world", to "free(ing) our fellow men, women and children from the abject and dehumanizing conditions of extreme poverty", to making "the right to development a reality for everyone," and to ridding "the entire human race from want". Obviously, ending hunger would be an essential component of the Millennium Development Goals, and MDG 1 actually calls for halving hunger and poverty by 2015 in relation to 1990. In pursuing the MDGs, we should seek the elimination of hunger on a realistic but ambitious time schedule. Cutting maternal and child malnutrition is to be part of the hunger goal, as these nutrition issues reduce cognitive ability, and rob nations of healthy and productive adults. Micronutrient malnutrition is a part of these larger, devastating "hunger" problems.

It is now well recognized that pursuing each of the eight MDGs separately without acknowledging their interlinkages will reduce the complex process of human and economic development to a series of fragmented, conflicting, and unsustainable interventions (von Braun *et al.* 2005). A comprehensive development strategy that addresses the whole set of goals is required for the efforts to be successful. These strategies differ by country due to resources and institutional conditions, so strategies must be tailored to the specific needs and circumstances of a given situation. The political and economic climate must be taken into account, along with historical, cultural, and geographic characteristics. At the same time, each of the goals needs to be reached and that requires specific action in the overall context. Policy actions that improve agricultural productivity and food and nutrition security are essential components of a successful MDG strategy that focuses on the poor, as there are strong, direct relationships between agricultural productivity, hunger and poverty. Two thirds of the world's poor live in rural areas and make their living from agriculture. Hunger and child malnutrition are more widespread in these areas than in urban areas, and that is likely to remain so for years to come.

The response to the food crisis should be multifaceted. It requires a strategic approach (development strategy), sector-relevant actions in production, consumption and trade policy. Moreover, under-nutrition should be addressed directly with new and strong actions. The world must also reduce waste in consumption and food processing. However, the often stated idea that the world food problem is mainly a problem of "distribution", that is to say, that there is enough food in the world for all and that it just needs to be shared more fairly and equally, is a gross simplification. The root cause of the food crisis was lack of agricultural productivity, and acute policy failures. But a broader set of risks needs to be comprehensively addressed. These include:

- The risk of *high and volatile food prices,* which limit poor people's food consumption, diet quality, and spending on health and general welfare, is likely to increase in the future. Moreover, volatility also impacts on production as it increases risk and thereby undermines productive investments.
- *Financial and economic shocks*, which lead to job loss, expensive and scarce credit, and decreased demand for agricultural commodities, are also likely to persist in some parts of the developing world.
- The impacts of *climate change*, including an increase in the incidence of extreme weather events such as droughts and floods and a decrease in yields in developing countries, will further exacerbate food insecurity. These impacts will be severe because the majority of the poor depend on agriculture as a source of food and income.
- The risks that *political disruptions and failed political systems* pose for people and economies. This includes the risk of structural failures of policy change, such as lack of property rights and of traditional land and water rights, eroding the assets of the poor, as can happen under increased land grabbing. In addition, societal and political risks – such as food riots, destabilization of governments and domestic and trans-border conflicts – can result from these food system risks.

2.3 Agricultural production systems delivering food and nutrition security

A sustainable and resilient agriculture in both small and large farm sectors, requires not only technological innovations, but sound institutional arrangements for well functioning markets that offer a conducive investment climate, access to infrastructure, and information and extension systems that serve farming men and women. An essential component of resilient agriculture is the end of land and soil degradation, as the natural resource base needs to serve future food security. The end hunger goal must be combined with related environmental sustainability goals in an inseparable package. Some part of the burden of food insecurity is an element of the costs of inaction to reduce land degradation.

The future of food security to a considerable extent relates to the transformation of small farms for two reasons: about half of the world's hungry poor live on small farms, and second, the small farms of the developing world have considerable potential for contributing to rural and economy-wide growth. In emerging economies, these two features of small farms connect development strategy with agriculture and food and nutrition security strategy. Thus, attention to agriculture remains important for many regions of the developing world. The above-mentioned tasks require public and private investments at scale.

Besides the strategic structural change and investment priorities just mentioned above, technological breakthroughs, and their adoption on a large scale, are critical in preventing food insecurity. Numerous studies have shown that spending on agricultural research and development (R&D) is among the most effective types of investment for promoting growth and reducing poverty. Advances in plant breeding have increased staple crops' nutritional value, their suitability to subtropical and tropical weather conditions, and their resistance to diseases and pests. Plant breeding and genetic modifications (GM) have created beneficial traits such as disease resistance, environmental improvement, higher nutritional value, and increased yields – traits that are difficult to achieve rapidly through traditional breeding techniques.

Disseminating new technology in agriculture requires substantial upfront investments in the foundations of effective technology utilization – that is, rural education, infrastructure, and extension services. However, public R&D investments have been stagnating since the mid-1990s, and the gap between rich and poor countries in generating new technology remains large, except in a few countries such as Brazil and China.

At the global level, a science and technology initiative is needed to prevent further increases in agricultural prices, reduce competition for natural resources, and adapt to and mitigate the effects of climate change. That global initiative should focus on increasing agricultural productivity, making agricultural practices more sustainable, enhancing food quality and health, and improving natural resources management. The initiative must also address nutrition insecurity directly by breeding new varieties of staple crops that are rich in micronutrients. This approach would allow the poor to receive necessary amounts of vitamin A, zinc and iron through their regular staple diets. This "bio-fortification" provides a means of reaching malnourished populations in relatively remote rural areas and delivering naturally fortified foods to people with limited access to commercially marketed fortified foods or supplements.

2.4 Addressing the land Issues

The amount of land that is presently used for agricultural purposes cannot be substantially increased, as either cultivation makes no economic sense due to low potential yields, or expansion would negatively impact the environment and climate. The preferred way of increasing productivity is, therefore, to intensify farming sustainably on the land that is already used for agriculture. Sustainable intensification crucially includes further advances in crop varieties by breeding techniques (Montpellier Panel 2013).

Viewed globally, soil may be one of the most important terrestrial resources for carbon storage. Yet land degradation is a rampant and inadequately quantified global issue. Research should focus on maintaining or improving the quantity and quality of productive soils. To achieve this, new national and international concepts of land use need to be devised and a global initiative for the assessment of costs of inaction on land and soil degradation is called for (Nkonya *et al.* 2011).

By means of innovative research into locally adapted crop cultivation, alternative farming scenarios must be developed which allow priorities to be set for land use. The rapid expansion of foreign direct investment in land acquisition reflects the strong demand for biomass that has become an international issue. The often unregulated land markets in which power rather than efficiency and price rules, and the investment ventures need more policy attention to protect rights of poor land users, especially small farmers and pastoralists.

Food security strategies must take a trans-sector perspective, beyond food and agriculture. The governance of the food system needs to pay renewed attention to property rights, especially for land, including communal lands. The emerging market for biomass and its agricultural underpinnings need sound institutional arrangements and codes of conduct beyond voluntary guidelines. A resilient and sustainably growing agricultural production sector remains essential for food security of the poor.

2.5 Policies to prevent extreme price volatility

Staple foods can be viewed from different perspectives given different actors' roles in production, trading, and consumption. For farmers, they are an income source; for food processors they are an input; for traders and financial investors they are part of an asset in portfolios; and for poor consumers they are implicitly "currency", as they spend a large share of their income on them. The latter is the most neglected role. For the poor, grain price spikes mean hyperinflation in their currency, and they have no central bank that guards their currency. Food price volatility – unpredictable large swings in prices – affects the poor the most and undermines their health and nutrition. Extreme price volatility also hinders investment and leads to misallocation of resources. It increases the incentive to construct commodity asset portfolios, which foster speculative trading, further boosting price spikes (Tadesse *et al.* 2013).

In view of the adverse role of biofuels subsidy policies for food security in times of tight grain supplies, these policies need to take food-security consequences explicitly into account, which they currently ignore. When food prices are high, subsidies for biofuel production should be frozen, reduced, or subjected to a temporary moratorium on biofuels from grains and oilseeds until extreme prices subside. Second-generation biofuel technologies are in the making but are still far from reality. If they are "smart", these technologies may partly overcome the food-fuel competition and lessen the negative effects on the poor.

Extreme price volatility is an international issue that requires international action. Together, national actions such as increasing grain stocks or restricting trade are inefficient and make global matters worse. These policy decisions – such as export restrictions which many countries have applied during the food crisis – often appear to be panic responses that give little attention to potential global market consequences. Food markets must not be excluded from the appropriate regulation of the banking and financial system, as the staple food and feed markets (grain and oilseeds) are closely connected to speculative activities in financial markets. There is growing evidence that the price formation at the main international commodity markets was significantly influenced by speculation that drove spot prices upward beyond market fundamentals (Tadesse *et al.* 2013; Algieri 2012). To prevent extreme volatility, it is essential to ensure open trade, and transparent, appropriately regulated market institutions. Any cost-benefit assessment of institutional actions need to consider the cost of action versus costs of inaction in three domains – the costs of human resources and suffering from the food crisis, the costs of losses from trade and from the political disruptions as trade would remain more open under such a regime, and the costs from higher national grain stocks and excessive self-sufficiency investments.

2.6 More and better social protection and nutrition policies

Actions related to agricultural production, trade, and reserves are necessary but not sufficient to overcome the food and nutrition security crisis; it is not just an acute problem, but a chronic global one. Another set of public policies is required to address health and nutrition risks through social transfers and health services. Most of these actions are carried out by national governments, but international support for these investments is also needed, especially in the least developed countries. Setting priorities in this area requires a sound metric for targeting actions and measuring progress. First, a focus should be put on lives saved and livelihoods improved (measured by reduced mortality and morbidity), criteria of success that might also be considered in any future MDG framework. Second, priority should be given to enhanced economic productivity, growth, and returns to investment (measured by human productivity and lifetime earnings). A framework that includes both of these very different concepts may be helpful for stimulating an informed policy discourse on priority setting. With that in mind, policy actions in three priority areas are called for: (1) expand social protection and child nutrition action to protect the basic nutrition of the most vulnerable; (2) take protective actions to mitigate short-term risks (such actions would include cash transfers, pension systems, and employment programs); and (3) adopt preventive health and nutrition interventions to avoid long-term negative consequences. Social safety nets not only ease poverty in the short term, but also enable growth by allowing poor households to create assets, protect their assets, and allocate resources to more risky but highly remunerative production activities. Since good nutrition is crucial for children's physical and cognitive development, as well as their productivity and earnings as adults, early childhood nutrition and school feeding programs should be strengthened and expanded to ensure universal coverage (Hoddinott *et al.* 2008).

Programs transferring income to the poor in response to food crises have a long tradition, in particular as food price subsidies and rationing schemes. Often, however, they are ineffective and fail to reach the most food insecure. Of relevance are also employment-related transfer programs, such as the Indian rural employment scheme, scaled up to the national level in the past decade. Cash transfer programs are increasingly common. These programs – which transfer cash to households partly on the condition that they meet certain requirements such as sending children to school and using preventive health services – have proven successful in reducing poverty in the short run (through cash transfers) and in the long run (through the human capital formation that they encourage). They work particularly well in countries with low school attendance and adequate schooling infrastructure. They are not magic, however – they do not work in every country, can have adverse fiscal and labour market effects, and alone they are not sufficient for reducing poverty sustainably. Early childhood nutrition actions should be connected to them.

Lack of food energy is generally an issue only in highly food-insecure areas, but micronutrient malnutrition is much more widespread and pervasive. The core problems of low birth weight and early childhood undernutrition need primary attention in nutrition and health actions. One promising way to start is to identify gaps where existing programs are insufficient to reach needed coverage and impact. Communities with the highest concentration of poor and vulnerable can guide priority setting. While problems of insufficient and poor-quality food persist, changes in the global environment are creating new nutritional issues such as the "nutrition transition" – a process by which globalization, urbanization, and changes in lifestyle are linked to excess caloric intake, poor-quality diets, and low physical activity, which together lead to rapid rises in obesity and chronic diseases even among the poor in developing countries. The main challenge for agriculture, health, and nutrition is thus to adapt to the changing environment and address the double burden of under- and over-nutrition by maintaining adequate food supply while increasing the production of low-cost, high-quality foods to improve diet quality among the poor. Unfortunately, there is still too little private sector engagement in food fortification and in child nutrition in developing countries, in such areas as the delivery of low-cost and healthy baby foods. New alliances among the private and public sectors and nongovernmental organizations (NGOs) are needed in this field of action.

3. Conclusions

In sum, accelerated action for achieving global food and nutrition security in the years ahead is called for, and should be based on a comprehensive concept:

- The prevailing concept of food and nutrition security (FNS) needs to be revisited and augmented, in order to provide appropriate guidance for policy actions. Better understanding of the dynamics, synergies and causal linkages in FNS for human development is called for. This also includes explicit attention to sufficient access to micronutrients for cognitive capabilities' protection and enhancement of health.
- The current and future MDGs should have a strong focus on the poverty and hunger goals. The hunger target that accompanies the poverty target brings attention to the food and nutrition security of the extreme poor – those far below the poverty line – and that should be maintained and further strengthened. A next set of MDGs should actually include an "End Hunger" goal over an ambitious but realistic time schedule, such as until 2025 or 2030, where the progress toward the goal is well monitored based on people-level data, not just broad trend estimates, as currently the case.
- Strategic elements of the required policy and program actions include approaches to overcoming supply constraints through enhanced food sector productivity. Essential components of a resilient agriculture are yield-increasing technologies, technologies for food quality, reduced

losses and waste in the food system and an end of land and soil degradation. The end hunger goal must be combined with related sustainable development goals (SDG) in an inseparable package.

- More attention to comprehensive and direct nutrition intervention is urgently needed, including addressing the micronutrient deficiencies in combination with public health investments. This is an essential element of food and nutrition security policies that have not only a focus on survival but an increased focus on protecting and enhancing the cognitive capacities and well being of people. This entails linking the end hunger goal with access to education goal through sound educational systems upgrading, i.e. linking "bread and brain" actions comprehensively.
- The actions for achieving food and nutrition security require strong prioritization, sequencing, transparency, and accountability for successful implementation. Related governance practices in many countries must be strengthened, as well as reformed global governance system of food, which does not currently deliver the necessary public goods to achieve food and nutrition security for the poor.

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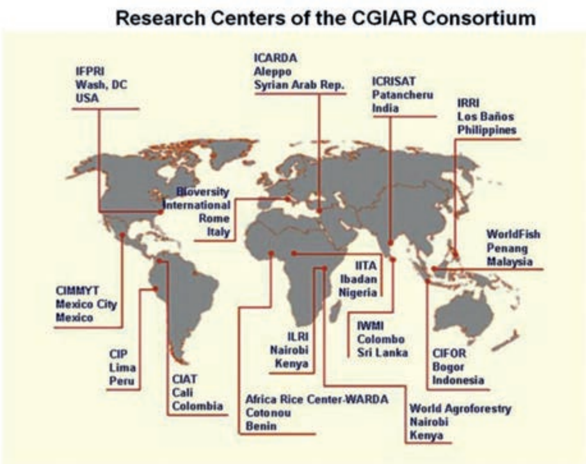
The Quest to Assure a Well-Fed World in 2050 Will Take an Integrated Global Effort[1]

Robert S. Zeigler[2]

It is my privilege to be a member of this distinguished Working Group formed by the Pontifical Academy of Sciences to examine the present state of malnutrition, brain development, and education problems, and to help identify a set of actions.

Our greatest challenge: producing more food to feed the world

As the global population continues to grow toward a predicted nine billion souls by 2050, I believe it will be humanity's greatest challenge to produce more food to feed the world 37 years hence without wrecking the planet. This is in the face of food production systems that are rapidly chang-



[1] Based on a presentation made at a meeting of the Working Group on Bread and Brain, Education and Poverty, 5 November 2013, The Pontifical Academy of Sciences, Vatican City.

[2] Director General, International Rice Research Institute.

ing, climate variability that is making the poor even more vulnerable, and urbanization that is drastically altering the agricultural landscape.

To alleviate poverty and malnutrition – the main concerns of this workshop – and to ensure food security for everyone, it will be essential to conduct targeted research with an aim to empower poor rural communities and raise the productivity of staple crops and agricultural systems, which include livestock, fish, and agroforestry. I maintain that a science-based second Green Revolution involving an integrated global effort will be required to ental task.

Enter CGIAR, a global partnership that has united organizations – one of those being the International Rice Research Institute (IRRI) – engaged in research for a food-secure future. CGIAR research is dedicated to reducing rural poverty, increasing food security, improving human health and nutrition, and ensuring more sustainable management of natural resources – all through targeted innovation. This urgent work is carried out by IRRI and 15 other centers of excellence and focus that are members of the CGIAR Consortium (see map), in close collaboration with hundreds of partner organizations, including national and regional research institutes, civil society organizations, academia, and the private sector. The 15 research centers are currently generating and disseminating knowledge, technologies, and policies for agricultural development through 16 CGIAR Research Programs (CRPs) that range from the staple cereals (rice, wheat, and maize) to other important crops (roots, tubers, bananas, and grain legumes), from livestock and fish to forests and trees, and from nutrition and health to policies and markets.

CGIAR | Research Program on Rice
Global Rice Science Partnership

Unfortunately, time and space will not allow me to provide details on all 16 of these vital CRPs. However, an excellent example is the very first CRP launched by the CGIAR Consortium Board on 10 November 2010, the Global Rice Science Partnership (GRiSP). This is not to mention the facts that rice is my area of expertise as director general of IRRI and that, if we want to do something about poverty, it is clear that we must invest in rice.

GRiSP is a sustained integrated effort to bring together the work of IRRI and the Japan International Research Center for Agricultural Sciences (JIRCAS) in Asia, the Africa Rice Center in Africa, and the International Center for Tropical Agriculture (CIAT) in Latin America into one global and comprehensive rice research program. Other major partners are

Box: GRiSP Research & Development Themes

- **Theme 1:** Harnessing genetic diversity to chart new productivity, quality, and health horizons
- **Theme 2:** Accelerating the development, delivery, and adoption of improved rice germplasm
- **Theme 3:** Ecological and sustainable management of rice-based production systems
- **Theme 4:** Extracting more value from rice harvests through improved quality, processing, and market systems and new products
- **Theme 5**: Technology evaluations, targeting and policy options for enhanced impact
- **Theme 6:** Supporting the growth of the global rice sector

the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD) and the Institut de Recherche pour le Développement (IRD). If we are successful in developing this CRP and having it reach the level of maturity that we hope it will, it could indeed be transformative in the future of global rice supplies.

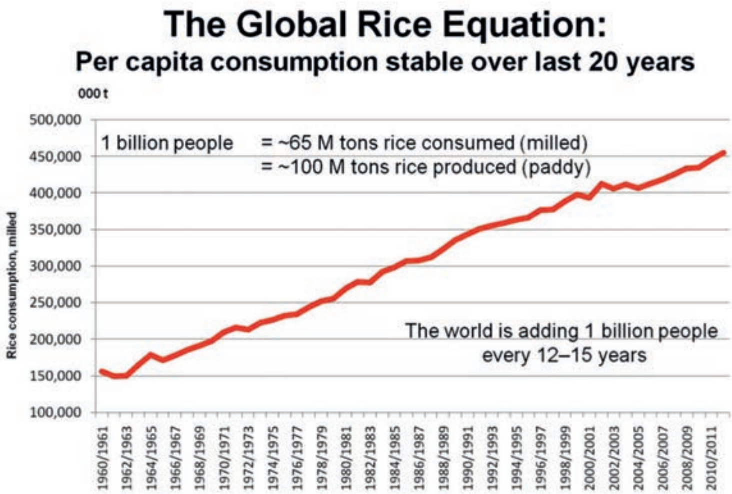
The proactive innovation of GRiSP involves

- A first phase work and business plan (2011-15; extended through 2016);
- Interdisciplinary, product-oriented R&D: 94 products currently clustered in 26 product lines under six themes (see box);
- New frontiers research; and
- Science capacity building.

Poverty is where rice is grown

Now, I'll provide a few more details on why investment in GRiSP – now and in future phases beyond 2016 – is so important, especially in addressing the concerns of this workshop. The map shows where rice is consumed in the world. In large parts of the world, people are eating 70, 80, or 100 kilos or more annually (shades of green). Where rice is widely consumed, each red dot on the map represents 250,000 people living on less than US$1.25 per day – abject poverty. The world today still has huge concentrations of poverty and most of these concentrations are where rice is grown. This is the message I try to make clear to anyone who will listen – if we want to overcome problems of poverty and hunger, rice must be part of the solution!

Now, if we look at the global rice equation, as far as we can tell, the demand for rice is going to continue to grow for many decades to come. Every prediction that the demand for rice is going to taper off has proven to be incorrect. If we look at the population trends for the next several decades, the world is going to be adding about a billion people every 12 to 15 years. Now, a billion people translate into 100 million tons of additional



paddy to feed them. So, just in order to keep pace with population growth, we'll have to add 100 million tons of paddy (produced rice) or 65 million tons of milled rice every decade and a half – a major challenge!

One key question is: Where will the world's rice come from in the future? Ideally, it will come from existing lands, primarily in Asia. We don't want to be clearing new land for agriculture. We want to make existing land more efficient. But, if we consider the social and economic dynamics across Asia and indeed the rest of the world, land is moving out of agriculture.

More challenges for GRiSP

In order to meet the needs of the future, GRiSP is going to have to come up with huge innovations in production practices, which must be driven by research, just to stay where we are – if you revisit that poverty map. However, "just where we are" is simply not good enough!

Climate change

So, the challenges that face the GRiSP partners on three continents are enormous. Just consider the world climate change that we got a sample of all around us in 2013 with particularly vicious storms in the Philippines and elsewhere and too much water in some regions while there was not enough precious moisture in others. Temperatures are increasing. CO_2 levels in the atmosphere are increasing. Rainfall patterns are shifting. Sea levels are rising (more on that in a moment). Weather hazards combined with rising sea levels will put the high population concentrations inherent near the coasts in ever-increasing danger. These are all facts.

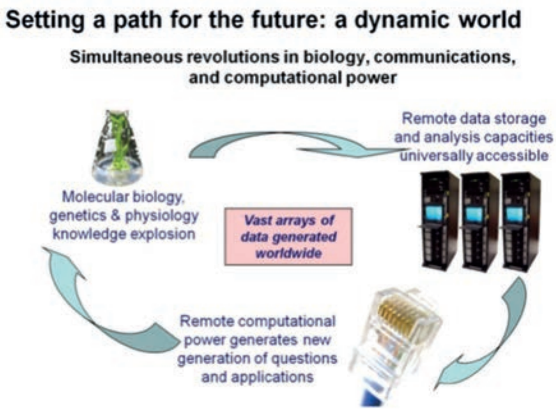
We face a situation in which the challenges brought on by climate change are going to affect agriculture, especially rice cultivation. We know that, in the future, we're going to have to have rice varieties that will tolerate higher temperatures and withstand floods. Rice likes to grow ankle-deep in water. However, if you put it completely under water, it will drown. We will also need rice varieties that will tolerate drought and saline soils, particularly along coastal areas. We're going to have to have production practices that are far more efficient, that will demand less water, but that still get a very good yield. We will need to use fertilizers much more efficiently.

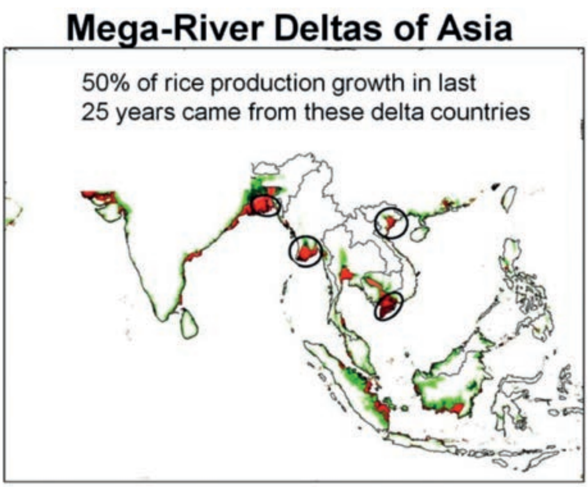
Since many people are moving out of farming, labor will have to be more efficient. So, with less available labor, we're going to have to grow rice far more efficiently using much more sophisticated tools. We can't have those who couldn't make it to be a doctor or a lawyer being our future rice farmers.

A convergence of revolutions

Basically, we're going to have to get sustainably high yields and productivity in ways that are not business as usual. As the illustration to the right, which I put together 10 years ago, still shows, we have had one simultaneous convergence of major revolutions in communications, in molecular biology, in genetics, and in computational power. All of these events by themselves would be revolutionary enough. But combined, they have transformed the way our world is. And no transformation is greater than that in the biological and agricultural sciences.

The GRiSP partners can now address challenges, in terms of understanding genetics, in ways that we could never have dreamed of before. I think





that this is best expressed in the area of genetic resources. IRRI's International Rice Genebank has the world's largest collection of rice germplasm – more than 117,000 rice accessions and wild relatives. Most people probably don't realize that a very tiny percentage of these materials has been used in global breeding programs. We are now just scratching the surface. Those other revolutions in molecular biology and genetics will now enable us to tap into that incredible wealth – thousands of years of farmer knowledge and selection – from very diverse environments. Now, we can really begin to exploit the genetic diversity of rice to meet our future challenges.

Sea-level rise

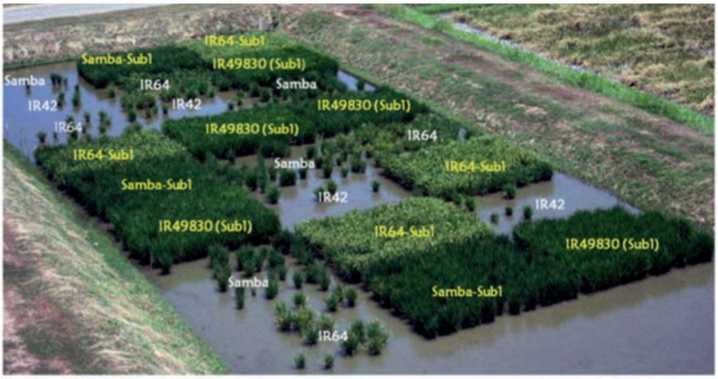
Back to sea-level rise, a major challenge that we have to deal with. The map provides a graphic representation of what we are up against. It shows the river deltas across Asia, which are threatened. The major food supplies of the world come out of these deltas. Research shows that 50% of rice production growth, which we enjoyed over the last quarter century has come from these delta countries. Now, sea-level rise is threatening these areas and, if they all drop off the map in terms of rice production capacity, the world is going to have a major food security crisis. It's up to us to see that this doesn't happen.

Flood- and drought-tolerant rice.

One area that will have great impact is the work we're doing to develop stress-tolerant rice varieties. Already, more than 10 million hectares per year of rice are lost to catastrophic flooding. Even in favorable areas, there are losses to occasional floods. So, just to meet the challenges of today, not to mention what we see coming in the future, some flood-tolerant rice would make a great contribution.

Over the years, IRRI scientists and partners have been working on flood-tolerant rice. A couple of decades ago, they identified a flood-tolerant variety from India, called *FR13A* (FR stands for flood resistance). If you put this variety under water for 10 days or so, it will recover after the floodwaters recede. The only problem is its terrible grain quality. So, you might produce a variety that can yield under stress, but people still have to want to eat it. And, if it also has poor agronomic traits and it is crossed with other varieties, a breeder's worst nightmare could ensue!

It wasn't until the application of the new molecular tools at IRRI and with U.S. colleagues that breeders were able to move the *FR13A* gene for flood tolerance into commercially acceptable varieties that farmers would be willing to grow – and want to grow.



New Sub1 lines after 17 days of submergence in the field at IRRI. The genes for submergence tolerance have been moved into popular "mega-varieties."

The photo here just can't be beat. It shows the same varieties labeled in white and yellow. The white ones don't have the flood-tolerance gene; the yellow ones do. After 17 days of submergence, one does not need a statistician to indicate which plants are tolerant of flooding and which ones are not!

Researchers' next step was to develop rice varieties that were both flood tolerant and drought tolerant. And today, we have varieties with combined flood tolerance and drought tolerance. It took 20 years but we now have rice varieties for all seasons!

Results in farmers' fields

The ultimate question is, How do these tolerant varieties perform in farmers' fields? Well, on 31 July 2008 at 1:17 in the afternoon, the top photo on the next page shows Indian farmer Asha Ram Pal standing in his rice field after two successive floods contemplating what to do. His neighbors told him to plow it up because he was not going to get any crop out of that field. Forget it! Well, he didn't plow it up and the bottom photo shows what his field looked like on 31 October.

I later asked Mr. Pal, How did his rice taste? He said he actually didn't know because he ended up selling the entire crop as seed to his neighbors – the same ones who laughed at him and told him to plow up the field in July.

Today, this same germplasm is in the hands of almost 3 million farmers, just in eastern India alone! And, it's also moving out into Bangladesh, Nepal, the Philippines, and elsewhere. Note again that time stamp in the upper photo. I would like to suggest that the Second Green Revolution that I mentioned earlier actually started in rice at 1:17 in the afternoon on 31 July 2008 – the exact time when Mr. Pal decided not to plow up his field.

Greener rice

Mr. Asha Ram Pal's rice field, Palia Goa village, Faizabad district, Uttar Pradesh, India.

Additional challenges for the GRiSP partners include reducing the water and environmental footprint of rice production. We are promoting climate-smart farming by scaling up and out what is called alternate wetting and drying (AWD) of rice fields. This simple and safe (for the rice) technique, which involves farmers monitoring the water levels in their fields with a *field water tube,* is already widely adopted across Asia and has the potential to benefit tens of millions of rice-farming families. Further adoption of AWD could free up 100 cubic kilometers of scarce water annually and, at the same time, help reduce methane, a greenhouse gas (GHG) that contributes to global warming, from rice production by from 30 to 70%.

AWD is helping rice farmers cut down their use of irrigation water by 30% and cope with water scarcity – an adverse effect of climate change – without compromising rice yield. It is cheap and easy to implement, thereby lowering the cost of irrigation, thus helping farmers maintain and improve the economic and environmental sustainability of their source of livelihood and contribution to food security.

GRiSP partners are introducing field-specific nutrient management decision tools to extension workers and farmers and also urging a significant reduction in the use of pesticides. Research has shown that most tropical rice crops under intensification require absolutely no insecticide use. But this is a difficult habit to break among farmers who have routinely used pesticides for the last half-century, particularly in Asia, where pesticide merchants are well organized in selling their wares.

Although pesticide use is indeed a management tool, the practice tends to overshadow all the other technologies that can help farmers. Science and other logical methods cannot compete with the pesticide marketers unless the rules that regulate these chemicals are rigorously enforced by the governments of individual countries. GRiSP can assist in this effort by focusing on designing governing structures in countries with this specific problem such as Myanmar, Thailand, Vietnam, and Indonesia.

On to malnutrition

Now, I move on to a challenge that is of particular interest to the participants of this workshop, that is, malnutrition, especially that caused by micronutrient deficiency. I don't want to steal the thunder of Ingo Potrykus, who will be speaking tomorrow on this topic and the valuable lessons learned from research on Golden Rice, which has been genetically modified to contain beta carotene that is a precursor to vitamin A, a particularly significant micronutrient. However, I do want to emphasize the critical importance of overcoming micronutrient deficiency.

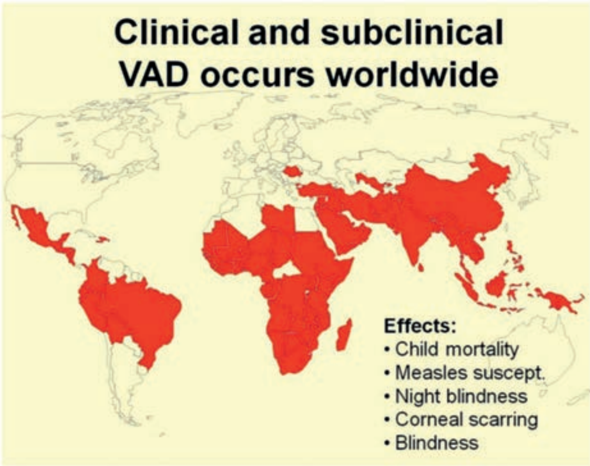
Worldwide, the most seriously limiting nutrient deficiencies in the human diet are iron, zinc, iodine – and vitamin A. Vitamin A is an essential nutrient needed for the visual system, growth, development, and a healthy immune system. Vitamin A deficiency (VAD) is most prevalent among young children and pregnant and nursing women. According to the World Health Organization (WHO), clinical to subclinical severe VAD affects most developing countries (see map).

Despite significant efforts, including capsule supplementation, dietary diversification, fortifying commonly used foods such as cooking oil with vitamin A, and optimal breastfeeding practices, VAD continues to adversely affect an estimated 190 million preschool children and 19 million pregnant women in the developing world. Since rice is widely produced and consumed in poor developing countries, it seems logical that, if this staple could be made to provide a source of vitamin A, it has the potential to reach millions of people who do not have reliable access to or cannot afford other sources of the vitamin.

The nearly 30-year history of the development of Golden Rice is an enlightening story of vision, imagination, technological creativity, and persistence that Dr. Potrykus will elaborate on further tomorrow. Many organizations and individuals in the public and private sector have been involved in this effort that has attracted more than its share of controversy. Recent Chinese studies unequivocally demonstrate that one bowl of Golden Rice (50 grams uncooked, 150 grams cooked) provides 60% of the Recommended Dietary Allowance for children 6 years of age and younger. So, I'm sure we all hope, along with Dr. Potrykus, that Golden Rice's delivery to farmers and consumers will not be delayed much longer by those who oppose the use of this new and promising technology.

Working together globally

As I emphasized at the outset, only a science-based second Green Revolution involving an integrated global effort will allow us to meet the many



challenges involved in feeding the world in 2050. This will require a large portfolio of response options. Certainly, CGIAR, in its current framework involving GRiSP and 15 other far-ranging CRPs (to date) and additional Challenge Programs, is uniquely positioned to carry out many of these options.

Already, CGIAR CRPs accounted for US$673 million or just over 10% of the US$5.1 billion spent on agricultural research for development in 2010. The economic benefits have run to billions of dollars. In Asia, the overall benefits of CGIAR research are estimated at US$10.8 billion a year for rice, US$2.5 billion for wheat, and US$0.8 billion for maize. Political, financial, technological, and environmental changes reverberating around the globe mean that there are many opportunities to rejuvenate the shaky global food system. Developments in agricultural and environmental science, progress in government policies, and advances in our understanding of gender dynamics and nutrition are opening new avenues for producing more food and for making entrenched hunger and poverty a thing of the past. Yes, the future looks bright!

Thank you.

Additional background and information resources

More about CGIAR: www.cgiar.org

More about climate change: http://irri.org/our-work/research/better-rice-varieties/climate-change-ready-rice

More about Golden Rice: http://irri.org/golden-rice

More about GRiSP: www.cgiar.org/our-research/cgiar-research-programs/rice-grisp

GRiSP video on YouTube: http://youtu.be/lCHqB6rLvvk

Scuba rice: stemming the tide in flood-prone South Asia (*Rice Today* magazine): http://fr.scribd.com/doc/94631646/RT-Vol-8-No-2-Scuba-rice

Flood-tolerant rice time lapse on YouTube: http://youtu.be/DJsNwYX1Nc0

Reducing pesticide use in Asia's rice fields: the job is far from finished (*Rice Today* magazine): http://irri.org/rice-today/reducing-pesticide-use-in-asia-s-rice-fields-the-job-is-far-from-finished

Zeigler RS. 2014. Biofortification: Vitamin A deficiency and the case for Golden Rice. In: A. Ricroch, S. Chopra, S. Fleischer, editors. *Plant Biotechnology – Experience and Future Prospects*. Springer (in press).

Hidden Hunger – Consequences for Brain Development

Konrad Biesalski

Introduction

Whenever we see a report in the evening news about a massive famine, which killed thousands, then generally for the first time we become aware that there are people on the planet who live in poverty and starvation. It is important, however, that we differentiate between 'hunger' and 'starvation' as these are two very different conditions. Hunger is a two-sided coin. It refers simultaneously to that which is visible and can be subjectively and objectively viewed, and that which is hidden. The visible hunger, undernourishment with very low body weight, is a result of an inadequate energy intake. The affected are more or less wasted as a result of the energy need of the body and subsequent depletion of his own fat stores and muscles.

This less-visible hunger is defined as 'hidden hunger'. Hidden hunger or chronic malnutrition can be defined as a low supply with essential micronutrients e.g. vitamins, minerals etc. Hidden because typical signs and symptoms of severe deficiencies are absent as long as a small amount of the micronutrients is present in the diet. If, at least, the body stores are exhausted typical symptoms may occur which finally but often too late unhide the hidden hunger.

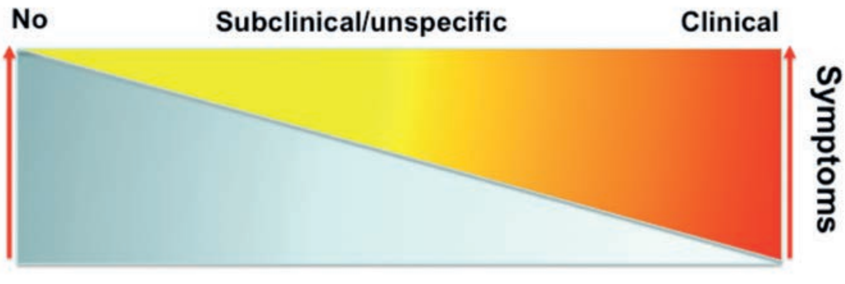


Figure 1.

Figure 1 shows a scheme of hidden hunger. Supply of a micronutrient declining from left top to right bottom. As long as the supply of a micronutrient is not near zero, specific clinical (e.g. scurvy and vitamin C-deficiency, or night blindness and at least blindness and vitamin A deficiency etc.) signs will not develop. However, long before, the inadequate supply results in more or less unspecific symptoms such as increased risk for infectious diseases (vitamin A and iron-inadequacy) or chronic diarrhea (zinc deficiency) occur.

Currently, three billion people are affected by hidden hunger. In particular iron, iodine, zinc, vitamin A and D are the major candidates of hidden hunger. Year after year it is hidden hunger, not only the physical torture of starvation, which is responsible for the deaths of millions of men and women, but the majority are children. Chronically malnourished women and children, most of all, are the ones who face the highest risk of suffering illness or death before having taken their first real steps in life. This is the real tragedy! Hidden hunger remains invisible over a more or less long period of life.

Box 1. Adverse effects of malnutrition among children [1].

- 186 million children under the age of five (30% of all children in this age group) suffer from stunting.
- 115 million children under the age of five suffer from wasting.
- 20 million children suffer severe and life-threatening malnutrition.
- 3.9 million children (35% of all fatalities) die from a lack of breast milk (or from breast milk with not enough nutrients), as well as from a micronutrient deficiency, most especially vitamin A, iron, iodine and zinc.
- In many countries, a child's diet after weaning (generally six months after birth) is not sufficient to provide it with the quality it needs for the first two years of its life.

Even in cases with adequate energy supply the missing micronutrients cause physical and cognitive impairment of the growing child. From the beginning of their life these children are captured in a vicious cycle of malnutrition and poverty. Poor physical strength and low educational level are the basis to remain in poverty and malnutrition.

Poverty and chronic malnutrition are inseparable, and yet the connection is very often overlooked. This combination dictates the daily activities of some 2.5 billion people. Despite numerous attempts to remedy this predicament and even more cries for change, there have hardly been any improvements during the past 25 years. In fact, the growth-centered globalized economy has led to even greater poverty levels, whereby the poor remain in the background. They may move temporarily to the forefront whenever a region is struck by famine, but then they inevitably disappear again into the shadows of the abyss and the hidden hunger remains.

The phenotype of hidden hunger

To understand the phenotype of hidden hunger, undernutrition and malnutrition need to be discriminated (Box 2).

Unternutrition is, according to the FAO, an intake of calories expressed as daily Dietary Energy Consumption (DEC)[2] which is less than the Dietary Energy Requirement (DER) (Cafiero & Gennari 2011). Using this formula, the number of undernourished or hungry persons in any population can be calculated. To determine the DEC, factors such as gender and light manual labor are taken into the equation, as well as data regarding the average daily requirements from the Food Balance Sheets (see below). The percentage of undernourished individuals is projected based on the averages values over a three-year period. Hence the term 'undernourishment' is expressed strictly in terms of quantity, whereby the undernourished are understood as having an insufficient energy intake in relation to their physical workload. As a result, the phenotype undernourished individual is underweight and 'under-productive'.

Malnutrition in contrast is a qualitative description, i.e. those persons affected by it have a deficiency of one or more nutritional components without necessarily consuming too few calories. If the average caloric intake of the population is calculated as being sufficient, no measures are undertaken to determine what percentage of that population is malnourished. By definition, a person who is undernourished is malnourished. Yet the opposite is not true, namely a person need not be undernourished to be malnourished and may even be overweight. The phenotypical malnourished individual is recognizable either due to symptoms arising from a specific nutritional deficiency (e.g. iron deficiency anemia) or because he or she often falls ill or shows signs of a developmental disorder (stunting).

The phenotype of undernutrition is wasting, the phenotype of malnutrition (hidden hunger) is stunting (Box 3).

Wasting (W/H > -2 SD) is the most serious form of undernourishment and it effects 10% of children under age five (i.e. 55 million children). 3.5% of children younger than five (i.e. 19 million children) suffer from a severe case of wasting (> -3.5 SD). Wasting is a visible signal of ongoing and acute undernourishment, depending upon the original bodyweight of the individual and it is the result of an insufficient diet (in both the qualitative and quantitative sense) or a serious illness.

Stunting (H/A < -2 SD) Children who suffer from stunting deviate from the average height of children in the same age group and population group by more than two SD. Unlike wasting, stunting is the same as being underweight since it is the result of chronic malnutrition. Those affected suffer from growth disorders and mental handicaps.

Restricted growth, defined as stunting, is a consequence of malnutrition during pregnancy and frequent infectious diseases and malnutrition during early childhood. The latter is a consequence of an impaired immune system due to malnutrition. Infections further deplete micronutrient body stores and promote malnutrition, and subsequently malnutrition negatively affects the immune system and promotes infections. Beside the above-mentioned factors, inadequate provision of care and living conditions may also have an impact on the development of stunting. Stunting however is not an isolated sign of growth retardation, but also a biomarker for a more or less impaired development of the brain.

The major reason for hidden hunger worldwide is poverty and poor education. Therefore hidden hunger occurs in developing and in developed countries, but to a different amount and magnitude (Table 1, 2).

It is evident that the prevalence of hidden hunger is highest in developing countries, but also occurs in more developed regions. The fact that malnutrition does not only cause an impairment of childhood development, but increases mortality in children below the age of five is inacceptable. The leading causes of childhood death are vitamin A- and zinc-deficiency.

Data depicted in table 3 show that deficiency of iron, iodine, vitamin A and zinc in pregnant women and children below the age of five, is not only present in developing countries, but also occurs in Europe to an extent, which is not marginal, with respect to childhood development. In some cases the prevalence is similar between low- and high-income countries. However, the severity of the deficiency consequences might be different but not the reason.

Table 1. Prevalence of the three major micronutrient deficiencies by WHO region [3].

	Anemia[a] (total population)		Insufficient iodine intake[b] (total population)		Vitamin A deficiency[c] (preschool children)	
	n (millions)	% of total	n (millions)	% of total	n (millions)	% of total
WHO region						
Africa	244	46	260	43	53	49
Americas	141	19	75	10	16	20
South-East Asia	779	57	624	40	127	69
Europe	84	10	436	57	no data available	
Eastern Mediterranean	184	45	229	54	16	22
Western Pacific	598	38	365	24	42	27
Total	2,030	37	1,989	35	254	42

[a]Based on the proportion of the population with hemoglobin concentrations below established cutoff levels.
[b]Based on the proportion of the population with urinary iodine ‹ 100 μg/l.
[c]Based on the proportion oft he population with clinical eye signs and/or serum retinol 0.70 μmol/l.

Table 2. Global deaths and DALYs in children ‹ 5 years of age attributed to micronutrient deficiencies [3].

	Deaths	% of deaths in children ‹ 5 years	Disease burden (1,000 DALYs)	% of DALYs in children ‹ 5 years
Vitamin A deficiency	667,771	6.5	22,668	5.3
Zinc deficiency	453,207	4.4	16,342	3.8
Iron deficiency	20,854	0.2	2,156	0.5
Iodine deficiency	3,619	0.03	2,614	0.6

Table 3. Hidden hunger in children ‹ 5 and pregnant women in developed countries [4]. Prevalence of vitamin A deficiency (1995-2005), iodine deficiency (2013), inadequate zinc intake (2005), and iron deficiency anemia (2011). Data are % (95 % CI). UIC = urine iodine concentration.

	Vitamin A deficiency			
	Children < 5 years		Pregnant women	
	Night blindness	Serum retinol < 0.70 μmol/L	Night blindness	Serum retinol < 0.70 μmol/L
Global	0.9 % (0.1 – 1.8)	33.3 % 29.4 – 37.1)	7.8 % (6.5 – 9.1)	15.3 % (6.0 – 24.6)
Africa	2.1 % (1.0 – 3.1)	41.6 % (34.4 – 44.9)	9.4 % (8.1 – 10.7)	14.3 % (9.7 – 19.0)
Americas and the Caribbean	0.6 % (0.0 – 1.3)	15.6 % (6.6 – 24.5)	4.4 % (2.7 – 6.2)	2.0 % (0.4 – 3.6)
Asia	0.5 % (0.0 – 1.3)	33.5 % (30.7 – 36.3)	7.8 % (6.6 – 9.0	18.4 % (5.4 – 31.4)
Europe	0.7 % (0.0 – 1.5)	14.9 % (0.1 – 29.7)	2.9 % (1.1 – 4.6)	2.2 % (0.0 – 4.3)
Oceania	0.5 % (0.1 – 1.0)	12.6 % (6.0 – 19.2)	9.2 % (0.3 – 18.2)	1.4 % (0.0 – 4.0)

	Iodine deficiency (UIC < 100 µg/L)	Zinc deficiency (weighted average of country means)	Iron deficiency anaemia (haemoglobin < 110 g/L)	
			Children < 5 years	Pregnant women
Global	0.9 % (0.1 – 1.8)	33.3 % 29.4 – 37.1)	7.8 % (6.5 – 9.1)	15.3 % (6.0 – 24.6)
Africa	2.1 % (1.0 – 3.1)	41.6 % (34.4 – 44.9)	9.4 % (8.1 – 10.7)	14.3 % (9.7 – 19.0)
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Malnutrition, the escort of poverty

The association between childhood poverty and negative developmental outcome is long established. One determinant of poor development is malnutrition. The reason for malnutrition is low household expenses to buy different food and to achieve adequate diet diversity.

Figure 2 shows the major reasons for hidden hunger, and the relation between income and diet diversity related to the risk of micronutrient deficiencies in low-income countries [5].

According to Deaton and Subramanian [6] the poorest people consume on average slightly less than 1,400 kcal/day. This amount of energy does not even cover the daily need. But also an increase of energy with increasing amount of starchy food is far from being adequate with respect to sufficient nutrition. The extremely poor (less than 1US$ income) spend nearly all money to buy starchy food. If the diet is composed mainly of starchy food, the risk of micronutrient deficiency is high. Starchy food creates satiety but is poor in nearly all micronutrients. The higher the diet diversity the higher the micronutrient content, and the lower the risk for micronutrient deficiencies. From the figure it is also easy to understand why even small changes in food prices of starchy food will lead to increased micronutrient deficiencies. The poor become very poor and the very poor join the group of the extremely poor. The critical role of starchy food is underlined by a recent calculation of the FAO (FAO, 2013)[7]. The report did not find a strong correlation between undernourishment and stunting, or average dietary energy supply. But the relation between the amount of starchy food (cereals, roots and tubers) in the daily diet and stunting was strong. If the daily amount exceeds 65% (total energy) within a household the number

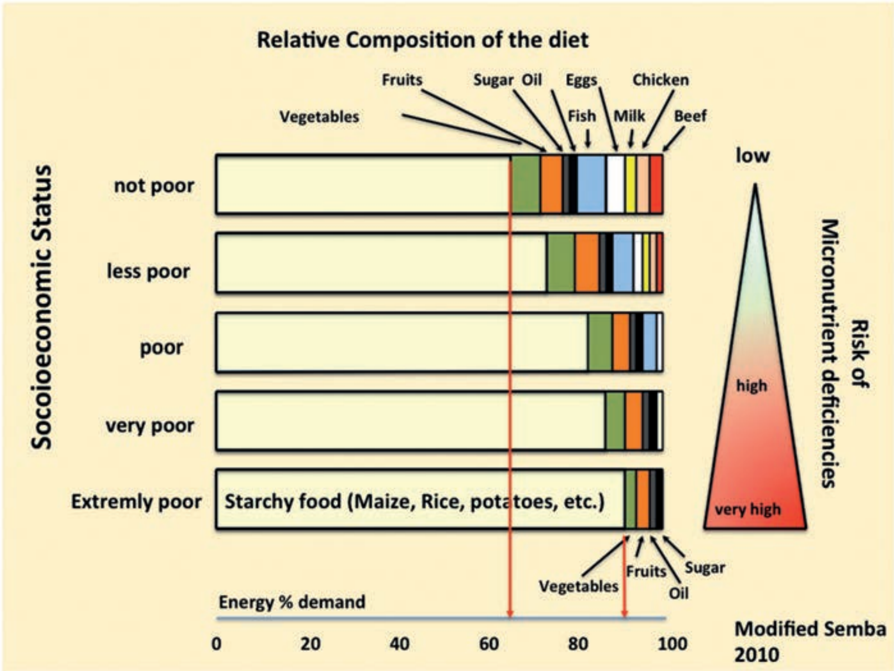

Figure 2.

of children stunted is greater than 40% in a country. Based on the data that the daily amount of starchy food in the diet has not really changed within the last twenty years (30% in developed regions, 60% and more in developing countries), the number of undernourished children may decrease due to increased availability of starchy food, but the number of malnourished might be unchanged.

The major risk groups affected by malnutrition are women and children. Consequently malnutrition at the time point of conception is not a rare case and will trigger a couple of events during the first 1000 days of life of a child. The focus of the following discussion on micronutrients and brain development will be therefore restricted to the first 1000 days of life, although micronutrients might exert effects on health and cognition later on in life.

The 1000-day window – a development window which might be irreversibly closed

During the first 1000 days of human life, from conception until the second year of life, the most important developmental steps occur. The nutrition status of the mother at the time point of conception is a critical condition with respect to embryonic development.

Intrauterine growth retardation results in low birth weight of the newborn. Major determinants of low birth weight, in particular in developing countries, are poor nutritional status of the mother and subsequent low nutrient flow to the developing child. Newborns with low birth weight (<2,500g) are four times more likely to die during their first 28 days of life than those weighing 2,500-2,999g, and 10 times more likely to die than newborns weighing 3,000-3,499g [8]. Low birth weight is, however, the phenotype of intrauterine stunting and consequently also a visible marker for a potentially impaired brain development. Indeed, it was documented that the effect of stunting on short-term memory was equivalent to the difference in short-term memory between children in US families that had experienced poverty for 13 years and children in families with incomes at least three times the poverty levels [9]. Malnutrition is a frequent companion of poverty not only in developing countries, and has a strong impact on brain development.

Brain development and poverty – fateful relationship

The human brain develops in different steps during embryogenesis. Interneuron connections develop during week 8 to 16 within the so-called cortical plate and are replaced by cortical neurons from week 24 until the perinatal period. The brain growth spurt begins in the last trimester of pregnancy and continues in the first two years after birth. During this time the majority of dendritic growth, synaptogenesis and glial cell proliferation occurs [10,11]. During the first 2 years of life (by the age of 2 the brain has 80%-90% of adult weight), this period is highly sensitive to deficiencies of micronutrients [12,13].

The structure of the brain at any time is a product of interactions between genetic, epigenetic and environmental factors [14]. Environmental factors include outside events and the internal physiological milieu. Consequently poor nutrition or stress will have an impact on brain structure and ultimately on its function. The connection between stress and poor nutrition is poverty. Developmental cognitive neuroscience dealing with poverty and social gradients is a new field of research, which emerged recently. It has recently been shown that pregnancy and growing up in a low socio-economic status (SES) will have neural and cognitive consequences [15,16].

Children living in poverty have poorer cognitive outcome and school performance. Poor SES is related to reduced attention, literacy and numeracy function which, beside other factors, may explain the poor educational level of children living in poverty [17]. Language and memory functions are related to brain regions sensitive to environmental and nutritional influences. Research in both animals and humans suggests that the experience of stress has important negative effects on the hippocampus and the amygdala which are highly susceptible during the late fetal and early neonatal period.

The amygdala and hippocampus serve emotion, language, and memory, functions that change markedly between age 4 and 18 years [14]. Amygdala and hippocampus volumes increase with age. Both are involved in stress regulation and emotion processing and are sensitive against environmental stimuli including nutrition. Different studies report lower hippocampal volume in children and adolescents (age 5–17) from lower-income backgrounds compared to the same age group from higher SES [18,19,20].

Poor nutrition as a result of poor income is not the only reason for developmental changes of the brain. Poverty is strongly associated with other factors with an impact on brain development, such as unsupportive parenting, poor education, lack of caregiver education and high level of stressful events. In particular, the income-to-need ratio, for example, to ensure daily nutrition, among others, might become a stressful event which influences brain development [21]. Income-to-need ratio – but not parental education – was positively associated with hippocampal size [18,19]. Stressors more directly related to income, such as limited access to material resources, e.g. variety of food, may have greater influence on hippocampal size than parental education related to cognitive stimulation and parenting style.

A study with healthy children in France showed a positive correlation between SES reading and verbal abilities and literacy [20]. The neural correlate was a significant correlation of SES and local gray matter volumes of bilateral hippocampi. Similar results were obtained from a study of US-American households, documenting a significant positive relationship between income and hippocampus gray matter volume. The authors suggest that differences in the hippocampus, perhaps due to stress tied to growing up in poverty, might partially explain differences in long-term memory, learning, control of neuroendocrine function, and modulation of emotional behavior. Lower family income may cause limited access to material resources, including food, which may be more important for predicting hippocampal size [22].

Two independent studies which might have used part of the same group of children in Germany (Brandenburg) documented an impact of SES on physical and cognitive outcome. The first study [23] investigated children at admission into primary school (aged 6 years in the year 2000) and documented an impairment of literacy in 18.2% of the children from low SES compared to 8.2% mean SES and 4.3% in high SES, and a impairment of cognitive development of 13.2% vs 2.8% vs. 0.9%.

In another study, anthropometric data from children living in Brandenburg on the effect of unemployment on childhood development was investigated [24].

Data from 253,050 preschool children during 1994-2006 were used and the authors stated that,

> *After an initial substantial height increase of school starters in the Eastern German Land of Brandenburg between the re-unification of 1990 and 1995, the upward trend stopped suddenly and even developed into a downturn in children's heights between 1997 and 2000. Since 2000, heights have been stagnating at a low level. This is all the more remarkable, as heights have never declined over longer time spans in Eastern German Laender since 1880 – except for the most recent period 1997-2006.*

They further conclude:

> *The interaction terms of unemployment and additional children are remarkably large. Above, it was already shown that households with four and more children fall behind smaller households with regard to children's height, the former's children being significantly shorter (-1.8 cm). The unemployment variable subtracts another height coefficient of -0.3 cm, in addition to the 'normal' sibling effect! In addition, if the parents are unemployed, the detriment is even larger.*

The height difference is around 1SD from the 95% percentile of children within that area, so it cannot be defined as stunting but it must be taken seriously. Together with the data from the other Brandenburg study showing a massive impact of SES on cognitive development in one of the richest countries of the world, the data are alarming because this has consequences for the later success of the children in terms of better education and income to escape from poverty. Accordingly, it was very recently reported in an analysis of ten European countries that economic conditions at the time of birth significantly influence cognitive function later on in life [25]. The authors argue that birth during a time of recession may lead to a low quality and/or quantity of food which impacts development during that time, with consequences later on in life.

Poor nutrition is not only documented in low-income countries but also in families living in poverty in high-income countries [26]. Diet quality is not only affected by age, traditions or personal preferences but also by education, living conditions and income, important indices of SES and social class. If the income-to-need ratio is not sufficient to ensure an adequate food pattern, either other needs (education, medicine) are reduced or the diet becomes poorer and poorer with respect to quality. If food costs rise, food selection narrows to those items providing the most energy at the lowest cost. When these conditions persist, essential nutrients disappear from the diet and malnutrition develops [27,28]. Indeed, a recent study on the effect of poverty on children's living conditions showed that, beside a lack of cognitive stimulation, food insecurity also has a strong association with income [29]. There is clear evidence that the SES has a strong impact on dietary quality because diet costs are positively related to food with a higher quality [30].

The individual driving force of food selection is to reduce hunger with an appropriate quantity of food! Food quality is then the second choice. Indeed, when indicators of well being in children living in poverty were compared in the US [31], the most obvious difference was related to "Experienced hunger (food insecurity) at least once in past year". 15.9% of poor children compared to 1.6% of non poor, a nearly 10-fold difference, followed by child abuse and neglect 6.8-fold, lead poisoning 3.5-fold and violent crimes, days of hospital stays, stunting, grade repetition or high school drop out all 2-fold.

Poverty and low income are often associated with poor dietary quality and, consequently, more or less expressed malnutrition. Although a lot of other factors (parental care, education) are involved, the impact of inadequate supply with essential nutrients on physical and in particular brain development should not be underestimated.

Micronutrients and brain development

Regarding couple of micronutrients we have scientific evidence that they are critically involved in pre- and postnatal brain development. In particular iron, iodine, zinc, folate, vitamin A and D. Micronutrients, which are the major missing sources isolated or in combination in the diet of one third of the world population. Further micronutrients, protein and energy and n-3 fatty acids may also have an impact on brain development.

Table 4 summarizes the specific brain-related micronutrients and their impact on brain development during the late fetal and neonatal period. The magnitude of any impairment of brain development and at least effect on brain function depends on the severity of the micronutrient deficiency. In many cases deficiencies do not exist in an isolated form. Other micronutrients may also be involved, depending on the food pattern, and protein-energy malnutrition might be also present. The latter has also a negative impact on brain development [32], but will not be discussed further in this article.

Although further vitamins are discussed to play a role in brain development, studies investigating the effect within the 1000-day window are not available. n-3 fatty acids, derived mainly from fat fish. Studies (n=6) investigating the effect of fish consumption during pregnancy on cognitive outcome showed that higher intakes of fish in pregnant women are linked to higher scores on tests of cognitive function in their children at ages between

Table 4. Impact of selected nutrients on brain development.

Nutrient	Requirement	Brain area
Iron	Myelin formation Monoamine synthesis Neuronal and glial energy metabolism	White matter Striatal frontal Hippocampal-frontal
Iodine	Myelination, neuronal proliferation	Cortex, striatum Hippocampus
Zinc	DNA synthesis Neurotransmitter	Autonomic nervous system Hippocampus, cerebellum
Copper	Neurotransmitter synthesis, energy metabolism	Cerebellum
Vitamin A	Neurogenesis Neurotrophic factors	Hippocampus
Vitamin D	Neurogenesis Neurotrophic factors	Hippocampus White matter
LC-PUFA	Synaptogenesis Myelin	Eye Cortex

18 month and 14 years [33]. n-3 fatty acids are not further discussed in this review, because they cannot really be attributed to hidden hunger.

Iron

Anemia due to inadequate iron supply with food is the most common single nutrient deficiency in the world. Two billion people are affected, including approximately 50% pregnant women and children. Iron is delivered and accumulates during the last trimester in a significant quantity and forms around 80% of the newborn's iron store. Inadequate supply during this time places the newborn at risk for iron deficiency anemia. In particular, infants born premature have a high risk of iron inadequacy due to the shortened period of accumulation. Even mild iron deficiency in the mother reduces the accumulation of iron in the fetus, resulting in neonatal iron deficiency. The majority of iron is used for erythropoiesis (red blood cell production) of the newborn. As a consequence, the developing brain of the newborn is at risk for iron deficiency. The most affected part of the brain seems to be the hippocampus. The human hippocampus is highly susceptible to iron deficiency during the late fetal and early neonatal period. In addition, poorer myelination has been described. Poorer myelination means that the speed of neural transmission is reduced, resulting in minor responses to stimuli of the auditory and visual brain areas [34]. Children (aged 9 to 15 month) from iron deficient mothers, or with iron deficiency during the first years of life, show a delayed electrophysiological response to recognition memory stimuli associated with delayed hippocampal function (established as impaired attention and recognition memory), compared to children with sufficient iron supply [35]. Indeed, it has been shown that iron deficiency results in long term altered gene expression of genes that are critical for hippocampal differentiation and plasticity [36]. This might question a complete recovery under iron supplementation.

A review discussing 14 different studies found associations between iron deficiency anemia and poor cognitive and motor development and behavioral problems in all studies. Longitudinal studies consistently indicate that children anemic in infancy continue to have poorer cognition, school achievement, and more behavior problems into middle childhood [37].

Zinc

Severe zinc deficiency is rare but moderate deficiency or inadequate supply affects up to 40% of the world population [38]. Diets low in animal-derived food (best source of zinc) or high in starchy food (low bioavailability of zinc) promote deficiency. Indeed, zinc deficiency during pregnancy as a consequence of a diet high in starchy food with high phytate (lowers bioavailability of zinc and iron) has been reported to be associated with a lower score on the psychomotor index of infants[39]. Diarrhea, frequently occurring during zinc deficiency and a major disease in children in developing countries, impairs zinc uptake and subsequently accelerates zinc deficiency and further micronutrient deficiencies. Children with a zinc deficiency often suffer from uncontrollable diarrhea, pneumonia and increased susceptibility to malaria. Even a moderate zinc deficiency is enough to promote infection, especially in the intestines. Diarrhea inhibits the proper absorption of micronutrients, which further exacerbates the situation faced by these children.

Zinc is one of the major micronutrients that are important during rapid growth, which places infants during their first years of life at risk for zinc deficiency. The impact of zinc deficiency on brain structure coincides with the period of rapid brain development, which occurs mainly during the first two years of life. Zinc is indeed a vital nutrient for the brain with important impact on functional and structural roles. This includes more than

200 enzymes involved in protein, DNA and RNA synthesis, which need zinc as a cofactor. In synaptic vesicles (important for signal transmission) of the hippocampal neurons zinc is found in high concentrations [40].

Different studies with zinc supplementation during pregnancy revealed controversial results on cognitive development. Zinc supplementation alone may unbalance the availability of other nutrients, or zinc deficiency may not occur alone. Indeed, it has been documented that a combination of zinc and iron showed an improvement in cognition [41]. In this double-blind trial, 221 infants were randomly assigned to 1 of 5 treatment conditions: iron (20 mg), zinc (20 mg), iron+zinc, MVM (16 vitamins and minerals, including iron and zinc), or riboflavin weekly from 6 to 12 months. Iron and zinc administered together and with other micronutrients had a beneficial effect on infant motor development. Iron and zinc administered individually and in combination had a beneficial effect on orientation-engagement. From animal experiments there is good evidence that zinc deficiency affects cognitive development (increased emotional reactions, impaired memory and learning capacity). Experiments with zinc-deficient rats compared to zinc-sufficient fed rats showed changes in hippocampal neuronal morphology and, as a consequence, impairment of memory and learning behavior [42]. Similar observations regarding memory have been made in newborns 6 month of age of zinc-deficient mothers [43].

Another important facet of zinc can be noted during early childhood development. Stunting is an early sign of zinc deficiency in a child's first two years. For this reason, zinc deficiency alone is believed to be a cause for developmental disorders which occur during early childhood [44]. A meta-analysis of 36 studies, which examined the effects of zinc supplements on stunting among children under the age of five, showed that zinc did indeed have a positive effect on promoting growth [45].

Iodine

WHO considers iodine deficiency to be "the single most important preventable cause of brain damage" worldwide. Approximately one third of the world population is estimated to have insufficient iodine intake, in particular in Southeast Asia and Europe [46]. Adequate maternal iodine stores within the thyroid are important for normal fetal and infant neurodevelopment. Adequate thyroid iodine stores (in iodine-sufficient regions) ensure the increased demand of iodine during pregnancy if optimal intake is maintained. In iodine-deficient regions, however, potentially inadequate iodine stores are rapidly depleted during pregnancy, placing the fetus at risk for developmental impairment, especially of the brain.

Severe iodine deficiency during pregnancy may cause "cretinism", which may include mental retardation as well as speech and hearing impairment. In particular, the impaired cochlear (inner ear) development results in congenital deafness, which is a severe burden in particular in developing countries with missing clinical care and special education to develop the ability to communicate. Children with deafness and vitamin A deficiency, which has resulted in blindness, are the most pitiful sights of hidden hunger.

Iodine deficiency causes hypothyroxinemia (low levels of the hormone thyroxin) in the fetal brain. Within the brain thyroid hormones regulate metabolic rate, myelination and play a special role in glucose transport to astrocytes. Astrocytes are important for energy and nutrient supply to neuronal cells. The fetal brain may become irreversibly damaged due to intrauterine iodine deficiency.Very recently it was documented that maternal mild iodine deficiency in rats causes a delay of the development of the hippocampal nerve fibers (axons)[47].

The effects of mild to moderate iodine deficiency on fetal brain development, however, are less clear. Observational studies from different countries in Europe and USA document a significant association between mild maternal iodine deficiency and cognitive impairment in children. Depending on the severity and onset of iodine deficiency during pregnancy, the clinical signs are more or less expressed. In particular, the severity of cognitive impairment seems to be associated with the degree of iodine deficiency [48]. In early childhood iodine deficiency impairs cognition, but in contrast to fetal iodine deficiency there is evidence for improvement with iodine treatment. Children from iodine-deficient areas had more cognitive impairments compared with children from areas with sufficient iodine [49]. Several European studies showed that isolated iodine deficiency during pregnancy is associated with impaired cognitive development in children (reviewed in [51]).

In a recent observational trial in the UK, the effect of an inadequate iodine status in 14,551 pregnant women on the cognitive outcome of their children (13,988) was evaluated. The data support the hypothesis that inadequate iodine status during early pregnancy is adversely associated with child cognitive development. Low maternal iodine status was associated with an increased risk of suboptimum scores for verbal IQ at age 8 years, and reading accuracy, comprehension, and reading score at age 9 years. The authors have shown that the risk of suboptimum cognitive scores in children is not confined to mothers with very low iodine status (i.e. <50 g/g), but that iodine-to-creatinine ratios of 50-150 g/g (which would suggest a more mild-to-moderate deficiency) are also associated with heightened risk [50].

Based on different intervention studies at different ages in children, it is argued that the developmental effects of iodine deficiency during early gestation are irreversible with later iodine repletion [39]. Supplementation of pregnant women, however, showed a clear benefit on the cognitive outcome of the children. In iodine-insufficient areas of Spain, the effect of a supplementation during pregnancy on cognitive development of the offspring (aged 3 months to 3 years) could be clearly documented in three out of four studies [51].

In contrast, supplementation after birth has no clear impact on cognitive development (reviewed in [52]). This underlines the importance of women's adequate nutrition in particular at the onset and during pregnancy [53,54]. In addition, it has to be considered that the newborn depends on iodine from breast milk during lactation. In areas with inadequate iodine supply, breast milk iodine concentration is not sufficient to meet the needs of the infant, even when their mothers were supplemented with 150ug daily iodine during the first 6 post-partum months [55].

Vitamin A

Inadequate vitamin A intake increases the risk of infectious diseases, in particular of the respiratory tract. As a consequence, further micronutrients become shortened due to either higher turnover, or disturbed tissue distribution, or impaired absorption. In addition, vitamin A deficiency is often accompanied by anemia. Both vitamin A and iron share the same sources. Consequently, it is not easy to discriminate the effects. However, based on recent data, Vitamin A seems to have an isolated effect on brain development. In the brain, the levels of retinoic acid (RA), the active metabolite of vitamin A, is relatively high, being highest in the hippocampus [56]. RA is critically involved in induction of neurogenesis (formation of neurons) and control of neuronal patterning (interaction and network between neurons) in the brain. This effect can be explained via strictly controlled formation of RA concentration gradients. Vitamin A deficiency (VAD) may have a negative impact on the plasticity of the hippocampus. Plasticity is required for neural networks to adapt to changes of the environment. This is important for the learning brain and, in the case of VAD, problems of learning and memory may occur [57]. The hippocampus is a region of the brain whose function is critically dependent on plasticity. Reduced hippocampal sizes in VAD rats and reduced learning abilities have been described [58]. According to Barth and co-workers [50], "it might be assumed that VAD seldom occurs in the Western world but recent results have pointed to high levels of RA signaling in hippocampus and it has been shown that human supplementation with RA results in improved learning and memory [59]. This suggests that normal human brain may have suboptimal levels of RA, perhaps of its high demand for the vitamin A". With respect to the impact of VAD during pregnancy and early childhood, VAD may influence hippocampal plasticity and, by the way, learning and memory. But supplementation with vitamin A during pregnancy or even later might help to improve the hippocampal function.

Vitamin D

Vitamin D (VDD) deficiency is a worldwide problem with a couple of health consequences in childhood and in adults. VDD is observed in 60% of Caucasian women and also in women with dark skin, where the rate is estimated to be even higher [60].

It has been frequently described that maternal VDD during pregnancy is associated with adverse health outcome of the offspring, including intrauterine growth restriction and impaired bone mass. Vitamin D deficiency is also related to different cognitive and behavioral dysfunctions e.g. schizophrenia [61]. VDD is more pronounced during wintertime, especially in northern regions, because sunlight is the major trigger for skin vitamin D synthesis. Indeed, schizophrenia is more frequent in high latitudes and birth during wintertime [62].

The fetus depends on the plasma vitamin D levels ($25(OH)D_3$) of the mother because $25(OH)D_3$ passes the placenta and is metabolized to form the active metabolite $1,25(OH)_2D_3$ in the fetal kidney. If the plasma levels of the mother are low, the fetus develops in a state of hypovitaminosis D, which may have consequences such as low bone mineral density in later life and risk of osteoporosis [63]. Infants born to mothers with VDD had significantly lower birth weights and an increased risk of being too small for gestational age compared with infants born to mothers with adequate plasma levels as a sign of vitamin D sufficiency [64]. In case of sufficient medical care, this might be without consequences, but under circumstances of developing countries with missing or poor medical care the lives of these children are in great danger.

Low maternal serum vitamin D levels during pregnancy of 743 Caucasian women in Australia are significant associated with offspring language impairment at 5 and 10 years of age [65]. Beside its well-known actions on bone and the immune system, vitamin D seems also important in the developing brain, controlling gene expression of so-called neurotrophins, which are important for neurogenesis [61].

The developing fetus depends on the vitamin D status of the mother, and if the status is not sufficient supply to the fetus might be inadequate.

Due to the fact that the only natural source of vitamin D are fatty sea fish and sundried mushrooms (present in some traditional diets) dietary supply in women living in poverty is rather poor. The most important source of vitamin D is the skin synthesis of the vitamin from solar irradiation. In cases of high pigmentation and poor sun exposure, either seasonal or due to clothing traditions, the formation of vitamin D becomes critical. The high prevalence of VDD in particular in northern Europe [66], in particular in migrants from the south (up to 70%), should be further investigated with respect to an impact on pregnancy and fetal development.

Conclusion

Nutrition plays an important role for fetal and newborn brain development. If malnutrition reduces optimal metabolic functioning during sensitive periods of cognitive development, that may have lasting negative consequences and may reduce the chance of the child to develop and escape from poverty. Lower physical strength and poorer brain development together are a fateful combination, which leaves the child in a hopeless situation with no chance to escape. Malnutrition during the first 1000 days of life can become a more or less irreversible but preventable burden for the child. Nearly 170 million children are stunted and it can be suggested that stunting is accompanied by impaired brain development.

In developed countries hidden hunger may appear as a single event related either to iron or iodine. Supplementation or advice on how to compose an adequate diet might be helpful. But in less developed countries, or in people living in poverty and food insecurity, a single micronutrient deficiency is a more or less rare case. The total diet composition is poor, resulting in hidden hunger of a couple of micronutrients. With respect to development, the missing micronutrients might act synergistically in a harmful sense on development. Supplementation of one or more micronutrients might be a kind of emergency intervention but is not a sustainable approach.

It should not be overlooked that a real selective deficiency of one micronutrient is a rare case, especially in developing countries. If the supply of a single micronutrient is inadequate and creates clinical symptoms it might not be sufficient to offer a single supplement. Deficiency is a consequence of inadequate dietary patterns containing these micronutrients. For example, the most important source of vitamin A is liver and liver products, followed by egg yolk. Liver, however, is an excellent source of iron in a bioavailable form and of zinc. Other food, e.g. meat or milk, are rather poor sources of vitamin A. Vitamin A also occurs as provitamin A in yellow fruits and vegetables. However, the conversion of the provitamin to the preformed vitamin is not very efficient and iron and zinc in fruits and vegetables are only present in small amounts. So at the very least it depends on the dietary pattern whether symptoms of VAD or zinc or iron deficiency are present. The clinical signs of vitamin A deficiency or iron deficiency reflect a poor supply of one or both. Depending on the food source, either the signs of VAD or of iron deficiency might be prominent. Substituting only one may overlook the importance of the other.

The tragedy of this hidden malnutrition is the fact that, due to missing assessments and clinical symptoms, no kind of intervention is implemented. In particular, in developed countries it seems hard to believe that there might be a problem. However, different studies show that food insecurity is related to poverty and the risk of malnutrition. A recent study estimated the relation between growth failure at 24 months and adult outcomes [67]. Data from 1338 Guatemalan adults (25-42y) were used who were studied as children (1969-1977). Individuals who were stunted scored worse on tests of reading and intelligence. Stunted individuals were more likely to have lower wages (men), and to live in poor households as adults.

The magnitude of malnutrition on the developmental impairment of children from poor settings is not known, and hard to estimate. But in contrast to problems coming from missing parental care or environmental impacts, adequate nutrition for pregnant women and children might be easier to achieve. However, this requires political will and public awareness. The basic approach is to ensure an adequate nutrition of females in childbearing age to avoid deficiencies during the early phases of pregnancy. This approach involves education and knowledge about the importance of food quality. In cases of selected deficiencies supplementation might be an alternative. However, some studies investigating the effect of supplementation with iron during the 1000-day window failed to show a real benefit on cognitive function [68].

Improved early life nutrition during the first two years of life using a micronutrient-enriched protein supplement showed a positive impact on cognition (reading comprehension and schooling) in adulthood, even after accounting for the effect of education [69]. Exposure to the supplement improved growth rates and reduced the prevalence of stunting at age 3 years compared to non-supplemented children, documenting the impact of adequate food quality on development.

Maturation of the brain regions responsible for higher cognitive functioning continues throughout childhood and adolescence [70]. Neuroimaging research suggests that even relatively brief interventions can lead to measurable differences in brain structure in children, and that this change is directly related to improvement in cognitive skill [71]. Nevertheless, the earlier adequate nutrition can be ensured, the better is the supply to the brain and the better the adequate development.

Malnutrition must be a top priority of national governments and international organizations. It is not acceptable that, in a globalized world with rapidly growing markets and per capita income, millions of children are born in poverty and will remain there. These children are the human capital of these countries, which should contribute to their economic and intellectual development. However, if these children remain fixed on the hunger carousel, they will again be a kind of starting point for the next generation with the same fate. To stop this carousel we need to unhide the problem of hidden hunger and intervene as early as possible with all players from government, civil and private sectors and the community of all religious parties, with all their available power. We do not only need to feed the world, we need to nourish the world.

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The Importance of Micronutrients for Economic Development

Bjørn Lomborg

With the Millennium Development Goals coming to an end in 2015, the UN is pondering which goals to set for the next decades to advance human development and sustainability.

The world spends some €100 billion annually on development aid. Beyond that we spend tens of billions on global efforts like peacekeeping forces, climate change policies, conservation and research on vaccines and more resilient crops. Yet, it is clear that more is needed. A billion people still live in abject poverty, 2.3 billion don't have access to modern energy, the world is still not at peace, we're not anywhere near tackling global warming or biodiversity, and 842 million people still go to bed hungry.

More often than not, priorities in spending become dictated by the loudest groups with the best PR. Campaigners of all stripes use powerful images and stories to capture our attention and influence aid budgets – from toppled buildings in Bangladesh, to devastation caused by droughts and storms, to hunger episodes in far flung places.

We need to ask the hard-headed question: where can we get the best value for our money? With the Copenhagen Consensus think tank, I asked 50 of the world's top economists where we could do the most good. They prepared research on nearly 40 investment proposals in areas ranging from armed conflicts and natural disasters to hunger, education, and global warming. The teams that drafted each paper identified the costs and benefits of the smartest ways to spend money within their area.

They presented their efforts to a high level panel of five top economists, including four Nobel laureates. The panel members were chosen for their expertise in prioritization and their ability to use economic principles to compare policy choices.

The panel indicated that if spent smartly, an extra $75 (€55) billion more over the next four years could go a long way to solving many of the world's challenges and help hundreds of millions of the world's poorest people.

The single most important investment, according to the panel, would be to step up the fight against malnutrition. New research for the project by John Hoddinott of the International Food Policy Research Institute and Peter Orazem of Iowa State University focuses on an investment of €2.3

billion annually. This would purchase a bundle of interventions, including micronutrient provision, complementary foods, treatment for worms and diarrheal diseases, and behavior-change programs, all of which could reduce chronic under-nutrition by 36% in developing countries.

This matters not just because more than 100 million children could start their lives without stunted growth or malnourishment. It matters much more, because new, long-term research shows that the benefits of such programs would stay with them for life: their bodies and muscles would grow faster, their cognitive abilities would improve, and they would pay more attention in school (and stay there longer). We can see this perhaps most clearly in the recent follow-up of an experiment in Guatemala. Beginning in 1969, preschool children in four villages got good nutrition whereas similar children in villages nearby did not. When researchers followed up 35 years later, the well-nourished children had better jobs, made more money, had smaller families, and basically dramatically better lives than those children who did not get micronutrient supplementation.

Ultimately, when all benefits are translated into economic terms, every euro spent on malnutrition will likely do €59 worth of global good.

So while micronutrient provision is rarely celebrated, a widescale effort could make a world of difference.

Likewise, the high level panel found that just €230 million would prevent 300,000 child deaths from malaria. In economic terms, the benefits turn out to be 35 times higher than the costs. Similarly, there are amazing investments to be made for tuberculosis treatment, childhood immunization and an HIV/AIDS vaccine.

As people in the developing world live longer, half of all deaths this year will be from chronic diseases in Third World countries. Getting low-cost drugs for acute heart attacks to developing countries would cost just €150 million, and prevent 300,000 deaths, doing €25 worth of good for each euro spent. Another amazing idea is to spend €1.5 billion annually in research and development to increase agricultural output. Not only would this reduce hunger by increasing food production and lowering food prices; it would also protect biodiversity, because higher crop productivity would mean less deforestation. That, in turn, would help in the fight against climate change, because forests store carbon.

These ideas may not be "rocket science", but orchestrated more widely, they can make a huge difference for people today and in the future. And more importantly, we need to get everyone, from high school pupils to UN ambassadors to start thinking about how we can help most effectively. It's a simple principle – and applied to policy problems, it will help build a better tomorrow.

Schooling and Poverty: How Education Can Enhance Quality of Life and Equity in Poor Populations

Structuring Opportunity for Immigration Origin Children

Carola Suárez-Orozco, Marcelo M. Suárez-Orozco

Abstract

Immigrant origin children are the fastest growing sector of public schools in many post-industrial countries. In this chapter we begin by reviewing key challenges that these students bring with them as they enter schools in their new lands. We draw on two studies to address how well schools are prepared to address the needs of recently arrived immigrant students. The first mixed-methods study followed 400 diverse recently arrived students for 5 years as they transitioned to their new land considering school, family, and individual factors. The findings from that study illuminated the cumulative challenges these youth encounter as well as the ways in which their educational environments often fail to meet their socio-emotional and educational needs. As not all schools are created equal, the other study used a multiple case study design of 4 promising schools in New York and Sweden, delineating practices that served immigrant students well.

Where migrant workers arrive, families often follow. Immigration, in its fullest sense, is about families, communities, and ultimately, the next generation. The children of immigrants are a fast-growing sector of the child and youth population in disparate high-income countries around the world such as Italy, Australia, Canada, Germany, the Netherlands, Spain, and Sweden. In the United States, approximately a quarter of all youth is of immigrant origin (over 16 million in 2010) and it is projected that by 2030 over a third of all children will be growing up in immigrant households (Mather, 2009). Because of migration, schools all over the globe are serving children of increasingly diverse origins, not always successfully.

Immigration is the human face of globalization emerging in classrooms the world over. Schools in cities, large and small, from New York to Reggio Emilia, from Beijing to Barcelona, from Toronto to Sydney, are being transformed by growing numbers of immigrant children. In Amsterdam, Rotterdam, and the Hague, two-thirds of all children in schools come from immigrant-origin homes. In Paris, a third of children are of immigrant origin. In Copenhagen one fifth are of immigrant origin. In Milan a third of all children entering kindergarten are of immigrant origin. In New York City, children from over 190 countries and territories, speaking over 170 different languages, go to school every morning. Schools face the opportunity and challenge of educating growing numbers of diverse students. The global integration and disintegration of economies requires the nurturing of ever more complex skills, competencies, and sensibilities on students to equip them to engage in the globally-linked economies societies and to become globally conscious, competent citizens in the 21st Century.

There is wide variation in the adaptation of immigrants coming from many contexts with a range of resources, settling in an array of settings – some more welcoming than others. Adaptations and successful integration require reciprocal interactions between individuals and their environments over time (Bronfenbrenner & Morris, 2006; Serdarevic & Chronister, 2005). Worrisomely, and somewhat counter-intuitively, a pattern has emerged contradicting conventional expectations: first-generation immigrant populations demonstrate the best performance on a variety of *physical health* (Morales, Lara, Kington, Valdez, & Escarce, 2002), *behavioral health* (Pumariega, Rothe, & Pumariega, 2005; Takeuchi, Hong, Gile, & Alegría, 2007), and some *educational outcomes* (Fuligni & Witkow, 2004; García-Coll & Marks, 2011; Suárez-Orozco & Suárez-Orozco, 1995), followed by a decline in subsequent generations. Thus, while many recently arrived immigrants face a wide range of stressors and risks (e.g., poverty, discrimination, fewer years of schooling, and social isolation), they do better than their counterparts remaining in the country of origin, as well as second-generation immigrants, on a wide range of outcomes (Alegría *et al.*, 2007; Corral & Landrine, 2008; García-Coll & Marks, 2011). Thus, the longer immigrants are within their new societies, the worse they appear to do. Over time, then, in many countries, we are failing in our tasks to embrace our newcomers as members of our societies.

Schools are the first setting where newcomer students are likely to have sustained contact with members of the host society. It is a space where they begin to learn the rules of engagement of their new land as well as the messages of reception of their hosts. Schools are the single most important elevator of social mobility in a knowledge intensive economy. Therefore how schools succeed or fail have clear implications for immigrants as well as our societies.

Chapter Aims

In this chapter we will begin by reviewing key challenges that immigrant origin students bring with them as they enter the schools in their new lands. We will provide some insights into ways in which schools typically misalign with immigrant students needs based on a longitudinal study of newcomer students. As not all schools are created equal, we will conclude with insights into schools that serve as islands of opportunity for their immigrant origin students, identifying common denominators of such schools.

Recognizing the Challenges of Immigrant Students

Whether or not immigrant students will be successful in school is determined by a convergence of factors – *family capital* (including poverty, parental education, and whether or not they are authorized migrants), *student resources* (their socio-emotional challenges and their facility in acquiring a second language); and the kinds of *schools* that immigrant students encounter (school segregation, the language instruction they are provided, how well prepared their teachers are to provide services to the them). This complex constellation of variables serves to undermine or, conversely, bolster academic integration and adaptation.

Immigrant families arrive to their new land with distinct social and cultural resources (Perreira, Harris, and Lee, 2006). Their high aspirations (Fuligni, 2001; Portés and Rumbaut, 2001), dual frame of reference (Suárez-Orozco and Suárez-Orozco, 1995), optimism (Kao and Tienda, 1995), dedicated hard work, positive attitudes towards school (Suárez-Orozco and Suárez-Orozco, 1995), and ethic of family support for advanced learning (Li, 2004) contribute to the fact that some immigrant youth educationally out-perform their native-born peers (Perreira *et al.*, 2006). On the other hand, many immigrant youth encounter such a myriad of challenges – xenophobia, economic obstacles, language difficulties, family separations, under-resourced neighborhoods and schools, and the like – that they struggle to gain their bearings in an educational system that often puts them on a path of a downwards trajectory (Garcia-Coll & Marks, 2001; Portes and Zhou, 1993).

Immigrant youth arrive from multiple points of origin. Some are the children of educated professional parents while others have illiterate parents. Some receive excellent schooling in their countries of origin while others leave educational systems that are in shambles. Some escape political, strife; others are motivated by the promise of better jobs while still others frame their migrations as an opportunity to provide better education for their children (Hagelskamp, Suárez-Orozco, and Hughes, 2010). Some are documented migrants while millions are unauthorized migrants (see Bean and Lowell, 2007; Suárez-Orozco, Yoshikawa, Teranishi, & Suárez-Orozco, 2011). Some join well-established communities with robust social supports while others move from one migrant setting to another (Ream, 2005). The educational outcomes of immigrant youth will vary considerably depending upon their network of resources (Portes and Rumbaut, 2001).

Family of Origin Capital

Poverty

Poverty has long been recognized as a significant risk factor for poor educational outcomes (Luthar, 1999; Weissbourd, 1996). Children raised in circumstances of socioeconomic deprivation are vulnerable to an array of distresses including difficulties concentrating and sleeping; anxiety and depression; as well as a heightened propensity for delinquency and violence. Those living in poverty often experience the stress of major life events as well as the stress of daily hassles that significantly impede academic performance (Luthar, 1999). Poverty frequently coexists with a variety of other factors that augment risks – such as single-parenthood, residence in neighborhoods plagued with violence, gang activity, and drug trade, as well as school environments that are segregated, overcrowded and poorly funded (Luthar, 1999). High poverty is also associated with high rates of housing mobility and concurrent school transitions, which is highly disruptive to educational performance (Gándara and Contreras, 2008). Although some immigrant students come from privileged backgrounds, large numbers suffer today from the challenges associated with poverty (Mather, 2009; Hernández, Denton, & Macartney, 2007; United Nations Development Programme, 2009).

Undocumented Status

An estimated 11.1 million immigrants live in the U.S. without authorization and of that population 78 percent are from Mexico and Latin America (Bean, 2007). Among the undocumented population in the U.S. 1.1 million are children or adolescents (Suárez-Orozco *et al.*, 2011). These undocumented youth often arrive after multiple family separations and traumatic border crossings (Suárez-Orozco, Todorova, and Louie, 2002). In addition, there are an estimated 4.5 million U.S. citizen children living in households headed by at least one undocumented immigrant (Passel, 2006). Unauthorized children and youth in households with unauthorized members live with fear and anxiety of being separated from family members, and that they or someone they love are apprehended or deported (Capps, Castañeda, Chaudry, and Santos 2007); such psychological and emotional duress can take a heavy toll on the academic experiences of children growing up these homes. Further, while unauthorized youth legally have equal access to K-12 education, they do not have equal access to either to health, social services, nor to jobs (Gándara and Contreras, 2008; Suárez-Orozco *et al.*, 2011). In addition, undocumented students with dreams of graduating from high school and going on to college will find that their legal status stands in the way of their access to post-secondary educational opportunities (Suárez-Orozco *et al.*, 2008). Thus, immigrants who are unauthorized or who come from unauthorized families suffer both from a particular burden of both of unequal access as well as from the psychological burdens of growing up in the shadows of unauthorized status (Suárez-Orozco *et al.*, 2011).

Family Educational Background

Parental education matters. Highly literate parents are better equipped to guide their children in studying, accessing and make meaning of educational information. Children with more educated parents are exposed to more academically oriented vocabulary and interactions at home, and they tend to be read to more often from books that are valued at school (Goldenberg, Rueda, and August, 2006). They understand the value and have the resources to provide additional books, a home computer, Internet access, and tutors than less-educated parents. They are also more likely to seek information about how to navigate the educational system in the new land.

Unfortunately however, many immigrant parents have limited schooling (The National Task Force on Minority High Achievement, 1999). Moreover, low parental education is compounded by parents' limited language skills of the new land, which index the support children receive for learning the language of instruction at home (Páez, 2001). Such disadvantaged backgrounds will have implications for the educational transition – unsurprisingly, youth arriving from families with lower levels of education tend to struggle academically, while those who come from more literate families and with strong skills often flourish (Kasinitz, Mollenkopf, Waters, and Holdaway, 2008).

Immigrant parents, however, often do not possess the kind of "cultural capital" that serves middle-class mainstream students well (Perreira *et al.*, 2006); not knowing the dominant cultural values of the new society limits immigrant parents ability to provide an upward academic path for their children. Parental involvement is neither a cultural practice in their countries of origin nor a luxury that their financial situation in this country typically allows. They come from cultural traditions where parents are expected to respect teacher's recommendations rather than to advocate for their children (Delgado-Gaitan, 2004). Not speaking English and having limited education may make them feel inadequate. Lack of documentation may make them worry about exposure to immigration raids (Capps *et al.*, 2007). Low-wage low-skill jobs with off-hour shifts typically do not provide much flexibility to attend parent-teacher conferences and childcare. The impediments to coming to school are multiple and are frequently interpreted by teachers and principals as "not valuing" their children's education. Ironically, however, immigrant parents often frame the family narrative of migration around providing better educational opportunities to their children (Suárez-Orozco *et al.*, 2008). While they may care deeply about their children's education and may often urge their students to work hard in school so they do not have to do hard physical labor as they do, immigrant parents frequently do not have first-hand experience in the host country's school system or in their own native system (Lopez, 2001). They also have very limited social networks that could provide the educational resources to help them navigate the complicated college pathway system host country (Auerbach, 2004). Thus, they often have limited capacities to help their children successfully "play the educational game" in their new land.

Student Level Challenges

Socio-emotional Challenges

Migration is a transformative process with profound implications for the family as well as the potential for lasting impact on socio-emotional development (García Coll and Magnuson, 1997; Suárez-Orozco and Suárez-Orozco, 2001). By any measure, immigration is one of the most stressful events a family can undergo (Falicov, 1998; Suárez-Orozco, 2001) removing family members from predictable contexts – community ties, jobs, and customs and stripping them of significant social ties – extended family members, best friends, and neighbors. New arrivals who experienced trauma (either as prior to migrating or as secondary to the 'crossing') may remain preoccupied with the violence and may also feel guilty about having escaped when loved ones remained behind (Amnesty International, 1998; Lustig, Kia-Keating, Knight, Geltman, Ellis, Kinzie, Keane, and Saxe, 2004); those who are undocumented face the growing realities of workplace raids that can lead to traumatic and sudden separations (Capps *et al.*, 2007). For some immigrants, the dissonance in cultural expectations, the cumulative stressors, together with the loss of social supports lead to affective and somatic symptoms (Alegría *et al.*, 2007; Mendoza, Joyce, and Burgos, 2007). Many immigrant parents are relatively unavailable psychologically due to their own struggles in adapting to a new country, thus posing a developmental challenge to their children (Suárez-Orozco and Suárez-Orozco, 2001). The immigrant parents of immigrant youth, whether their children are of the first or second generation, often turn to them in navigating the new society. Children of immigrants are asked to take on 'parentified' roles including translation and advocacy (Faulstich-Orellana, 2001). Such tasks often fall more to on the shoulders of daughters, which has both positive and negative consequences for their development (Suárez-Orozco *et al.*, 2005).

Immigrant children and youth also face the challenges of forging an identity and sense of belonging to a country that may reflect an unfamiliar culture while honoring the values and traditions of their parents (Berry, Phinney, Sam, and Vedder, 2006; Suárez-Orozco, 2004). Acculturative stress has been linked to high levels of intergenerational conflict as well as psychological and academic problems (Gibbs, 2003; Suarez-Orozco, 2000). They are often asked to take on responsibilities beyond their years including sibling care, translation, and advocacy (Faulstich-Orellana, 2001), which at times undermine parental authority. These often highly gendered roles may have both positive and negative consequences for development (Smith 2002; Suárez-Orozco and Qin-Hillard, 2004).

First generation immigrant youth face their parents' challenges of adjusting to a new context. They also, often, immigrate not simply to new homes but to new family structures (Suárez-Orozco *et al.*, 2002) as many are separated for long periods of time from their parents during the course of their migration (ibid.). Further, the first generation must learn a new language going through a difficult transition when they are unable to communicate their thoughts with ease; while some acquire competency over time, most are marked by accents, and others never gain proficiency (Mendoza *et al.*, 2007). The significant time it takes to acquire academic English presents significant educational as well as social challenges for immigrant students (Cummins, 1991; Suárez-Orozco *et al.*, 2008).

The second generation often has limited facility in their parents' native language (Portes and Hao, 1998), which present other challenges in maintaining communication at home with parents (Suárez-Orozco *et al.*, 2008). While immigrants and their first generation parents may share a lack of access to those who can guide them through the institutions of the unfamiliar dominant society, they are spared the challenges of pre-migratory trauma, status related stress, and family separations. On the other hand, they often face the stressors of poverty, typically in urban contexts (Noguera, 2003) without the protection of immigrant optimism (Kao and Tienda, 1995) and a dual frame of reference (Suárez-Orozco and Suárez-Orozco, 1995); the burden of forging a transcultural identity where they can navigate both their parents' culture and the dominant culture also falls more to them (Suárez-Orozco, 2004).

Data examining the wellbeing of immigrant origin populations in general and immigrants in particular across generations and ages reveals mixed results according to country of origin, developmental group, cohort, and age of arrival as well as developmental outcome (Rumbaut, 2004; Takeuchi, Hong, Gile, and Alegria, 2007). While there is a fairly consistent "immigrant paradox" showing a decline across generations with greater length of residency for *physical health* outcomes and engagement in *risk behaviors*, the results are inconsistent in regards to the risk to *psychological health*. Further, the body of evidence on the immigrant health has focused on adults and families rather than on adolescents (Lansford, Deater-Deckard, and Bornstein, 2007; Taningco, 2007). Immigrant youth of refugee origin appear to be at greatest risk for affective disorders (Lustig *et al.*, 2004). Immigrant and immigrant adolescents show patterns of progressive risk-taking behaviors the longer they are exposed to U.S. culture (Vega, Alderete, Kolody, and Aguilar-Gaxiola, 1998). This is also the case for academic engagement – an increasingly important indicator of wellbeing in the knowledge intensive economy – also decreases across time across generation and with increasing time in the U.S., particularly for immigrants (Fuligni, 1997; Portes and Rumbaut, 2001; Sirin, 2005). Given the limited and mixed evidence on the developmental trajectories of this growing population of urban residing immigrant adolescents, more research on a variety of indicators of their wellbeing is needed using both qualitative and quantitative lenses.

Challenges of Language Acquisition

Many immigrant children experience difficulties with English in school. In 2000, about three-quarters (71 percent) of all children who spoke English less than "very well" were immigrants in Pre-Kindergarten to 5th grade (Capps *et al.*, 2005). A more recent survey in 2006 revealed that 18.4 percent of all immigrant school age children (5-17) spoke English with difficulty (Planty *et al.*, 2008). The struggle to speak English among immigrant students is not just a challenge for immigrant children. Among Pre-Kindergarten to 5th grade immigrant children in the U.S., 62 percent of foreign-born children spoke English less than "very well", as well as 43 percent of the U.S. born children of immigrants and 12 percent of children of U.S. born immigrants (Capps *et al.*, 2005).

Learning a second language often takes a long time and being a competent language user at an academic takes even more. It has been well established that the complexity of oral and written academic English skills generally requires between 4 to 7 years of optimal academic instruction to develop academic second language skills comparative to native English speakers (Collier, 1987, 1995; Cummins, 1991, 2000). Struggles in language are well presented in LISA data; only 7 percent of the sample had developed academic English skills comparable to those of their native-born English-speaking peers after 7 years on average in the U.S. (Carhill, Suárez-Orozco, and Páez, 2008). Yet, immigrant ELLs do not typically encounter robust second-language-acquisition educational programs, as noted earlier, and also often face individual disadvantages and structural linguistic isolations that may hinder their adequate academic English development.

Many immigrant students from strife-ridden or poverty-stricken countries enter schools in their new lands with little or no schooling, and they may not read or write well in their native languages (Hernández *et al.*, 2007). Research in second language acquisition suggests that when students are well grounded in their native language and have developed reading and writing skills in that language, they are able to efficiently apply that knowledge to the new language when provided appropriate instructional supports (August and Shanahan, 2006; Butler and Hakata, 2005). Many immigrant students do not enter schools with this advantage. Further immigrant ELL students often cannot receive support for learning English from their parents at home. Immigrant parents who have often limited education and limited language skills of the host country are unable to support host language learning contexts for their children (Capps *et al.*, 2005).

This state of linguistic isolation is a reality in the social contexts of many immigrant students who live in segregated neighborhoods. Many immigrants live in predominantly minority neighborhoods, which do not promise much direct contact with well-educated native English speakers. At school, ELL students in general and immigrant students in particular, are also often segregated from the native English speaking peers by being relegated to the basement or a wing of the school (Olsen, 1997). In many cases, children have almost no meaningful contact with English-speaking peers (Carhill *et al.*, 2008). Indeed, more than a third of the immigrant students in LISA study reported that they had little opportunity to interact with peers who were not from their country of origin, which no doubt contributed to their linguistically isolated state (Suárez-Orozco *et al.*, 2008). This isolation is clearly disadvantageous to immigrant ELL students by minimizing exposure to English they need to learn. Research suggests that sustained interactions with educated native speakers, particularly in informal situations (such as at work, with friends, in the cafeterias and hallways of school, and in neighborhood contexts) in peer and community contexts, predicts stronger academic second language proficiency outcomes (Carhill *et al.*, 2008; Jia and Aaronson, 2003). Without such contact, an important source of language modeling is missed.

Less-developed Academic English proficiency often masks actual skills and knowledge of immigrant second language learners. Even when second learners are able to participate and compete in mainstream classrooms, they often read more slowly than native speakers, may not understand double-entendres and simply have not been exposed to the same words and cultural information of native-born middle-class peers. Their academic language skills may also not allow them to be easily engaged in academic contents and to perform well on "objective" assessments that designed for native English speakers. Taken together then, it is not surprising that limited English proficiency is often associated with lower GPAs, repeating grades, poor performance and standardized tests, and low graduation rates (Ruiz-de-Velasco and Fix, 2000; U.S. Department of Education, 2004).

School Contexts

Segregation

Segregation in neighborhoods and schools has negative consequences on academic success for minority students (Massey and Denton, 1993; Orfield and Lee, 2006; Orfield and Yun, 1999). In all but a few "exceptional cases under extraordinary circumstances, schools that are separate are still unquestionably unequal" (Orfield and Lee, 2006, p. 4). Nationally, immigrants tend to settle in highly segregated and deeply impoverished urban settings and attend the most segregated schools of any group in the U.S. today – in 1996, only 25 percent of immigrant students attended majority white schools (ibid.). The degree of segregation results in a series of consequences; in general, immigrants who settle in predominantly minority neighborhoods have virtually no direct, systematic, or intimate contact with middle-class white Americans. This in turn affects the quality of schools they attend, and the networks that are useful to access desirable colleges and jobs (Orfield, 1995; Portes, 1996).

Segregation for immigrant-origin students often involves isolation at the levels of race and ethnicity, poverty, and language – aptly named "triple segregation" (Orfield and Lee, 2006). These three dimensions of segregation have been associated with reduced school resources and to a variety of negative educational outcomes, including low expectations, difficulties learning English, lower achievement, greater school violence, and higher dropout rates (Gándara and Contreras, 2008). Such school contexts typically undermine students' capacity to concentrate, their sense of security, and hence their ability to learn.

The Longitudinal Immigrant Student Adaptation[i] (LISA), a mixed-methods, five-year longitudinal study that collected student, parent, teacher and student level data found a number of associations between triple segregation and more negative academic adaptation for recently arrived immigrant youth over the course of time (Suárez-Orozco *et al.*, 2008). Numerous negative qualities were associated with this level of segregation.

For example, when asked to relate their perceptions of school in the new country, many students spoke of crime, violence, gang activity, weapons, drug dealing, and racial conflicts. Students who attended highly segregated schools with high levels of perceived school violence were more likely to demonstrate patterns of academic disengagement and grade decline over time. Indicators of school inequality, including: percentages of inexperienced teachers as well as out-of-subject certification rate; greater than average school size; drop-out rate; daily attendance; higher than average suspension and expulsion rates; percentage of students performing below proficiency on the state-administered English language arts and math standardized tests; and a significant achievement gap on the standardized exam between one or more ethnic groups that attend the school, were linked to these highly segregated schools and consequently lower student performance. Indicators of school segregation and violence were consistent with poor performance school-wide on standardized tests across the immigrant groups. Mexican, Central American, and Dominican were most likely to attend highly segregated schools. At the group level, the LISA study found that only 20 percent of Dominican and Central American students, and 16 percent of Mexican students in low quality schools, reached proficiency level or higher on the federally mandated, state-wide English language arts exam. There was also a significant relationship between segregated schools and individual achievement outcomes, including both grades and students' standardized achievement test scores (Suárez-Orozco *et al.*, 2008).

Segregation places students at a significant disadvantage as they strive to learn a new language, master the necessary skills to pass high-stakes tests, accrue graduation credits, get into college, and attain the skills needed to compete in workplaces increasingly shaped by the demands of the new global economy. Unfortunately, all too many schools that serve the children of immigrants, like schools that serve our other disadvantaged students, are those that are seemed designated to teach "other people's children" (Delpit, 1995). Such segregated, sub-optimal schools offer the very least to those who need the very most structuring and reinforcing inequality (Oakes, 1985).

Second Language Instruction

The majority of immigrant students must learn a new language in their journey to their new land; as such, second language instruction is a critical component to ensuring their academic success (Batalova, Fix, and Murray, 2007). Frequently, students are placed in some kind of second language instructional setting as they enter their new school (Gándara and Contreras, 2008). Students are then transitioned out of these settings in various schools, districts, and states with very little rhyme or reason for transition (Suárez-Orozco *et al.*, 2008; Thomas and Collier, 2002). Research considering the efficacy of second language instruction and bilingual programs reveals contradictory results. This should not be surprising given that there are nearly as many models of bilingual and language assistance programs of a wide array of practices and programs as well as philosophical approaches (Thomas and Collier, 2002) as there are districts. Well-designed and implemented programs offer good educational results and buffer at risk students from dropping out by easing transitions, providing academic scaffolding, and providing a sense of community (Padilla, Lindholm, Chen, Duran, Hakuta, Lambert, and Tucker, 1991).

There is, however a huge disparity in quality of instruction between settings. While it has been well demonstrated that high quality programs produce excellent results, not surprisingly those plagued with problems (August and Hakuta, 1997; Thomas and Collier, 2002) produce less than optimal results. Many bilingual programs, unfortunately, face real challenges in their implementation characterized by inadequate resources, uncertified personnel, and poor administrative support. Perhaps the most common problem in the day-to-day running of bilingual programs is the dearth of fully certified bilingual teachers who are trained in second language acquisition and who can serve as proper language models to their students (U.S. Department of Education, 2002). Because many bilingual programs are ambivalently supported throughout the nation, they simply do not offer the breadth and depth of courses immigrant students need to get into a meaningful college track. Hence, there is an ever-present danger that once a student enters the "second language" or "bilingual" track, she will have difficulty switching to the college-bound track. The mission of the schools is often not focused on meeting the needs of newcomer students – at best they tended to be ignored and at worst they were viewed as a problem contributing to low performance on state mandated high-stakes tests (Suárez-Orozco *et al.*, 2008).

Teacher Expectations

In schools that serve immigrant students we commonly find cultures of low teacher expectations where what is sought and valued by teachers is student compliance rather than curiosity or student cognitive engagement (Suárez-Orozco, Suárez-Orozco, & Todorova, 2008; Conchas, 2001). Low teacher expectations shape the educational experience and outcomes of their students in fundamental ways beyond simply exposing them to low educational standards (Weinstein, 2002). Classrooms and schools typically sort students into those who are thought to be talented versus those who are thought to be less so. These expectations may be made based on impressions of individual capabilities, but are often founded upon stereotyped beliefs about their racial, ethnic, and socio-economic backgrounds as well (e.g., "Asian students are smart and hard-working" while "immigrant students are not"). Students are very well aware of the perceptions that teachers have of them; well-regarded students receive ample positive social mirroring (or reflections and feedback) about their capacity to learn and thus are more likely to redouble their efforts (Suárez-Orozco, 2000). Students who are found wanting on any combination of these characteristics, however, tend to either become invisible in the classroom or are actively disparaged. Under these circumstances, only the most resilient of students tend to remain engaged. Immigrant students from families who do not always share the culture of the teachers who teach them are particularly susceptible to such negative expectations and poor outcomes (Súarez-Orozco and Súarez-Orozco, 2001).

Adaptations Over Time – Findings from the Longitudinal Immigrant Student Adaptation Study

How are schools doing in helping newcomers adapt over time? The data reported here were derived from the Longitudinal Immigration Student Adaptation (LISA) study – a five-year longitudinal study[ii] that used interdisciplinary and comparative approaches, mixed-methods, and triangulated data in order to document patterns of adaptation among 407 recently-arrived immigrant youth from Central America, China, the Dominican Republic, Haiti, and Mexico. Ecological (Brofenbrenner, & Morris, 1998) and segmented-assimilation (Portes & Zhou, 1993) theories informed the conceptual framing of this study.[iii] We deepened our examined academic trajectories of performance by using a complementary mixed-methods strategy (Hammersley, 1996). Latent growth modeling was used to describe trajectories of performance over time. Multinomial logistic regression was used to delineate associations between indicators of family capital, school characteristics, and individual characteristics to academic trajectories. We implemented multiple case studies to uncover unanticipated causal links, which quantitative data do not reveal, and to shed light on the developmental and interactional processes at play (Yin, 2003). This mixed-methods approach allowed us to triangulate our findings and deepened our understanding of the ecological challenges recently arrived immigrant adolescent youth encounter as they enter their new schools (*For more details on this project see Suárez-Orozco, Suárez-Orozco, & Todorova, 2008 and Suárez-Orozco, Gaytán, Bang, Rhodes, Pakes & O'Connor, 2011*).

Latent class growth modeling revealed five distinct trajectories of performance for the recently arrived students (*see Suárez-Orozco, et al., 2008 for details*).

We examined the contributing role of several family capital factors, school characteristics, and individual characteristics using multinomial logistic regression analyses (*see Suárez-Orozco, et al., 2011, for details*). These analyses established factors that distinguished trajectories including: having two adults in the household, school segregation and school poverty, student's perceptions of school violence, academic English proficiency, reported psychological symptoms, gender, and being over-aged for grade. A multiple case study approach (Yin, 2003) triangulated and validated many of these quantitative findings. The multiple case study approach "capture[d] the complexity of the experiences" (Foster & Kalil, 2007, p. 831) across school and home contexts, allowing us to make cross-case conclusions, and revealed patterns that did not emerge simply from the descriptive data nor from the multinomial regressions.

Trajectories of Performance

Five trajectories emerged from the analyses (Suárez-Orozco *et al.*, 2008) (*See Figure 1 below*).

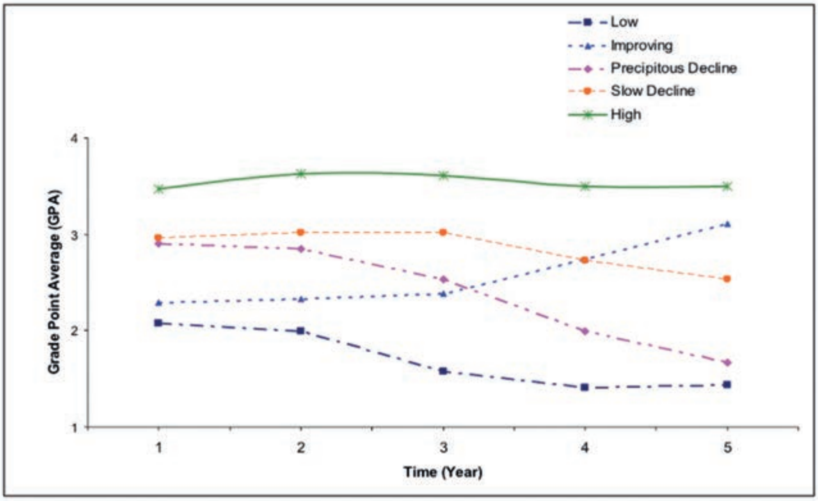

Figure 1. GPA Performance Trajectories.

Approximately a quarter of the participants did remarkably well academically. These *High Achievers* started out as high performers and maintained high achievement through the course of the 5 years of the study. High Achievers demonstrated predictable advantages in family capital and family structure associated with academic achievement (Bourdieu & Passeron, 1977; Madaus &

Clarke, 1998; Sirin & Rogers-Sirin, 2005). Relative to the other groups, High Achievers attended schools that were the least segregated and had the fewest students qualifying for free lunch. They had the strongest English language skills and were the most engaged in their studies.

The academic performance of nearly two-thirds of the sample declined over the course of the study. Approximately a quarter of the participants were *Slow Decliners*, demonstrating a waning in performance of approximately a half of a grade over 5 years. The analyses of our multiple-case studies data set allowed us to code for unanticipated patterns, which revealed that in many cases, a premature transition into a demanding academic setting led to a downward trend in grades. Often we would see a recently arrived student put in a Herculean effort in a fairly sheltered setting, one which was not particularly demanding academically, and achieve high grades in that setting. After two or three years, students would then be transferred into a more demanding academic setting. However, they did not necessarily have the requisite academic English skills in place and received little in the way of social or academic supports while making that transition. This academic context would lead to a drop in grades as well as a highly stressful academic voyage. Some young people swam against these strong currents, eventually getting to the other side, but others had trouble sustaining the energies it took to do so (Suárez-Orozco *et al.*, 2008).

More alarming was the grade-and-a-half drop that *Precipitous Decliners* (who comprised 27.8% of the sample) experienced. The multinomial logistic regressions indicate that these students struggled with multiple school and background impediments. They attended low quality schools and had poor English language proficiency. In addition, *Precipitous Decliners* were the most likely of all the groups to report psychological symptoms both at the beginning and end of the study – clearly, these issues took their toll. The case studies revealed that many of these students had difficult pre-migratory histories (hardship abroad and long separations from parents) and arrived to complicated circumstances (difficult reunifications, less than optimal neighborhoods and schools) once they arrived to their new land. Students who were initially engaged in their schoolwork had difficulty maintaining this engagement for long in far from optimal and often hostile school environments (Suárez-Orozco *et al.*, 2008). Few had adult supports or academic models, though they sometimes had active social lives with peers. Although the majority of *Precipitous Decliners* arrived with great hopes and dreams, they could not sustain them in the face of cumulative adversity.

Another 14.4% of our participants – the *Low Performers* started out with low performance and declined further over time. Low achieving students tended to arrive to their new land with a series of significant challenges. The quantitative data showed that these students had families with the least resources. Their English skills were weak, and they admitted to the least academic engagement, which distinguished them from all of the other trajectories. Their low engagement was not surprising given that school segregation and poverty, indicators of poor quality schools, also separated them from all of the other performance trajectories. The multiple case study analyses added further insights into the role of interrupted schooling, lengthy family separations, undocumented status, and barren social worlds in the poor academic performance of these youth. The *Low Achievers* simply never found their academic bearings and found the lure of work both economically more viable and a salve to their egos.

The remaining 11% of the students – the *Improvers* – started out quite low but over the course of time, overcame their initial "transplant shock" and reached nearly the same levels of achievement as the *High Achievers*. With these participants, the quantitative data revealed that they tended to be more engaged and attend less problematic schools than their counterparts who precipitously declined or who achieved poorly. The multiple case studies, however, provided evidence that there were other distinguishing patterns among these recently arrived immigrants. Many had sustained some sort of pre-migratory trauma. They had undergone long family separations and problematic initial family reunifications. To their advantage, they tended to settle into schools that provided them a healthy fit with their developmental needs (Eccles *et al.*, 1993). Over time, many found mentors and community supports that guided them in their journeys in their new land, and who arguably contributed to their academic engagement (Suárez-Orozco *et al.*, 2008).

Thus, overall, students with the most school, familial, and individual resources tended to perform better academically over time. The *High Achievers* often demonstrated a constellation of advantages: they started out as high performers and maintained high achievement throughout the five-years of the study. On the other hand, the *Low Performers* started out with low performance and declined further over time, unable to engage in school given the myriad of risk factors. The *Precipitous Decliners* started out doing better in school than their *Low Achieving* peers but after struggling with multiple school and background impediments, appeared unable to sustain the effort over the course of time. *Improvers*, on the other hand, faced initial challenges but had enough environmental supports that over the course of time, allowed them to overcome their initial "transplant shock".

"Sites of Possibilities"?

This data illuminated the cumulative challenges recently arrived immigrant youth encounter as well as the ways in which their educational environments often are misaligned with their socio-emotional and educational needs. Understanding various school, family, and individual variables that contribute to varying patterns of academic trajectories for recently arrived youth is important; focusing on schools is essential due to the mutable nature of this setting. Working to develop and implement policies to bridge the gap between recently arrived immigrants' developmental challenges and their educational environments is the crucial step to help our nations' newest students achieve their potential.

Newcomer immigrant students with limited resources often enter our poorest and most segregated schools, which have the very least to offer the students most in need of support. The poor performance of *Low Performers* and *Precipitous Decliners* can, in part, be attributed to the particularly low quality of the schools these students attended, which did little to foster engagement of their students and possibly motivated frequent transfers to other schools, augmenting academic risk (Eccles *et al.*, 1993; Orfield & Lee, 2006). The majority of our recently arrived participants enter highly segregated, high poverty, linguistically isolated schools (Orfield and Lee, 2006) that provide far from optimal learning conditions. Our ethnographies showed that high levels of poverty and racial segregation within the schools was linked to a variety of forms of inequitable distribution of resources including run down facilities, less access to basic supplies like textbooks, as well as high rates of teacher and principal turnover (Suárez-Orozco, *et al.*, 2008). In many such schools, we observed low standards and aspirations for the students and frequent exchanges of disparaging comments. Many of these schools were sites of gang activities and/or bullying and the adults on site demonstrated little connection with their students or the parents they ostensibly served (See Suárez-Orozco *et al.*, 2008 for detailed descriptions of these "less than optimal schools"). Rather than acting as "sites of possibilities" (Fine & Jaffe-Walter, 2007) all too many schools were failing to meet the needs of their newcomer students.

Recently arrived immigrant children have almost no meaningful contact with mainstream peers in their schools (Suárez-Orozco *et al.*, 2008). Indeed, more than a third of the immigrant students in the LISA study reported that they had little opportunity to interact with peers who were not from their country of origin. This contributed to only 7 percent of the sample having developed academic English skills comparable to those of their native-born English-speaking peers after an average of 7 years in the U.S. (Carhill, Suárez-

Orozco, & Páez, 2008; Suárez-Orozco *et al.*, 2008). These students were often provided less rigorous academic material and academic contexts. It has been well established that 4 to 7 years of *optimal academic instruction* are generally required for students to develop academic second language skills comparative to native English speakers (Cummins, 1991; Hakuta, Butler, & Witt, 2000).

The strong emphasis on high-stakes tests made educational context of second language learners extremely challenging (Menken, 2008). To meet the required 'adequate yearly progress,' the second language learners' curriculum and daily instruction was increasingly focused on language skills rather than academic content knowledge; many of the recently arrived immigrants were tested well before their skills are adequately developed with assessments that were not psychometrically valid (APA, 2012).

The effects of immigration are not confined to mere changes of geography. The political upheaval, ethnic or religious persecution, and traumas prior to migration add additional burdens for many youth beyond the usual dislocations and adjustment of immigration. Separations from parents for lengthy periods of time occur in a majority of migratory journeys. Some face the added stress of undocumented status. The repercussions of these burdens were particularly evidenced by the higher levels of reported psychological symptoms among *Precipitous Decliners*. Lamentably few of the educators serving the recently arrived immigrant students were aware of the issues their students were facing. In recognition of the unique constellation of risks that burden some immigrant youth and their families, mental health and community support services should be made available to at-risk students.

Social relationships and daily interactions with schoolmates, teachers, and counselors along with the flow of informational capital (Perreira, Harris, & Lee, 2006; Pianta, 1999; Ryan, Stiller, & Lynch, 1994) play a significant role in shaping academic outcomes for youth with limited opportunities (Stanton-Salazar & Dornbusch, 1995). For recently arrived immigrants, positive relationships with family, community, and *school members* serve to create a sense of well-being in school. Formal and informal relationships with supportive adults and mentors can help recently arrived immigrants by providing crucial information about the educational system, as well as explicit academic tutoring, homework assistance, and college pathway scaffolding. Programs developed with the needs of this target population in mind can play an important role in the easing their transition to their new land (Roffman, Suárez-Orozco, & Rhodes, 2003; Suárez-Orozco *et al.*, 2008). Our ethnographies and case studies demonstrated that not all schools were created equal. While all too many were disconnected from their students and parents, some were islands of opportunity. This led to the Promising Practices Project – just what were the common denominators of schools that were "sites of opportunity" (Fine & Jaffe-Walter, 2007).

The Promising Practices Project

As we have seen, immigrant-origin students bring to schools a variety of academic and linguistic challenges and many of the schools that receive them provide far from optimal educational opportunities (Ruiz-de-Velasco & Fix, 2001; Suárez-Orozco *et al.*, 2008; Valenzuela, 1999). While it is not a challenge to critique the myriad of ways that schools fail to meet the needs of these students, it is decidedly more difficult to identify promising practices that serve them well (Lucas, 1997; Walqui, 2000). In this study we[iv] sought to illuminate curricula and programs that prepare students from immigrant backgrounds to be active and empowered actors in the multicultural, global contexts of their receiving nations. The Promising Practices Project hoped to shed light on the strategies that teachers, students, and administrators develop as they attempt to meet the educational challenges of preparing immigrant-origin youth for this global era in two quite distinct social, political, and educational contexts – large cities in Sweden, and New York City.

Both the United States and Sweden[v] share a contentious climate of debate over immigration (see Chavez, 2001 for an example in the United States; see Mattsson & Tesfahuney, 2002 for an example in Sweden). These two nations also share a similar pattern of low achievement by minority students from low-income backgrounds (Bunar, 2001). Both countries exhibit the problem of a gender achievement gap – girls consistently outperform boys (Suárez-Orozco & Qin, 2006; Öhrn, 2002). Further, in both contexts, students of minority ethnic backgrounds are likely to be taught by teachers of mainstream backgrounds (Ingersoll, 2003; Ljungberg, 2005). Schools in both Swedish cities and New York are subject to marketplace-driven school reforms, which place high value on testing, performance, and accountability (Apple, 2004). This emphasis on "objective" measures does not take into account that second-language acquisition presents a unique set of challenges. The lack of consideration for these challenges takes a particularly high toll on immigrant-origin students and the schools that serve them (2008; Suárez-Orozco *et al.*, 2008). Finally, while in most parts of the United States, students attend neighborhood high schools, in Swedish cities and New York alike, another market-based reform, "school choice", provides students with the option to "apply" to high schools. This process allows students to rank a number of schools and thereafter go through a selection process that can include entrance or standardized exams, interviews, audition, and/or lottery, and neighborhood demographics.

We were guided by the question of what school-based practices were implemented in innovative, promising school settings to both ease the *transition and integration* and *foster and enhance the academic performance* of immigrant-origin youth?[vi]

School Practices Conducive to Positive Outcomes for Immigrant-Origin Youth

Across schools we sought to identify approaches and strategies implemented in the various school sites that would serve to ease the adaptation and meet the educational needs of immigrant-origin youth. We began with overarching conceptual categories based on previous research in the field. As part of the iterative process of fieldwork, we added new practices to our conceptual categories as we encountered them. We then sought to determine if these practices occurred in each site.

We found that some practices were sound, promising, or innovative for immigrant-origin students whether they were second generation, newcomers, or second-language learners. Arguably, some of these practices are simply sound for students in general, regardless of whether they are of immigrant origin. We organized the conceptual categories along the lines of: 1) curriculum; 2) pedagogical approaches; 3) school structures; 4) school climate; 5) assessment strategies; 6) educational supports and enrichment outside of class; and 7) preparation for higher education and the workplace (*See Table 4*). We also, found that other practices were very specific to the needs of newcomer students and second-language learners, serving to ease their negotiation of the cultural transition and learning a new language. We considered these separately later.

All four schools practice reforms founded on progressive multicultural education (Banks & Banks, 2007; Nieto, 2004). Interdisciplinary, project-based, and student-centered approaches to curriculum and instruction are central to teaching and learning across the schools. All four schools utilize an integrated curriculum in some form, and the two Swedish schools place particular emphasis on the integration of technology into the curriculum. The four schools have attempted to create curricula that are relevant to the lives of the diverse students they serve. To successfully deliver content, the schools use decentralized pedagogical strategies designed to place the student at the center of learning and move away from traditional teacher lectures for at least part of the time. In addition to rethinking content and delivery, the schools seek multiple strategies to assess their students as well as ways to prepare them for the high-stakes testing where immigrant origin youth are at a notorious disadvantage. All of the schools have implemented some kind of academic supports to help them to be successful. And finally, several of the schools place particular focus on the postsecondary school experience.

In addition to the practices described above, newcomer immigrant youth and second-language learners have additional academic and socio-emotional needs, different from those of the typical non-immigrant or second-generation student. At the forefront is the need to develop both the social and academic language of their new country while mastering the content knowledge necessary to be successful in the new society. Most graduation pathways are quite unforgiving of the 5 to 7 years it takes for most students to develop the academic language to the point of competitiveness with native peers (Cummins, 2000; Hakuta, Butler, & Witt, 2000). This is the level of language competence required to be competitive on a timed multiple choice test, write a well argued essay, or confidently join in a class discussion. Thus, immigrant students often are tracked into non-college-bound courses, falter in confidence, and fall behind their nonimmigrant peers (Menken, 2008; Ruiz-de-Valasco, Fix, & Clewell, 1998; Suárez-Orozco *et al.*, 2008).

Further, as noted earlier, it is important to keep in mind that immigration is a stressful event (Suárez-Orozco, 2001; Suárez-Orozco *et al.*, 2008), removing youth from predictable contexts while stripping them of significant social ties (Suárez-Orozco *et al.*, 2008). Many have been separated from their parents for protracted periods of time and may face emotionally complex reunifications (Suárez-Orozco, Todorova, & Louie, 2002). Immigrant children must contend with the particular acculturative challenges of navigating two worlds (Berry, Phinney, Sam, & Vedder, 2006). They are often asked to take on responsibilities beyond their years, including sibling care, translation duties, and advocacy for their families (Faulstich-Orellana, 2001), which at times undermine parental authority. These often highly gendered roles may have both positive and negative consequences for development (Smith, 2002; Suárez-Orozco & Qin, 2006). Children of immigrants also face the challenge of forging an identity and developing a sense of belonging to their new homeland while honoring their parental origins (Suárez-Orozco, 2004). This acculturative stress has been linked both to psychological distress (APA 2012; García-Coll & Magnuson, 1997) as well as to academic problems (Suárez-Orozco *et al.*, 2008).

Thus, we considered innovative and promising practices that served to ease the emotional and linguistic transitions of newcomer and second-language learners at two school sites: World Citizen High School, which serves only newcomer immigrant youth, and Bergslunden, whose dedicated second-language-learners team gave the researchers full access to their work and their program. Both schools paid particular attention to the following innovative strategies to address both the academic needs of newcomer youth as well as their acclimation to their new environment: 1) support in helping students navigate the cultural transition to the new country; 2) support for students who had gaps in literacy or due to interrupted schooling; 3) teaching across content areas; 4) language-intensive instruction across the curriculum; and 5) language-learning accommodations.

Negotiating Cultural Transitions

The schools were highly strategic in their approach to help newcomer youth adjust to their new environs. As new students came in, teacher teams met to discuss each one, and a series of assessments were conducted and discussed in order to develop the best plan for him or her. The teachers tried to meet with as many of the parents as possible. Parents were asked to bring in signed forms/health records at the beginning of the school year. Teachers also met with parents sometime around the end of the first grading period. This is when students first get to see their report cards, and it is an opportunity for teachers to get a sense of what their students' home and family situations are like. The information gleaned from these conferences is then shared when teachers meet across the teams working with each student.

The ongoing transition was primarily the responsibility of the advisory program, which helps students to adjust to their new school under the guidance of an advisor who is looking out for them. One of the guidelines for forming advisory groups is to have a newcomer/beginning learner of the new language in the same group as at least one student who shares the same native language and is also proficient in the new language, so that the more advanced new language speaker can translate. In advisory groups, students would discuss a range of topics from difficulties with a class, missing families and friends back home, to boyfriend/girlfriend issues.

Further, aligned with the language-intensive and student-centered-learning approaches, instructional tasks, in particular writing tasks, encouraged students to share their personal experiences both in their old and new countries and in the transition from one to the other. For example, students often wrote of their migratory experiences and were encouraged to share their stories with one another. Such activities help them to recognize that they are not alone in the difficulties of transition.

Supports for Gaps in Interrupted Schooling and Literacy

Some students enter secondary school with limited prior education or significant interruptions in their schooling. These may occur for a variety of reasons including socio-economic or gender inequities in original educational access, political strife that could have interrupted schooling, or hiccups in the migratory process that may have led to a sustained period out of school before reentry in the new land. Whatever the cause of an interruption in schooling, the consequence is often students who are over-aged and under-skilled and have considerable catching up to do in the classroom. This takes significant creativity, flexibility, and sustained effort on the part of school administrators and teachers. Understanding was shown for these students. Sensitivity was demonstrated towards the over-aged students; support was provided with encouragement to allow as much independence and peer support as possible.

SIFE students receive the same supports provided to other newcomer students and more. Particular emphasis is placed on literacy. Typically, these students take longer than the standard four years to graduate from high school – often stretching to seven years. With the right amount of scaffolding, the daunting tasks of learning a new language, acquiring literacy, mastering content knowledge of a new culture, accruing graduation credit courses, and passing high-stakes tests are achievable for many students who would have given up in another setting.

Second-Language Learning

While not all immigrant students are second-language learners, many if not most are; and, in some cases, immigration requires learning three or more languages. As noted earlier, learning a second language to a competent academic level takes considerable time (Christensen & Stanat, 2007; Collier, 1995; Cummins, 2000; Cummins, Brown, & Sayers, 2007; Hakuta, Butler, and Witt, 2000; Thomas & Collier, 2002) and the preparation of incoming students vary widely. Some students arrive from high quality educational systems while others arrive from war torn zones schools are shut down. Those students will need more time to be prepared for high stakes test. Thus, immigrant students entering secondary schools with little background in the language of instruction require systematic and effective long-term curriculum plans for language education.

All the schools we observed had systematic second-language acquisition policies and practices (though typically schools in the United States do not, which places ELL students at a disadvantage). Second-language instruction is most successful when learners are placed into a progressive and systematic program of instruction that first identifies a student's incoming literacy and academic skills (Christensen & Stanat, 2007). Research shows that consistency of instruction is essential for students as frequent transitions place them at considerable disadvantage (Gándara & Contreras, 2008). Second-language learning is most successful when high-quality second-language instruction is provided with continued transitional academic supports – like tutoring, homework help, and writing assistance – as the language learners integrate into mainstream programs (Christensen & Stanat, 2007). In order to ensure a smooth transition between grades as well as the continual development of skills, teachers need to both understand and conform to the instructional model ascribed to by the school or district (Sugarman & Howard, 2001). Further, assessment of skills growth should be done annually using portfolio assessment as well as testing in order to measure progress and adjust interventions (Christensen & Stanat, 2007).

Teaching Across Content Areas

In addition to developing communicative proficiency in the language of their new country, second-language learners (SLLs) need to simultaneously build content literacies; many of them also have low cognitive academic-language proficiency skills (CALP). Second-language acquisition programs (e.g., bilingual education, self-contained SLL programs) primarily focus on literacy development in terms of language proficiency, with only limited attention to academic second-language acquisition in content areas (August & Hakuta, 1997). It is a challenge for students to learn content across the academic disciplines while at the same time acquiring new language and literacy skills, and it poses an instructional challenge to many teachers as well (August & Hakuta, 1997; NCES, 1999). Teachers in the exemplary schools received extensive training in language-intensive curriculum; language learning is embedded across the entire curriculum. Writing is not simply an activity for language-arts classes. Students are pushed daily to write and use their developing language skills in every class.

Language-Learning Accommodations

Students were encouraged to use their first language to help them learn the second language, even if others don't know their mother tongue. Informally, students are encouraged to translate for the newest immigrants, read and write in their first language during silent reading times, and carry bilingual dictionaries, but gently prodded toward their new language over time. The mother tongue is thus used strategically to aid the development of the new one. A teacher explained: "We encourage our kids to continue to develop their native language. [We encourage this] because we believe it develops the second language and it [acknowledges that] the base is the native language, and ... it becomes so much more difficult to build their second language if there is no foundation. So because we encourage our kids so much, our kids feel free to speak whatever language they speak". Examples of the use of first languages are commonplace. After one small-group assignment, students were told to assess their group with a twist; they had to answer questions such as "What worked well in your group?" and "Who made the group work particularly successful?" On one side of a sheet of paper, students first had to translate the questions into their native language; on the other side, they answered the questions in English. Second-language learners are not only encouraged but expected, during Problem-Based Learning assignments, to write key concepts in both their first language and second language. Teachers encourage and expect individual students to maintain first-language fluency. The tolerant attitude facilitated by teachers has had an unanticipated, yet welcome consequence. The diversity of language backgrounds means that the new language becomes the lingua franca, the language spoken in the hallway that allows students to converse with one another. In other words, speaking new language to friends becomes something that second-language learners do by choice instead of by force.

In addition to the use of first languages as a teaching/learning tool, a 9^{th}-10^{th} grade math teacher shared her strategy for making sure that every student is keeping up and understands: "I think it helps if I spend 5 minutes before the end of the class, reading the question, or the writing prompt, reading it to them ... and have them talk amongst themselves to make sure that they understand it, and have other kids translate for the ones who may not understand English. So make sure they understand the homework, and ... think about where kids are going to get stuck". Assignments are continually modified to make them accessible to students, an 11^{th} grade science teacher explained. These accommodations provide the much-needed scaffolding to newcomer students as they make the transition to their new educational setting. They begin to gain confidence in themselves and take the necessary strides in their new language to gain the academic skills they will need to be successful in their new land.

Implications for Policy and Practice

Immigrant-origin students bring a myriad of challenges to the classroom, which are compounded by the late twentieth-century climate of school reforms (Meier & Wood, 2004), which has had a series of unintended consequences for this population. Clearly there are no facile solutions to the complex problems facing many of these students. These principles, we would argue, are sound canons of pedagogy to serve all students, whether or not of immigrant origin. At the very core is a confluence of rigorous standards and high expectations coupled with a "pedagogy of care" (Noddings, 2003). Rather than taking a remedial approach, or taking an approach that is simply good enough for "other people's children" (Delpit, 2006), these are principles we would be happy to provide our own. This education is framed within an ethic of relations and care. Lastly, the schools recognize the needs of students within the context of their families.

Preparing Students for the Twenty-First Century Global Era

More than ever before, education in the twenty-first century requires the development of higher-order cognitive skills in order to be able to engage with the marketplace realities of our global era (Bloom, 2004; Suárez-Orozco and Qin-Hilliard, 2004). However, the educational practices we presented in this chapter are not limited to providing students with skills for the marketplace. Teachers diligently work to prepare students for life in general, regardless of whether they are planning on going on to college (Suárez-Orozco *et al.*, 2013).

The four schools we studied are rich with innovations that allow youth to develop the ethics, skills, sensibilities, and competencies needed to identify, analyze, and solve problems from multiple perspectives (Suárez-Orozco *et al.*, 2013). These schools nurture students to be curious and cognitively flexible, and to synthesize knowledge within and across disciplines (Gardner, 2004; Schleicher & Tremley, 2006; Suárez-Orozco & Sattin, 2007). The schools have an explicit agenda to prepare their students to successfully navigate in a multicultural world and impart skills deemed essential not merely to survive but to thrive in the global era (Bloom, 2004; Gardner, 2004). These promising schools put rigor, relevance, and relationships (Gates, 2006) at the core of their pedagogy. Unfortunately, however, rather than featuring such a preparation agenda, all too many schools serving immigrant-origin youth, like schools that serve other disadvantaged students, are those that are relegated to teaching "other people's children" (Delpit, 2006) – such suboptimal schools typically offer the very least to those who need the very most (Kozol, 1991, 2006).

In all of the schools we examined, we found a commitment to marginalized and disadvantaged students (Suárez-Orozco *et al.*, 2013). The schools offer a stimulating, rigorous, and relevant curriculum but also provide a number of supplemental resources (such as after-school programs, tutoring, high-stakes test preparation, homework help, explicit college entry information, and so forth) to at-risk students in order to ease their educational transition and ameliorate their outcomes. Teachers make their pedagogies transparent, and there is a wealth of initiatives taken from different levels in the school system as a whole. The schools promote an alignment of instructional methods, content, and assessments and foster collaborative efforts to raise students' achievement levels and reduce barriers to educational equity. Notably, these services are helpful not only for immigrant-origin students but for other at-risk youth as well (Suárez-Orozco *et al.*, 2013).

Conclusion

Over the last century schooling has emerged as a normative ideal the world over. Schools are now defining institutions in the lives of more children than ever before in human history. In complex democracies schools are powerful institutions ideally structured to socialize emerging citizens for a "shared fate" (Ben-Porath, 2013) and to become democratic agents in a diverse, fragile and interconnected world. Schools also prepare future workers and, ideally, enable children and youth to forge the tools and sensibilities they will need to achieve the eudemonic ideal of flourishing, living well and doing good (Allen & Reich, 2013). In high income countries marked by structural inequalities schools both replicate the larger order while paradoxically expecting children to learn to be equal (Ladd & Loeb, 2013).Vast inequalities propel disadvantaged parents to want and indeed need more of the schools their children attend (Harris, 2013; Noguera, 2003). For immigrant children, schools serve a great potential as the "sites of possibilities" (Fine & Jaffe-Walter, 2007) for systematic, intimate, and long-term immersion in the new culture and society. Multiple studies have documented the varieties of immigrant optimism, academic engagement, and faith in schools and the future (Kao & Tienda, 1995; Suárez-Orozco & Suárez-Orozco, 1995). For the ancient Greeks, a student was "the eager one" (Allen & Reich, 2003) and immigrant students are doubly eager – as students and as newcomers. But by enacting current policies and practices noxious to their needs, schools are in too many cases conferring disadvantage, perpetuating parental disempowerment, and revealing a studied indifference to authentically and successfully engage our newest future citizens. We can do better. We know how. As societies we simply must demonstrate the will and the care to do so.

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Endnotes

[i] See section entitled *Longitudinal Immigrant Student Adaptation Study* and footnotes [ii] and [iii] for more detail about the study.

[ii] We would like to thank our funders – the National Science Foundation, the W.T. Grant Foundation, and the Spencer Foundation.

[iii] Most scholars that have examined the adaptation of immigrant origin students have employed cross-sectional approaches comparing two or more generations or cohorts (Portes & Rumbáut, 2001; Steinberg *et al.*, 1996; Suárez-Orozco & Suárez-Orozco, 1995), rather than addressing trajectories of change over time within the same cohort (Fuligni, 2001). Moreover, studies that include second- and third-generation immigrants have been less able to capture the initial adjustment patterns and unique experiences of recently arrived immigrant students (Fuligni & Pederson, 2002; García-Coll *et al.*, 2005; Portes & Rumbáut, 2001). The LISA study sought to address these limitations through a longitudinal study of recent immigrant youth.

Students were recruited from seven school districts in regions of Boston and San Francisco areas with high densities of recently arrived immigrant students. Students in our study were recruited from over 50 schools in seven districts representing typical contexts of reception for recently arrived students from each of the groups of origin (Suárez-Orozco *et al.*, 2008). By the end of the study, the students had dispersed to over 100 schools. Transfer rates, which included normal administrative school transitions (i.e., from middle to high school), ranged between 1 and 5 transfer incidents per participant (M = 2.4) over the course of the five years of the study. Data on school quality for the quantitative analyses became available from school district data in the last year of the study as a result of No Child Left Behind Act (NCLB). These data included the percentage of students who were poor (as assessed by eligibility for free or reduced-cost school lunch), segregation rates (the racial and ethnic composition of the school), and the percentage of students performing at proficient levels on state-mandated English language arts standardized tests. While there was fluctuation in school quality for individual students, ethnographic data revealed that students tended to stay within district and transitioned to schools of comparable quality. By the last year of the study, 74 percent of the participants were attending high school, with 96 percent attending public non-charter schools. The majority of the participants (65 percent) attended large schools (i.e., those with more than 1,000 students), while 22 percent attended schools with between 500 and 1000 students. Most of the students' schools were highly racially and economically segregated (see Table 1) and were characterized by high percentages of students living in poverty, with an average of 59.2% (SD = 23.9) of the student population receiving free or reduced-cost lunch. The minority representation rate at the schools was, on average, 77.9% (SD = 23.6). There were significant differences in segregation patterns by country of origin. Dominicans were most likely to attend low-income schools, followed by Mexicans. Fewer than half of the Chinese students in our sample attended schools where most of the students were of color, whereas nearly all of the other immigrant students attended such schools. Chinese and Haitian students were less likely (27.8 and 30 percent respectively) to attend hyper-segregated schools than the Latino students in the sample. Consistent with the findings of Orfield and Lee (2006), Dominicans, Central Americans, and Mexicans were all very likely to attend schools where more than 90 percent of the students were of color (83.1, 61.4 and 68.6 percent respectively) (Suárez-Orozco *et al.*, 2008). On average, only 31.98% of participants attended schools where other students tested at or above the proficient level in state English Language Arts exam; again, the Latinos were most disadvantaged in this regard.

Students were interviewed annually and parents were interviewed at the beginning and then again five years later at the end of the study. In the third year of the study we selected 75 students evenly distributed by country of origin (15 participants in each) who represented a range of academic engagement profiles for case study research. These students were selected based upon an examination of school records and ethnographic observations by the research assistants, with an eye to capturing a range of patterns of school engagement and performance across country-of-origin groups analyses of the case studies.

[iv] We want to gratefully acknowledge my co-investigators on this project – Margary Martin, Mikael Alexandersson, Lory Janelle Dance, and Johanes Lundenblad. We would like to thank the National Science Foundation's Partnership for International Research and Education for funding Richard Alba/Roxanne Silber, Jennifer Holdaway/Maurice Crul, Mary Waters/Anthony Heath, & Margret Gibson/Silvia Carraso and Carola Suárez-Orozco/Mikael Alexandersson's "Children of Immigrants in Schools" partnership study which made the research presented here possible.

[v] New York City has a long-standing history of incorporating immigrants to its shores. Currently, half of the students in NYC public schools have an immigrant parent and nearly 10 percent arrived in the United States within the past three years (NYSED 2006). The vast majority of these students are poorly served; many are attending schools suffering from the "savage inequalities" (Kozol, 1991) between school contexts. While the 1954 U.S. Supreme Court decision Brown v. Board of Education legislated equal access for students regardless of racial background, the requisite investments in schools serving different subpopulations have not been made (Heubert, 1998).

Swedish schools make for an interesting point of comparison because of their commitment to provide equal access to all students. The Swedish Education Act of the 1940s legislated that: "All children and youths shall have equal access to education". As a result, Swedes invest heavily in their schools and in their most challenged students. Hence, second-generation students in Sweden have significantly lower secondary-school dropout rates as well as higher rates of university participation than in other nations (OECD, 2006). On the other hand, once immigrant students graduate in Sweden, they encounter a low glass ceiling and find it difficult to enter the employment sector (OECD, 2006). Sweden is relatively new to large numbers of immigrants from countries outside of Northern and Western Europe. It also has taken in a much higher proportion of refugees than has the United States. This population represents a significantly different set of incorporation challenges (Athey & Ahearn, 1991; Lustig *et al.*, 2004). Refugees face significant psychological trauma; while some are highly educated (e.g., Chileans), others suffer from high levels of illiteracy (e.g., Somalis); and many live in a liminal psychological space hoping to return to the homeland when 'things settle down'. Further, many of the new immigrants are of Muslim origin, which has resulted in a considerable degree of ambivalence, backlash, and social unrest (Cesari, 2006).

[vi] We used a case study methodological strategy (Yin, 2003) in order to describe in detail each school context serving this population. This approach allowed us to illustrate findings in the lived experiences of diverse adolescent youth and to shed light on the processes and causal links that emerge from the data. The multiple-case study approach

also provides the advantage of allowing analytical theoretical generalizations to emerge from empirical findings (Burawoy, 1991;Yin, 2003) and provides insight into the "crucial role of pattern and context" (Yin, 2003, p. x) in determining phenomena. The "replication logic" (Yin, 2003, p. 4) of the multiple-case study approach allows for cross-case comparisons and conclusions.

We identified 4 schools that were lauded locally as being particularly innovative in their approach to immigrant-origin students (see Table 3 below). Our research team used a variety of methodical strategies to gather data across sites. We conducted ethnographic fieldwork as the primary data collection strategy in order to gather information about innovative school practices, and assess the school ethos, teacher/student, teacher/teacher, and student/student relationships, school climate and intercultural understanding, as well as impediments to the implementation of innovative practices. Every school site included informants from three mixed cultural groups based on variation in: 1) demographic proportions in the school, 2) social status at each school, and 3) success in terms of grades and performance. The selected students were studied in four different contexts (classrooms during lessons, groups working on specific subjects, groups discussing general issues, and groups working together) for a period of 12 to 20 weeks (i.e., 3 to 4 months of data collection at each school). Semi-structured interviews and focus groups with teachers and administrators were also conducted to learn about their perspectives on the implementation of innovative practices and the impediments that they encounter along the way. We examined the performance of schools on quantitative indicators gathered from school records and city education statistics, which included student retention and graduation rates, and university entry rates. Lastly, the team conducted structured focus-group interviews with students in order to contextualize emerging findings. The triangulated data from each site was coded according to innovative practices important for all immigrant students along with those specific to the needs of newcomers or second-language learners. In addition, we examined theoretically relevant analytic themes (e.g., preparation vs. remedial agenda; significance of relationships; and priority of immigrant student needs) (Yin, 2003).

We used several criteria to select our case-study "innovative" schools. The schools had to serve a high proportion of immigrant-origin youth. They had to have a reputation within the broader educational community for being innovative and attaining superior outcomes on standard performance indicators in comparison to other schools with high proportions of "low-status" immigrant kids (e.g., student stability rates, teacher/student ratios, graduation rates, recruitment of highly qualified teachers, and retention of teachers). Also, three of the four schools were part of networks of innovative schools. We purposefully did not use standardized testing results as a criterion, since such tests underestimate the skills of second-language learners (Menken, 2008; Solano-Flores, 2008). All schools had an institutional commitment to prepare students for the new global era by confronting core educational challenges. All of the selected schools claimed a grand narrative of providing engaging and relevant learning environments in order to foster personally meaningful relationships and constructive habits of work shown to contribute to academic performance. These schools also explicitly had preparing its student youth to successfully navigate in a multicultural world as a central agenda. (*See Table 1 and Figure 1 below for at a glance features of schools. Greater detail is beyond the scope of this chapter but is provided in Suárez-Orozco, Martin, Alexanderson, Dance, & Lundenblad, 2013*).

TABLE 1: Promising School Project Characteristics				
	New York High Schools		Swedish Gymnasiums	
	World Citizen	Progressive	Ekdalsskolan	Bergslunden
School Site Inclusion Characteristics				
Publicly recognized for its innovative approaches	✓	✓	✓	✓
Serves significant numbers of immigrant-origin youth	✓	✓	✓	✓
Does not have entrance exams	✓	✓	✓	✓
Academic Relationship Building Narrative	✓	✓	✓	✓
Higher than average graduation rates compared to schools serving similar populations in the area	✓	✓	✓	✓
Higher than average results on performance indicators compared to schools serving similar populations in the area	✓	✓	✓	✓
Part of Network	✓	✓	✓	
	New York High Schools*		Swedish Gymnasiums	
	World Citizen	Progressive	Ekdalsskolan	Bergslunden
Comparisons to Other Citywide Schools on Performance Indicators				
Student Graduation Rates in 4 years (USA & SE)				
~City Rate	FB= 57.5% All=50.6%		74.5	73.1
~Site Rate	64.8%	95.5%	85.2	67.0
Prepared to Enter University				
~City Rate #	36.5%	36.5%	89.5	86.4
~Site Rate ##	41.4 %	84%	70.7	82.9

* New York Source: NYSED (2006). New York State of Learning: A report to the governor and the legislature on the educational status of the state's schools. Sweden Source: Swedish Department of Education (Skolverket, 2007).

** In Sweden, upper secondary education (i.e., high school) consists of three years instead of four. However, the statistics for students who have completed their upper secondary education are calculated within a four-year time frame.

In both the U.S. and Sweden, students may remain in public secondary schools up to the age of 21. It is quite common for newcomer youth, and especially SIFE students to take longer to complete their high school education. In the U.S., graduation rates are typically reported in terms of both 4-year and 7-year rates; however, the cohorts of students participating in the study will not be at 7 years until 2011; therefore these data are not provided. Note that the 7-year graduation rate for the World Citizen Network is 90%.

For NYC, we report the percent of students who passed the Regents Diploma – a comprehensive exam that represents college readiness. For Sweden, we report the percentage of students who, based on their performance in high school, *qualify* for entry into University.

Note that for the World Citizen, the Network graduation rate is 90%.

Sleep, Slums and Shelter: Impact of a Slum-housing Upgrading Program

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Abstract

The unprecedented urban growth in face of increasing poverty and social inequity in developing countries is posing an immense challenge at all levels. The urbanization of poverty is reflected mainly by the proliferation and expansion of slums. Over one billion people (about 14 percent of the world population) are slum dwellers. According to UN-HABITAT predictions, the number of slum dwellers could double by the year 2030, due to the increase of social inequality and poverty in the context of an extraordinary urban growth. Slum dwellers do share the fact that they live in the most adverse of circumstances and poor sleep conditions presumably could amplify health related problems typical of the slum environment like psychological distress, poor diet, a sedentary lifestyle and cardiovascular disease. In a first part of our study we applied a brief version of the Pittsburgh sleep quality index (PSQI) to the sample population examined by the Barómetro de la Deuda Social Argentina, Pontificia Universidad Católica Argentina (N= 5766). The aim of this program is the identification, monitoring and evaluation of the dynamics and scope of the social debt understood as deficit in human development capabilities and social integration of the population. It also assesses the effect of policies and public-private actions affecting its state and evolution. Analysis of the distribution of sleep disorders as a function of socioeconomic status, residential status and place of residence indicated that the very low socio-economic stratum had a higher percentage

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of subjects with poor quality of sleep and daytime sleepiness ($p < 0.001$). The residence in slums was associated with a higher percentage of subjects with poor sleep quality and obesity ($p < 0.001$). In the second part of our study we evaluated the impact of a housing transition on sleep quality and quality of life in slum dwellers, participating in a slum-housing upgrading program in 5 slums located in Buenos Aires' Metropolitan Area. A total of 150 slum dwellers benefited by a housing program of a non-profit organization ("TECHO") moving from their very low quality house to a basic prefabricated 18 m^2 modular house,This was an observational before-and-after study with a convergent-parallel mixed method design.The PSQI and WHO quality of life (QOL) brief scales were administered before and after housing upgrading. Semi-structured interviews were used to expand and nuance quantitative data obtained from a poorly educated sample. Results showed that sleep quality significantly increased after the housing program ($p < 0.001$). Overall QOL and physical health domain, psychological well-being domain and environmental domain of QOL were also improved. Therefore a minimal improvement of basic housing can significantly increase sleep quality and quality of life among slum dwellers.

1. Introduction

Sleep is an essential process in life. It is a behavioral state defined by: (i) characteristic relaxation of posture; (ii) raised sensory thresholds; (iii) distinctive electroencephalographic (EEG) pattern; and (iv) ready reversibility (1). One difficulty in understanding sleep is that it is not a unitary state but composed of two sub-states. Based on polysomnographic measures, sleep has been divided into categories of rapid eye movement (REM) sleep and non-REM (NREM) sleep (also called slow wave sleep). Sleep alternates between NREM and REM stages approximately every 90-120 min. Periods of NREM sleep constitute about 80% of the total sleep time and NREM reaches its greatest depth during the first half of the night (1).The recurrent cycles of NREM and REM sleep are accompanied by major changes in physiology. Indeed, it can be said that we live sequentially in three different physiological states ("or bodies"): that of wakefulness, that of NREM sleep and that of REM sleep. Since epidemiological data indicate that in our modern society we indulge about 6 h of sleep per day, the relatively longer wakefulness stage, and the relatively shorter NREM stage, have strong negative consequences for health. There is an increasing evidence that a number of endemic pathologies like obesity, the metabolic syndrome and neurodegenerative diseases can be related to the prevalence of wakefulness in face of NREM sleep loss in contemporary, 24/7 Society (2-4).

2. Sleep disturbances are very common in the general population

Healthy adults need 7-9 hours of sleep per day and school-age children might require 10-11 hours of sleep (5). In 2010, approximately 30% of USA adults and 44% of shift workers reported less than 6 hours of sleep/day (6), which has been associated with fair/poor general health, frequent mental and physical distress, depressive symptoms, anxiety, and pain (7). Sleep insufficiency can also result from sleep disorders such as chronic insomnia, restless legs syndrome, sleep apnea, or narcolepsy (8).

Thus the impact of sleep restriction is relevant and matter of public concern. On the one hand, sleep impairment is linked as a contributing factor to motor vehicle crashes, industrial disasters, and medical and other occupational errors. On the other hand, persons experiencing sleep insufficiency are more likely to have chronic diseases such as cardiovascular disease, diabetes, depression, or obesity (9,10).

In addition to biological and psychological determinants, sleep quality is strongly influenced by social factors. Among them, the place and type of residence, socioeconomic status and working conditions, among others, are relevant (11). In Argentina field studies on this matter are lacking regardless of their necessity for designing public health policies to mitigate biological, psychological and social impact of a sleep deprived society. In the first part of this study we assessed the possible link of sleep disorders, demographic characteristics and health status in the general population sample surveyed by the Barómetro de la Deuda Social Argentina, Pontificia Universidad Católica Argentina. The aim of this program is the identification, monitoring and evaluation of the dynamics and scope of the social debt understood as deficit in human development capabilities and social integration of the population. It also assesses the effect of policies and public-private actions affecting its state and evolution. In Latin America despite the significant economic progress over the past two decades, many of the region's city inhabitants are poorly housed. Of the 130 million urban families in the region, 5 million rely on another family for shelter, 3 million live in houses that are beyond repair, and another 34 million live in houses that lack either title, water, sewerage, adequate flooring, or sufficient space (12). The second part of our study evaluates the transitional impacts on quality of life, sleep quality and sleep conditions of slum dwellers who participated in the slum-housing upgrading program run by the nonprofit organization TECHO in the metropolitan area of Buenos Aires, Argentina.

3. Socio-demographic aspects of sleep habits and their relationship with health

In a survey we conducted in large urban areas of Latin America (Buenos Aires, Sao Paulo and Mexico City) two thirds of the population reported sleep problems, a quarter of it with a poor quality of life because of these problems (13) In that study a daily "sleep debt" (hours of desired sleep minus hours of actual sleep) of about two hours was verified, quite in agreement to the longitudinal evaluation of sleep length decreased recorded in the last 30 years (5).

In the present study we assessed the possible link of sleep disorders, demographic characteristics and health status in the general population sample surveyed by the Barómetro de la Deuda Social Argentina, Pontificia Universidad Católica Argentina (N= 5766). We applied 5 questions derived from the Spanish version of the Pittsburgh Sleep Quality index (PSQI) (14,15) plus a question about nap habits. The questions were: 1. During the last month: At what time do you usually lay down to sleep at night?; 2. After turning off the light to sleep: how long it took to fall asleep on average?; 3. At what time do you

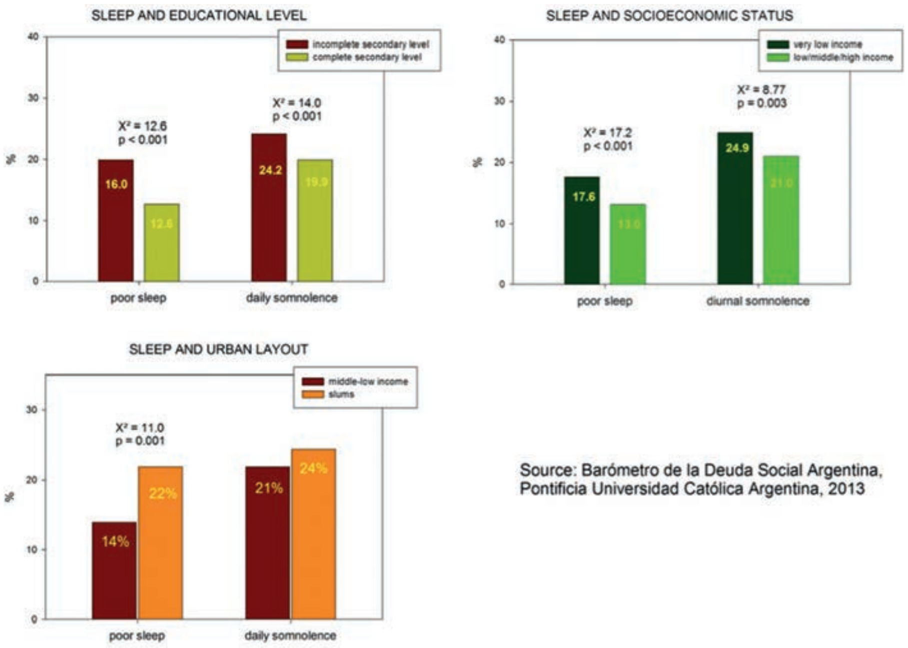

Figure 1. The distribution of sleep disruptions as a function of the educational level, socioeconomic status and urban layout in Argentina (N= 5766).

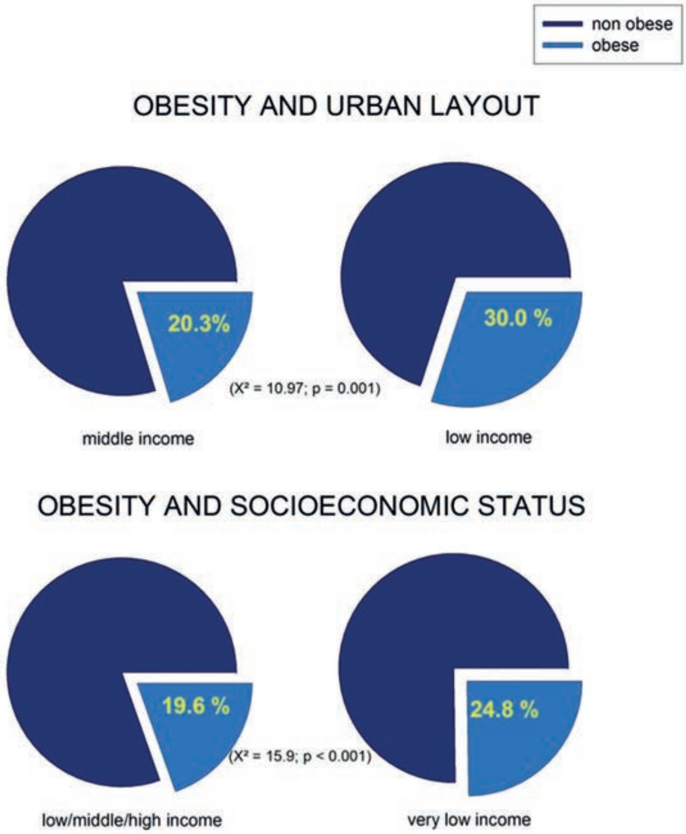

Figure 2. Obesity as a function of the educational level and urban layout in Argentina (N= 5766).

usually wake up in the morning?; 4. How would you rate your overall quality of sleep? (Very good, fairly good, fairly bad or very bad); 5. How often have you had trouble staying awake during the day? (Never, or rarely, once or twice a week, three or more times a week), 6. If you nap on a regular basis (every day or almost every day) how long do you nap?

Total Sleep Time (TST) was calculated as "time in bed - time to fall asleep + nap time"). TST was divided into two categories: < 6 hours and > 6 hours. Sleep was defined as "poor sleep" as the presence of "fairly bad" or "very bad" quality of sleep. Daytime somnolence was defined as the presence of daily sleepiness one or more times a week. Additionally, body mass index (BMI) was calculated as "weight/height^2", from recorded weight and height data. The presence of overweight was defined by BMI ≥ 25 kg/m^2 and of obesity by BMI ≥ 30 kg/m^2. Data were analyzed according to sex, age, education level, socioeconomic status, and type and place of residence. We also evaluated how the presence of sleep disorders was associated with perceived health status or obesity. The variables were reported as percentages of total number of subjects. Assessment of statistical significance was done through the X^2 test.

The prevalence of TST less than 6 hours/day was 14.8%. Poor sleep quality or daily somnolence was reported by 14.2 and 22.0% of the individuals surveyed. The percentage of men with TST < 6 h was higher than that of women (X^2= 15.9, p < 0.001) whereas the percentage of women with poor sleep quality was higher than that of men (X^2= 20.2, p < 0.001). A higher percentage of subjects with TST < 6 h lay in the range 35-59 years (X^2= 127.3, p < 0001). This age group also reported the lowest sleep quality (X^2= 12.2, p= 0.002). Large metropolitan areas had a higher percentage of individuals with poor quality of sleep (X^2= 20.1, p < 0.001). The distribution of sleep disturbance as a function of socioeconomic status, ed-

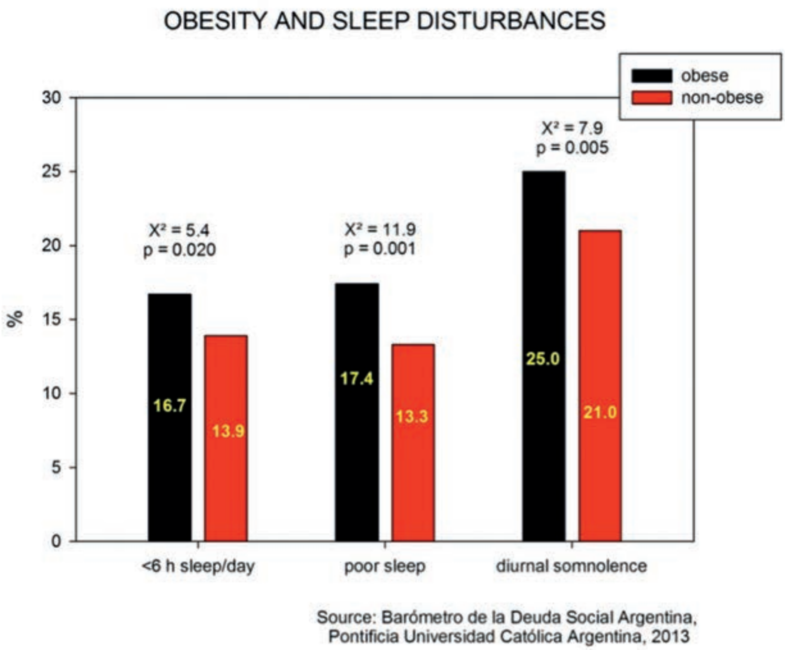

Figure 3. Relationship between obesity and sleep disturbances in Argentina (N= 5766).

ucational level and residential status is summarized in Fig. 1. A low level of education was associated with a higher percentage of subjects reporting poor quality of sleep (X^2=12.6, $p < 0.001$) and daytime sleepiness (X^2= 14.0, $p < 0.001$). The socio-economic stratum classified as very low had a higher percentage of subjects with poor quality of sleep (X^2=17.2, $p < 0.001$) and daytime sleepiness (X^2= 8.77, p= 0.003). The residence in slums was associated with a higher percentage of subjects with poor sleep quality (X^2= 11.0, p=0.001) (Fig. 1).

Obesity was more prevalent in subjects with low socioeconomic status (X^2=61.6, $p < 0.001$), and living in slums (X^2= 52.7, $p < 0.001$) (Fig. 2). The presence of obesity was associated with a higher percentage of subjects with TST < 6 hours (X^2=9.5, p=0.009), poor quality of sleep (X^2= 11.9, p= 0.001) and daytime sleepiness (X^2=7.9, p= 0.005) (Fig. 3). A perceived health status reported as severely poor was associated with a higher percentage of subjects with poor quality of sleep (X^2=130.1, $p < 0.001$) and daytime sleepiness (X^2=5.0, p=0.025).

In summary, we observed asymmetries in the distribution of sleep disorders associated with substandard housing, a very low socio-economic status and educational level. Likewise the present survey supports the link between poor sleep quality and health problems, including obesity.

3. Impact of a slum-housing upgrading program on sleep

The unprecedented urban growth in face of increasing poverty and social inequity in developing countries is posing an immense challenge at all levels. Urbanization of poverty is shown mainly by the proliferation and expansion of slums (16). Such places generally contain houses built using plywood, wood boards, cardboard, corrugated metal and sheets of plastic. Over one billion people (approximately 14 percent of world population) are slum dwellers (17). According to UN-HABITAT predictions, the number of slum dwellers could double by the year 2030, due to the increase in poverty and social inequality in the context of an extraordinary urban growth (18). Slums can vary substantially in their structure, composition, and culture; those involved in our study differed in a variety of aspects that ranged from electricity access to flood risk, from crime to contamination and the size of parcels. Nevertheless, slum dwellers do share the fact that they live in the most adverse of circumstances. In this context poor sleep could amplify other health-related problems typical of the slum environment, such as psychological distress, poor diet, a sedentary lifestyle and cardiovascular disease, demonstrating its important role in chronic illness and health (19-26).

The Latin American youth-led nonprofit organization TECHO, which is active in 19 countries of Latin America and the Caribbean, defines slums as settlements of eight or more families occupying land and lacking at least one of three basic services: water, electricity or sewage. Through the joint work of families living in extreme poverty with young volunteers, TECHO seeks to overcome poverty in slums. TECHO's first phase of intervention is in assessment of the family's need and promotion of organization, participation and community co-responsibility. During the second phase, TECHO focuses on building of transitional housing to urgently address the need for adequate shelter that is present in most slums. These transitional houses are based on a prefabricated 18 m^2 module that is elevated off the floor, includes a zinc roof, and is built in a lapse of about two days.

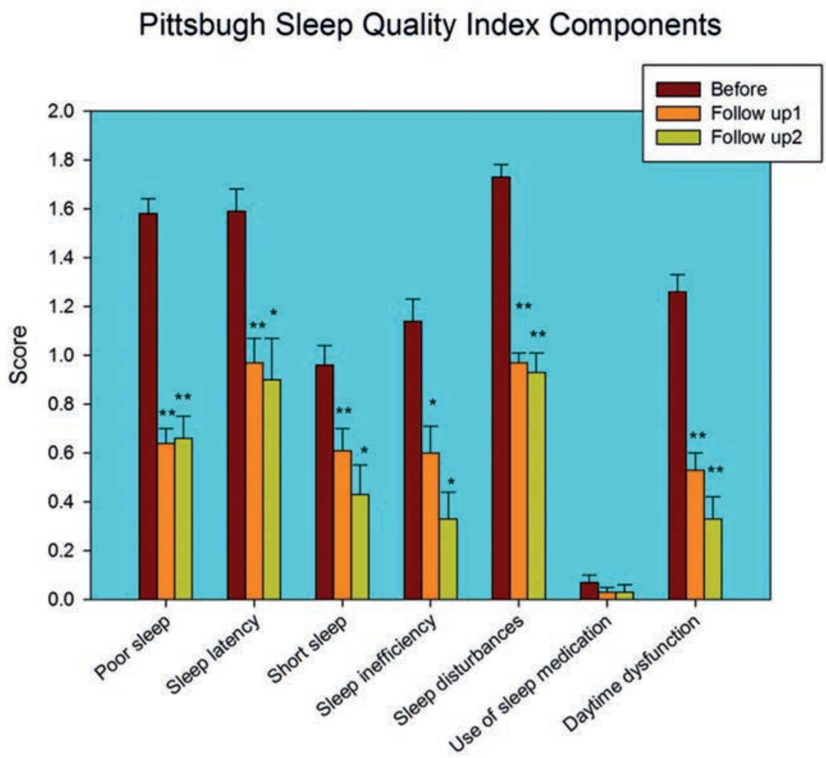

Figure 4. Pittsburgh Sleep Quality Index components before and after house upgrading. Follow up 1= 1month, follow up 2= 6 months after intervention. TECHO study.

However, the quality of sleep, sleep routine, sleep context and sleep habits among slum dwellers has not yet been examined in the scientific literature. Understanding sleep disparity within this unique population could provide insight into quality of life parameters, and can aid with the development and use of novel interventions.

A total of 150 adult slum dwellers on the waiting list for the TECHO housing program, were invited to participate in the study carried out from April to October, 2011. They were all residents of slums located in the metropolitan area of Buenos Aires, Argentina. All participants met selection criteria defined by TECHO. These criteria are based on a thorough evaluation of housing conditions, income, family size and composition, health conditions and access to social networks.

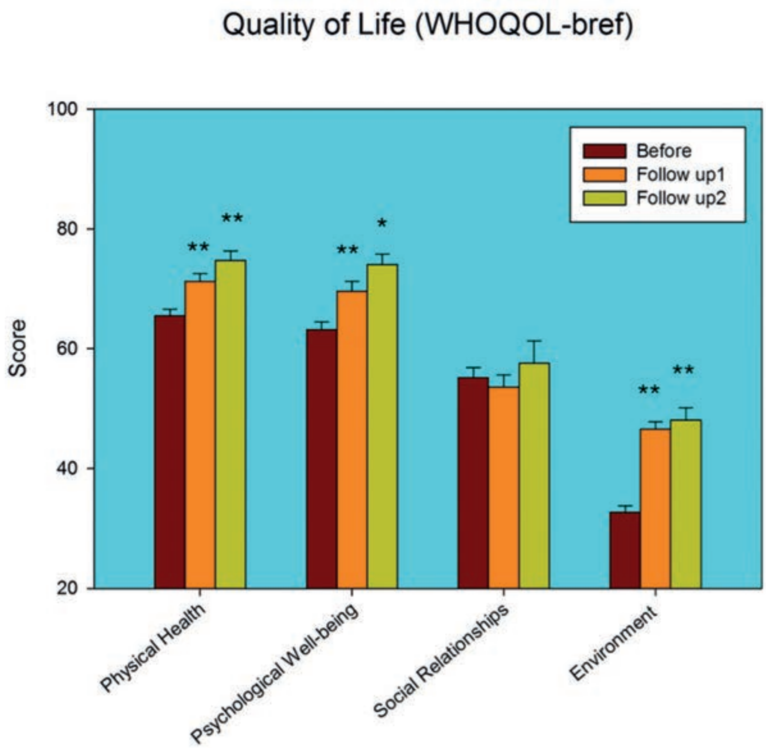

Figure 5. Quality of life (WHOQOL-BREF) before and after house upgrading. Follow up 1= 1month, follow up 2= 6 months after intervention. TECHO study.

Among 150 participants (91 females and 59 males), 77 (47 females and 30 males) successfully completed the protocol by answering questionnaires once before and once after the housing improvement. A total of 30 (19 females and 11 males) were available for a re-interview after six months with the same measurement tools.

The mean ± SEM age of the initial sample was 30.6 ± 0.74 years. The average income per family member was considerably below the poverty line according to the national standard measured by the access to an average diet. The families also matched at least two criteria from unsatisfied basic needs (more than three people living in the same room, living in a substandard house/tenancy, a children aged 6 to 12 not attending to school or no sewage), another complementary tool used to measure poverty. The entire sample attended primary school, however only 46% completed the 7th Grade (from a total of 12 years of compulsory education). A total of 4% had finished high school and none had attended post-secondary education. Subjects were asked about income level, formal education, attained demographic and health data including age, height, body weight and the presence (yes or no) of smoking habits, cardiovascular disease family history, and diagnosed diabetes, hypertension or dyslipidemia.

Participants answered questions about self-perceived psychological stress defined as a feeling of tension, irritability or anxiety, or as having sleeping difficulties as a result of conditions at work or at home during the past month.

To assess sleep, a Spanish version of PSQI (14) was used (15). The questions generated seven component domain scores: subjective sleep quality; sleep latency; sleep duration; habitual sleep efficiency; sleep disturbances; use of sleep medication; and daytime dysfunction. Each of them was weighted equally from "0" to "3" and the global PSQI score ranges from "0" to "21", with higher scores indicating poorer sleep quality.

For assessing quality of life the WHO Quality of Life (WHOQOL-BREF) was used. The brief version of WHOQOL is a self-report generic quality of life inventory of 26 items, including 4 domains: a) Physical health: activities of daily living, dependence on medicinal substances and medical aids, energy and fatigue, mobility, pain and discomfort, sleep and rest, work capacity. b) Psychological well-being: bodily image and appearance, negative feelings, positive feelings, self-esteem, spirituality/religion/personal beliefs, thinking, learning, memory and concentration. c) Social relationships: personal relationships, social support, sexual activity. d) Environment: financial resources, freedom, physical safety and security, health and social care: accessibility and quality, home environment, opportunities for acquiring new information and skills, participation in and opportunities for recreation/leisure activities, physical environment (pollution/noise/traffic/climate), transport. Two of the items measure Overall QoL/health. The measure is rated on a 5-point Likert scale ranging 0 to 100 with higher scores indicating better QoL (27,28).

The first phase used questionnaires to evaluate quality of life sleep and sleep quality before moving to the new house. The second phase explored sleep and life's changes through the same questionnaires.

The PSQI and WHOQOL-BREF were applied before and one month after the housing upgrading (follow up 1). Data on housing conditions, sleeping conditions, income, education, and cardiovascular risk were also collected. Participants who successfully completed the questionnaires after one month were re-interviewed after 6 months (follow up 2). The semi-structured interview took place during phase 2, i.e. between one and six months of living in the new house.

Housing conditions significantly improved after the program. The percentage of people who reported struggling weekly with structural aspects of their roof decreased from 57.3 to 2.6%, the number of cases in which rain was considered a big problem decreased from 70.0 to 3.9% and the number of cases where dampness was considered a major problem decreased from 70.0 to 1.3% ($p < 0.001$). Overall dissatisfaction with housing conditions decreased from 78.7 to 2.6% ($p < 0.001$). Before the housing intervention 39.4% of participants reported being stressed quite often, while after one month and six months that percentage decreased to 5.6 and 3.3% respectively ($p < 0.001$).

Figure 4 and 5 summarize the results of the different domains of the PSQI and WHOQOL-BREF before and after TECHO intervention. Marked improvements were seen in subjective sleep quality, sleep distur-

Figure 6. Overall improvement in sleep quality and quality of life after housing improvement. TECHO study.

bances and daytime dysfunction. The use of sleep medication was similar before and after intervention. After six months of follow up, results remain mostly the same (Fig. 4). In the case of WHOQOL-BREF, the most significant difference was seen in overall quality of life and environment domain, while changes were non-significant as far as the social relationship domain (Fig. 5). As shown in Fig. 6 global score of PSQI and WHOQOL-BREF improved significantly after TECHO intervention.

4. Conclusions

Although several studies support the conclusion that sleep problems are associated with an increasing number of diseases and health problems (see e.g., (9,10)), few observations have been published on the way social factors can predict or influence the length and quality of sleep. It has been reported that a higher level of education is associated with better quality of sleep through the possibility of obtaining a higher level of income (29). The data presented herein allow us to conclude that socioeconomic status, type of dwelling, place of residence and level of education are important determinants of health. Disorders in the length and quality of sleep may have an important role in explaining how these social factors translate into specific pathologies.

As shown in the second part of the present study a slum-house upgrade has a significant positive impact on sleep quality and QOL. This could be showed in both quantitative (reported herein) as well as in qualitative results (see (30). Sleep quality was mostly associated with QOL domains before but not after the intervention.

It has been proposed that sleep quality is a significant mediator and amplifying factor in the association between neighborhood and psychological disorder (19,31). Additionally, being a resident of a disadvantaged neighborhood and low socioeconomics in general, have been associated with poor sleep and worse self-reported health (32-34). Interestingly, our result show that a good sleep is possible even in a very poor and adverse environment, providing that you have four solid walls, a roof and you feel serene.

In the future, the use of physiological measurements may be necessary to glean a broader perspective of sleep in urban slums. The neighborhood structure, location and other slum conditions should also be taken into account since slums can vary substantially between one another in their composition and its level of urbanization and integration to the city. The addition of semi-structured interviews to questionnaires showed context orient answers, even to a standardized questionnaire. More mixed method researches could enhance and nuance knowledge about sleep. Concurrent investigations of low cost housing interventions that can lessen the adverse societal effects of poor sleep with a consequent impact on quality of life are warranted.

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Conflict of Interest

The authors report no conflicts of interest.

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The Reading Brain, Global Literacy, and the Eradication of Poverty

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Reading represents one of the most powerful, cultural inventions that humans have ever created. The importance of this achievement for the advancement of our global society cannot be exaggerated. The acquisition of reading changes the brain, propels the individual reader's intelligence, and advances the species' collective intelligence (Wolf, 2007). When a child acquires literacy, the life of the child is transformed, and so is the life of the surrounding society. That almost 200 million children, through no fault of their own, will never learn to read (either proficiently or at all) means that a huge segment of our species will never reach their potential for cognitive and social transformation. It is an incalculable and, we believe, preventable loss.

This chapter will be comprised of four parts, each of which will describe different theoretical and applied dimensions of our work. In the first more theoretical and historical section of the chapter, our goal is to describe – cortically, cognitively, and ethically – what it means to be literate for a child, and by implication, what it means to be illiterate. The second section will describe a bold, innovative set of efforts by our group to promote global literacy in remote regions of Ethiopia. This radical initiative combines advances in technology, cognitive neuroscience, and child development to develop an advanced form of digital learning. As will be detailed, our ultimate goal is to create an open-source platform that supports literacy development over the next decade that can reach millions of children who would otherwise never become literate. The third section provides more specific details on the methods, evaluation, and preliminary results of our efforts to date. Finally, in our last section we will argue that work on global literacy represents one of the most hopeful applications of theoretical knowledge to one of the world's most intractable sources of poverty.

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I. Theoretical Background

The Origins of the Reading Brain

Let us begin with a very simple, but profound insight: Human beings were never meant to read. We were biologically programmed to speak, see, think, and remember, but not to read. These other, more basic critical processes require vast neuronal networks that are genetically given. More pertinent to literacy, they are also the essential component parts for the development of a new *reading circuit* in the brain of every literate person. The reading circuit represents one of the most powerful examples of the brain's semi-miraculous ability to form new circuits from the neuronal networks used for older, genetically programmed processes. Numeracy (see Dehaene, 2011) and writing represent other examples. In the case of reading, the networks for vision, language, cognition, affect, memory, and attention are all brought together for something outside our basic repertoire of abilities. Pascal once wrote that there is nothing new under this earth, but that there is "rearrangement". The reading brain circuit is, from our perspective, the physiological instantiation of Pascal's principle of *rearrangement*.

But how does this rearrangement begin in a child? Although there remains much we have to learn about the development of any of the "new circuits", the combination of decades of work in child development and more recent brain imaging allows us to follow the formation of this circuit with increasing accuracy. It begins at the very start of life, as young children slowly develop each of the genetically preprogrammed parts of the circuit, particularly processes underlying language, hearing, cognition, and vision. For most individuals about five years are required for the development of each of these individual component parts before children gradually learn how to integrate the separate parts into one wholly new circuit for the purpose of reading. This integration, which is the basis for the reading circuit, never simply emerges without exposure to a writing system, and the nurturance of the environment or culture around the child.

Given the brain's *rearranging* capacity, most children learn to associate what they see, hear, and know with symbolic characters through varying amounts of teaching assistance. Although some children might be able to induce the alphabetic principle themselves (see Sartre's unusual account of his auto-didactic learning, in Sartre, 1963), the alphabetic principle requires demanding cognitive insights into the nature of a symbolic function. Whether the child is learning the alphabetic principle or other writing systems like Chinese and Japanese Kanji, the child must learn that a visual symbol corresponds to a specific sound, syllable, word, or concept.

Indeed the perceptual, linguistic, and cognitive hoops that every child has to move through to learn what it means to decode letters and words into meaningful units can be likened to a three-ring cognitive circus. In the first ring, the language system must be developed in multiple ways: from the outset, children must be exquisitely attuned to the unique individual "phonemes" or sounds of their language, that make up the sound structure of each word. Equally importantly, they must know the meanings and grammatical functions of hundreds and ultimately thousands of words, so that when they eventually read the word, they know what it means in a sentence.

The second ring is comprised of the fine-tuned perceptual processes that allow the child to detect the often subtle visual features of individual letters or characters. There are very specific groups of neurons responsible for the particular features that letters are comprised of, and indeed Dehaene (2009) writes eloquently about the "neuronal niche" that letters inhabit. In similar fashion, with sufficient exposures, other "working groups" of neurons become specialists for recognizing the particular letter patterns, and highly used words in any writing system.

The third ring involves the increasingly sophisticated and abstract cognitive processes that allow the child first to learn that a letter (or character) symbolizes a sound; second, that in an alphabetic system these sounds are blended to make words; and third, that words come together to give meaningful thoughts and information that ultimately propel their own thoughts. This last accomplishment requires ever more complex processes over time like inference, analogical and deductive thinking which all contribute to what we call "deep reading" (Wolf & Barzillai, 2009).

Finally, each ring's "acts" must be learned individually till they can be ultimately performed in tandem – flawlessly and synchronously – as a group of seemingly effortless performances. What we do when we read is very much like what a ringmaster does while conducting a three-ring performance. Quite literally, huge portions of the brain's visual, linguistic, cognitive and motoric areas are activated when first reading a single word or sentence. From a physiological perspective, it is one of the most impressive displays of activated cortex. Those who believe that human beings use only part of their brains have never seen images of the young reading brain at work! It is an extraordinary and impressive performance, that may be the most difficult the brain is ever called upon to perform at so young an age.

Understanding exactly what specific processes and underlying areas of the brain are activated at different stages of reading's development has been one of the foci of our work for many years, along with MIT colleagues, John and Susan Gabrieli and their research team. This systematic examination of the reading brain's formation in childhood has been and continues to be the basis for our group's efforts to create new approaches for helping children learn to read.

More specifically, we have created innovative reading methodologies that systematically target each component part of the developing reading circuit (Wolf, Bowers, & Biddle, 2000; Wolf, Barzillai, Gottwald, *et al.*, 2009; Wolf, Ullman-Shade, & Gottwald, 2000). Along with colleagues Robin Morris in Atlanta and Maureen Lovett in Toronto, we demonstrated through more than a decade of systematic, randomized treatment – control design studies how carefully targeted emphases in reading methods can help young and particularly young, struggling readers with dyslexia, learn to read with significantly more fluency and comprehension than other methods (see Morris, Lovett, Wolf *et al.*, 2012). From these studies, and related studies by other researchers, we have learned how to model the reading brain and to apply this knowledge to the teaching of the young in traditional school settings.

History of the Project

In the process of our work on intervention with struggling readers, we became increasingly aware of literacy issues outside our traditional research base in classrooms in the United States. A little over two years ago Nicholas Negroponte, the founder of the MIT Media Lab and the One Laptop Per Child initiative, approached the first and last authors with questions concerning literacy in remote regions around the globe – that is, places where there are neither schools nor teachers. Negroponte had become concerned about these issues because of what he discovered during his leadership of the One Laptop Per Child initiative, in which 2.4 million laptops were distributed to children in varied regions of the world. Although there were successes in countries like Uruguay, laptops in some other places could not be effectively used, because the children were simply unable to read. Negroponte, Breazeal, and Wolf began to discuss whether a digital learning experience, based on their different areas of expertise in reading and technology, could be created to help children learn to read on their own who had no access to school or teacher.

The facts then and now were and are overwhelming and more compelling than the multiple hurdles: 72 million children worldwide can never really become literate because they have no school. At least another 100 million children have such insufficient resources in their schools that they will never become functionally literate. The realities of these 172 million illiterate children pose staggering challenges and questions. We asked: Can our insights into the formation of the young reading brain and our research on methods for teaching children with dyslexia and other learning differences provide the basis for a completely new application of this knowledge base? Can we find and/or create apps and activities that target all the important areas in the reading brain circuit? Will children be able to teach themselves and each other with no adult instruction or help? Can our mobile technologies prove capable of delivering these apps and also assessment tools to ensure the efficacy of the approach? How can we implement these technologies and evaluate the children in the remote regions where most of these 172 million children live? In other words, we asked ourselves *whether it is possible to create a digital learning experience capable of combating illiteracy through mobile technology devices like tablets and smart phones in places and situations where schools and teachers are either unavailable or insufficient.*

Three factors convinced us that we have a unique opportunity to achieve massive inroads on illiteracy on a global scale. First, our increased understanding of the young reading brain and how to teach it makes the curation and development of innovative digital content a conceivable goal. Second, within technology there are increasing breakthroughs that make new mobile computer technologies affordable and available around the world, thus making the financial basis of digital learning possible for large numbers of children, something that would have been heretofore impossible. Moreover, wirelessly connected mobile computing devices have become a cost-effective platform for delivering learning content through multiple experiences (e.g., apps, videos, e-books, games, and online communities) to children across varied knowledge bases and skill domains.

Third, the growing ubiquity of connectivity, along with cloud computing and big data analytics, enable completely new forms of assessment both of children's individual progress and also of the performance of large populations (e.g., from the village to the country to the global levels). More specifically, by creating a tightly iterative design in which a child's performance can be immediately assessed, we could provide ever more targeted individualized instruction on the specific areas of need for a given individual. Such a design could provide one of the most important means for advancing learning on digital technologies, particularly in remote areas of the world.

These three factors became the context for our research consortium. Members of the Tufts Center for Reading and Language Research, MIT Media Lab, Georgia State University, and most recently the Dalai Lama Center for Ethics and Transformative Values came together to work towards one overarching goal: to investigate whether our evolving knowledge of the young reading brain, big data analytics, child development (particularly child-driven learning), and new technologies can be applied on mobile technologies.

Specifically, we sought to understand whether theoretically based content on affordable tablets could help children learn to read by helping themselves and each other, even in the absence of a teacher or literate adult. Nicholas Negroponte and the One Laptop per Child Foundation provided both the funding and infrastructure for the first deployments in Africa, and also the assistance of OLPC Matt Keller in negotiations with government officials. More recently, Negroponte went on to become director of a different, but analogous literacy-related initiative within the X Prize.

The responsibilities of the current members in the consortium are multiple: Tinsley Galyean, a member of both the MIT Media Lab and also the Dalai Lama Center for Ethics and Transformative Values, coordinates technological development and multiple dimensions of open-source platform development. Georgia State University's Robin Morris directs study design and statistical methods for the use of big data analytics in our evaluations; in addition, he coordinates new deployments in the rural South of the United States where literacy development also lags. Venerable Tenzin Priyardarshi from the Dalai Lama Center of Ethics and Transformative Values helps with future deployments in India and elsewhere, and also to spur the next phases of curricular offerings to include principles of ethical development in the overall project. MIT Media Lab Professor Cynthia Breazeal directs varied assets of software design and technological implementation, along with David Nunez, who is creating a mentoring engine for the tablet, in which children's choices of apps lead to more (or, in some cases, less) sophisticated content based on their performances. Finally, cognitive neuroscientist Maryanne Wolf and linguist Stephanie Gottwald and members of the Tufts Center for Reading and Language Research provide the basis for content curation and new content design, based on their research on the reading brain and early language and reading development.

II. First Deployment: Ethiopia

Overview and Background

In the fall of 2011, our consortium began an extraordinary, ongoing study in two remote regions of Ethiopia. Ethiopia represents one of the ten countries with the highest rates of illiteracy. Over half of its population of 91,196,000 people are illiterate. Two thirds of the women are not literate. The government spends approximately $86 per person a year on education, making it one of the lowest rates in the world. These particular sites were selected because of the infrastructure provided by the earlier OLPC initiative. Through these existing contacts with the Ethiopian government, and the critical support of the government and local leadership, the particular villages were chosen as representative of most of Ethiopia's inaccessible populations. The government refers to children in these regions as "pastoral children" who will have almost no opportunity for any form of traditional education in their area. The first village, Wonchi, is found on the rim of a volcanic crater at 11,000 feet and is an agrarian community with relatively good access to well water, but little access to main roads. To reach the village requires transportation by foot or animal in the last segments.

The second village, Wolenchiti, is located at the edge of the Great Rift Valley, which anthropologists believe may be our species' ancestral "cradle of humanity". There is no easy access to water in this second, tiny village, where children and adults walk daily five hours to and from the nearest source of water for their village. There is little vegetation in the arid, harsh living conditions surrounding Wolenchiti, and access to the village is extremely difficult. To assure that the investigators could reach their village by overland vehicle, the elders of the village removed almost one-half mile of large volcanic rocks to allow passage from the nearest road to their settlement.

Children and the adults in these two villages live "off the radar": they have neither electricity nor running water nor sanitation nor easy access to any form of transportation or communication. To the best of our knowledge, the children have not seen books or paper or pencils; they have not seen any form of technology, although this has not been independently confirmed. Perhaps most importantly for this work, the children speak Oromo, one of several languages in Ethiopia, and have never, or very rarely, heard English, or seen written language in either Oromo (which uses a Latin script) or English.

The four major hurdles that the children face are individually and collectively massive. First, they have had no exposure to any technology and must become computer literate at a basic level for any digital learning to occur. Second, many of the concepts that would appear on any of the varied apps and activities would be unknown by the children (for example, even the verb "swim" is a foreign concept to children who have no easy access to water). Third, the children have no exposure to the English language, and there were no appropriate apps or digital activities available in the children's native Oromo language. Fourth, although Oromo possesses a writing system, the children have had no exposure to it or to any other form of symbolic representation. No adults in these villages have had formal education or read in any language. Any one of these hurdles, much less all four, could prove insurmountable. The reason, however, for such a radical choice for our first deployment was that if we are able to demonstrate that children in these most difficult of conditions can make progress towards literacy, then there is a considerable rationale to believe that the millions of children in similar, seemingly impossible conditions for learning can also learn to read, using digital devices with carefully curated and/or designed learning applications.

In addition, there were two additional, powerful forces that mitigate against the acknowledgedly difficult hurdles these children face. The first was what we refer to as "Child-Driven learning". We believe that children everywhere around the world learn best when motivated by their own curiosity and desire to understand and "figure things out" for themselves. Child-Driven Learning involves learning that occurs alongside one's peers, almost all of whom share similar interests and have a drive to discover together. We believe that this additional factor is a key aide in education in areas where children do not have access to teachers. This form of learning has been the focus of some ground-breaking work in India by Sugata Mitra, who served as a consultant to our project in its earliest conceptualization. We sought from the start to study whether children would share their knowledge (which we conceptualize as a form of "teaching") with each other in this intrinsically peer-learning setting.

The second powerful force that we encountered from the outset involves the desire of the children's parents for their children to learn English. Indeed it was more important to the parents that the children would be learning English than literacy, because they knew that their children would have more opportunities for future employment if they knew English. The parents feel that the ability to speak English in Ethiopia is a virtual pass to higher paying jobs. From the perspective of the Ethiopian government, if the children begin to learn English, this factor might enhance some of the children's chances for future educational opportunities in Ethiopian schools, where English is typically taught. Based on these reasons, in our sites to this point, we have focused on the deployment of an English language-based literacy curriculum. There were good reasons for this initial choice in our sites, but it is one that we now hope to shift to include the native Oromo language as described below.

Directly corresponding to the four seemingly insurmountable hurdles that the children embody, we set four seemingly impossible goals for our work with them. The first goal of the project was to propel the children to a level of computer literacy, without human direction or instruction, that enables digital learning to occur. Without it, the rest of our work would be meaningless. The second goal involved helping the children to understand basic concepts of child development that may not be known in their culture, for example, basic categories around time, nature, colors, number knowledge (etc.) are not necessarily known in remote villages like Wonchi or Wolenchiti. Because our apps employ many of the basic concepts in their content, it was important to ensure sufficient exposure to these categories of conceptual knowledge so that the apps could be effective in teaching more abstract pre-literacy skills.

Our third goal comprised activities to help the children begin an understanding of oral English. For example, we have begun to create the first Oromo-English vocabulary apps that are based on the principle that children learn words most easily when they represent things (animate and inanimate) in their immediate environments. Thus, we asked our Ethiopian counterparts to take pictures of the children holding their own personal objects with the words *spoken and written* in both Oromo, the children's language, and English. For example, a boy from Wonchi held up a very thin chicken, while a girl from Wolinchite pointed to a very dusty, furry donkey. In the newest app, the words for the objects will appear on the side in both English and Oromo, and are audible when the viewer touches the word on the screen, a technique they have mastered already from other existing apps on the tablet .

Ultimately, we seek to build a more *universal template* for learning to read across various languages and writing systems. Towards that end, we are attempting to construct principles for the choice and/or creation of all apps, regardless of language. For example, from a linguistic viewpoint, we want children to know the full repertoire of the phonemes in whatever language they are learning to read, as well as the meanings of the basic concepts in early child development, regardless of culture. We want to provide apps, therefore, that present the more universal perceptual, linguistic, and cognitive principles that are needed for the development of the reading circuit, whatever language is being read. Similarly, we want all apps embedded within a design that arouses children's intrinsic curiosity and allows them to learn on their own initiative. This design will be agnostic of content and curriculum and even mobile device.

Our fourth and most difficult goal was to introduce the children to the *precursors of literacy*. These included the important elements of alphabetic knowledge, such as 1) learning the alphabet and being able to "recite the alphabet" in a group or as an individual; 2) learning to identify letters by pointing to a letter that is heard; 3) learning to give the name of the letters in both serial and mixed arrays of letters; 4) knowledge of letter-sound correspondences (e.g., being able to give the sound or sounds associated with each letter of the alphabet); 5) writing letters to dictation; and 6) acquiring very basic sight word recognition (e.g., reading – though *not yet decoding* – the most common early words like *mother, father, baby*).

Our thinking throughout this early phase of our deployment is that if we can someday achieve all of the first four goals, the immediately subsequent goals will involve basic decoding of simple words and basic reading comprehension of brief passages. We would then be able to introduce several other curricular domains, such as numeracy, health and hygiene, and ethical development. For example, plans are currently underway to use student seminars at Tufts, MIT, and the Rochester Institute for Technology to create apps that will begin to extend learning into these domains.

An old maxim in reading research, often quoted, by the late renowned reading researcher Jeanne Chall, is that children must learn to read, so that they can "read to learn" (Chall, 1983). Our ultimate objective for these children is to enable them to move along a continuum of literacy pre-reading precursors to reading acquisition to that critical reading transition from learning to read to reading to learn. If we can propel them to this stage, we can also introduce them to a whole world of learning across multiple domains.

If, over time, we can help the children in the two tremendously challenging Ethiopian environments to attain first or even second grade levels of reading comprehension, this level of early reading development is sufficient to serve as a platform for true literacy in the children. Such a level involves fluent decoding and what we are calling "deep reading" (Wolf & Barzillai, 2009). The latter form of reading represents a hierarchy of skills that are necessary for more sophisticated forms of thought including: inference, analogy, inductive and deductive reasoning, and finally insight and novel thought. These skills, in turn, become the foundation for the equally abstract thought necessary to develop more heightened understanding of concepts like empathy, perspective-taking, and moral problem-solving.

By the time we reach the stage of learning in which children are reading fluently across varied domains, our very largest goal is to have developed a global open-source platform that is a repository of many different apps from around that world that can introduce children to multiple areas of learning and whole different cultures and languages. We are already receiving requests from Ethiopia for content in health and hygiene. We wish to ensure the opportunity for all types of learning to occur on our platform, particularly in numeracy, math, science, and ethical development. We envision that such a platform will also include data collection and data analytics to be able to measure and assess what children are doing with the tablets or other devices, their level of engagement, and their level of mastery of the materials and activities.

A key dimension of this platform involves harnessing the power of Child-Driven Learning as a social force that propels how children explore, discover, share and learn together. Our vision is not only to support child-driven learning within each local community of children, but also to connect these learning communities across the globe. In this way, children from different deployment sites will be able to discover, share and communicate through specially designed apps that support children's desire to create, communicate, and share with one another. For instance, something as simple as a dictionary of culturally relevant concepts (e.g., the concept of "home") could be co-created with children in different locations via a specially designed app that grows as children add contributions. Children can take pictures or videos of what constitutes a "home" in their culture, describe it with written words, recorded voices, or their personal drawings, and then share them with each other. Over time, children all over the globe could contribute what "home" means to them. This not only serves to build children's conceptual knowledge and vocabulary in a rich multi-modal format, it also helps to build empathy and understanding across different cultures, a parallel goal of our work.

III. Methods, Design, and Results of First Deployment Study

Tablet Description and Usage

In this section we present more detailed information about our efforts to date. At the most general level, we pioneered a tightly-iterative, evidence-based approach to global literacy in which we a) collected data (cross-sectionally and longitudinally) through android tablets to track how children use the tablet and apps; b) assessed their learning via the tablet; and then c) used these data to improve, adapt and revise our custom apps and tablet experience.

The devices used in this first deployment were android Motorola Xoom tablets. The tablets required a solar-charging system that was provided to each village. The villagers built a small structure for the solar-charging units. The structure served almost immediately as a gathering place for the children. Two computer engineers from the University of Addis Ababa, Michael Girma and Markos Lemma, who were part of the original OLPC infrastructure, taught adults in the village to use the solar power units so that the tablets could be recharged every night. The computer engineers were the first to give the tablets to each of the forty children (twenty in each village), but were instructed not to teach the children how to use them or problem solve for them. They developed strong relationships with the children and their families in the villages. Twice a month, the two computer engineers visited the villages, maintained the equipment, and swapped memory cards so that researchers in the consortium were able to study how the tablet contents were used from minute to minute by the children.

The MIT team developed an automated method for data collection and remote app updates via a cloud backend where wifi is accessible. Such a system is currently working with new deployments in the US, with plans to provide this capability with other communities in other countries, often where there is a school or a community place where a wifi access and a place to charge the tablets is available.

Tablet Content Principles

As described, the components of the reading brain circuit for written English comprised the template for what we called the essential "app map". This template involved what we conceptualize as the ideal set of components necessary for the formation of pre-reading, with emphases on the well-known and not-so well-known language, perceptual, and attentional processes in the young reading brain circuitry. For example, some skills included in the app map are those commonly associated with learning to read: i.e., phoneme knowledge or sound awareness, vocabulary growth, conceptual knowledge, letter-naming and letter-sound knowledge, sight word recognition, decoding and comprehension skills. Other skills, less commonly emphasized, involve auditory perception of phonemes and rhythmic patterns known to foster phoneme awareness; knowledge of the multiple meanings of words; learning syntactic functions of words (e.g., action verbs), etc. This more comprehensive ideal template for apps was used as the basis for selection of the digital learning activities included on the software in Ethiopia, each of which are in English.

It is important to note, however, that what we selected and what we sought were not the same. At the time of our first curation, there was a paucity of high-quality apps and activities for the android tablet that target the multiple components of our ideal app map. We chose, therefore, a group of apps which were approximations of the apps we hope someday to use; a large group of E-books of well-known children's stories; videos of topics that taught early conceptual development; and selected segments of educational television devised for young pre-readers through the cooperation of our public television colleagues in WBGH in Boston. Altogether there were over 325 apps, videos, and activities for the children to select from on the tablets. The basic processes that were addressed at least in part with these apps and activities included: alphabetic knowledge, letter name knowledge, letter-sound correspondence principles, early conceptual knowledge, early language learning in the English language, some basic decoding principles, and some sight word recognition.

What we found during our curation was that while there has been much work in developing educational apps, the skills and abilities that they promote represent a relatively small portion of the entire app map that we envision. Further, there were very few apps that targeted some of the most important precursors like phoneme awareness and blending. One app which we consider a prototype for future development of apps for concept development was particularly engaging to the children in both villages. Called a TinkrBook, this app represents a new kind of interactive story that supports and invites children to "tinker" with text and graphics to explore how these changes impact the narrative (See Chang and Breazeal, 2013). One key design principle is called "textual tinkerability", where an interactively reinforced association links the written word, the spoken word, and the graphical depiction of the concept.

For instance, in the version of TinkrBook used in Ethiopia, the child follows the story of the hatching of a baby duck. More importantly, through the interactive features of the app, the child *guides* the duck through its very first day of life. First, the child helps the duck hatch out of the egg by being " invited" to tap on an egg that is wiggling and obviously about to hatch. The words on the first page are "Tap, tap, tap. Pop!" Second, each time the child taps the egg with his or her finger, the egg cracks a bit more. Each successive "tap" of the child's finger highlights the word, as it is spoken. The child can touch the word "tap", and hear the word, as well as see the egg crack a bit. Thus, there is a consistent multi-modal reinforcement of the concept "tap", even in the first word of the Tinkrbook. Third, once the egg is tapped three times, the egg pops open, and the word "Pop!" is highlighted and spoken. From this point on the child helps to guide the baby duck through the rest of its memorable "first day". The child bathes the duck with colored soaps and, in the process, can experiment and learn about colors and mixing colors creates new shades of color.

With each new concept that is introduced in the TinkrBook to the child, there is an in-built assessment component for the child to demonstrate his or her knowledge on the next page of the story. Importantly, the TinkrBook records all the data for how the child explores the story and the concepts within it. For instance, we know how many times the child has touched a particular word, has heard a word spoken, or has interacted with a graphic that illustrates the word. In the case of the frog scene, we know which color words the child has explored. As a result, the TinkrBook will only present the child with a "probe" for those colors the child has in fact engaged. Over repeated exposures to the TinkrBook, we can aggregate how many times children have been exposed to specific color concepts over weeks or months. This is another important kind of longitudinal data that can also be leveraged to evaluate the children's understanding of color in other apps. For instance, we designed a simple matching app to examine children's ability to match the words within the TinkrBook and other apps to pictures of those words. We specifically designed the matching game app to test those concepts we knew the children had many encounters with through the data we collected via the tablet.

This simple example of one app's construction illustrates how we can harness the flexibility of cloud-connected devices and app features to inform the design of new apps. But the process of curation for our first deployments also illustrated the need for far more, theoretically grounded apps for the android tablets.

Testing Measures

During this year, the first author collected the first preliminary behavioral data with the children in both villages. Both U.S.-standardized and non-standardized measures were used in these areas: receptive vocabulary; knowledge of the alphabet (through letter identification on serial and mixed letter arrays; alphabet recital; letter-sound correspondence rule knowledge; and letter-writing); and basic sight word recognition and decoding.

Receptive Vocabulary. The children were assessed using experimental versions of commonly-used U.S. standardized measures adapted for the harsh environment, fully acknowledging the many limits of such cross-cultural evaluations. For example, a common measure used in reading and language development research is the Peabody Picture Vocabulary Test (Dunn & Dunn, 2007). The published version of this test would have been unsuitable for an environment in which testing the children could not take place in a quiet, one-on-one setting and had to be completed quickly. Moreover, we knew the children would only have the chance to know those vocabulary words to which they had been exposed on their tablets. Thus, we used a similar format – where the children hear a word and see four pictures and are asked which picture matches the word they heard – but only included a random sample of 20 words based on both conceptual categories and on the content available on their tablets.

Knowledge of the Alphabet. We tested the letter-naming and letter-sound knowledge of the children in several ways: 1) Letter Identification – a small selection of letters were to be pointed to when named by administrator; 2) if successful on (1), the subject was asked to point to a letter that could appear anywhere within a random array of the 26 letters in the alphabet; 3) Alphabet Recital –children were asked to recite alphabet orally; 4) Letter Naming – children were asked to name the sound that the letter represents in a limited selection of letters.; 5) Letter Writing – children were asked to write all the letters they knew on paper with pencil (note they had no experience with either).

Sight Word Recognition and Decoding. Finally, if children could perform at high levels (80% accuracy) on the vocabulary and alphabetic tasks, they were asked to read a short list of basic sight words that represented known concepts and were found in apps (e.g., *baby, mother, father, dog, cat).* If children could perform well on sight recognition words, they were asked to read a selection of easily decodable words, that were not common sight recognition words (e.g., *bat, tap*).

Summary of Behavioral Results and Engagement Data

Our first formal assessments of the four goals for the children in Ethiopia after one year are extremely promising (i.e., technological familiarity; basic conceptual growth and vocabulary development; and literacy precursor skills).

First, except for two children whose parent decided that children cannot learn without a teacher, all the children are completely "computer-literate" with the tablets. The earliest data indicated that in Wonchi, all the children were able to turn on their laptops within the first day without instruction or direction; in Wolenchiti, by the second day all were engaged. By the end of the first month every app had been activated. The children are totally "at home" with these technologies.

With regard to our second and third goals for growth in concepts and vocabulary, all of the children in Wonchi knew some of the tested English vocabulary words; over half of the children knew the meaning of over half of the words. This result is encouraging when one takes into account two facts: 1) the words on the assessment were randomly chosen from the apps on the tablet, and 2) the children had no environment to practice their knowledge of these words. Despite the fact they speak no English, most of the children learned many basic vocabulary words.

The "precursors of literacy" goal is both the most challenging and the most surprising. The children are achieving remarkable precursor literacy skills with the tablets even in this short time period. All of the children were able to recite all of the letters of the alphabet. Most of the children recognize most letters in any array – serial or mixed. Most were able to write their letters, despite not having had paper or pencil before the testing (although we have pictures of them writing letters in the dirt with sticks).

In other words, they were able to generalize motoric skills from tablet and ground (!) to paper. A smaller group knew letter-sound correspondence rules. This group can recognize almost all English letters in any array, can write letters from memory, and most importantly can read a group of sight words. These top performers, therefore, were and remain at this writing on the cusp of beginning to read. No child in either village was able to decode the words in the decoding task.

It was noteworthy that in both villages, the older girls were among the most advanced readers and were actively teaching the other children: the creation of a teacher from amidst a situation in which there had been no teacher before was an important emergence. It was akin to watching the emergence of the "first school".

This latter observation suggests at the present moment that with improvements to the platform and the applications and media that are to be delivered in the coming year, some portion of the children in the two villages will be able to make the next critical step to learn to decode and to comprehend what they are reading. To help them connect this textual knowledge to their own knowledge, we are presently creating stories and apps that are based on Ethiopian village life and also on our first analyses of the engagement data, described next.

Engagement Data

We have begun to analyze some of the massive data we have to date on multiple dimensions of the children's usage of the tablet. At the most general level, data collected over the last year indicate that children used the tablets about 6 hours a day, often sharing the multiple apps and educational media on the tablets with each other. More specifically, five findings in Wonchi during the first 12 months of the project are illustrative. First, over 325 apps (including ebooks, video stories, games, music videos, and related materials) were opened and explored. Second, based on the 20 tablets most used by children, over 85,000 app opening events occurred (Wolonchete had over 166,099!), with the most frequent being the TinkrBook app (described above) with 5882 initiations. Third, peak app use occurred during weeks 3 and 4 with over 9883 apps opened; lowest use occurred during the summer (averaging 405 apps opened during August). Fourth, children developed favorite apps, with only 20 apps accounting for 25 percent of all activities (over 20,000 app opening events), a majority of which were literacy-focused. Finally, as the year progressed, quantitatively, children opened less apps, but qualitatively spent much more time using a specific app, thus indicating more in-depth engagement with apps over time.

Overview of Preliminary Data

When taken as a whole, the behavioral data in the present deployment provide a vehicle for studying the emergence of literacy in a group of children who have never seen symbolic text. They also demonstrate a first proof of concept to show how mobile devices like the tablet can give children access to the precursors to literacy and to beginning to learn another language.

There are observational data that are less formal, but that require note. As described by both the first author and in the bi-weekly site visits by the two computer engineers, the child-driven learning dynamic that emerged in both groups of children in Ethiopia created a natural collaborative atmosphere in which kids of greater ability appeared compelled and excited to help the other children by taking a leadership role. If expanded and reinforced over time, we believe that such positive, collaborative exchanges among children will create a natural environment for the development of such interactional abilities as empathy, a sense of interconnectedness, and a stronger awareness of self and other. They may also contribute to facilitating heretofore unknown leadership capacities. Certainly the young boy who taught everyone how to use the tablets initially became the unlikely hero of the village and took on the role of teacher over the last year. Similarly the older girls were clear teachers for the younger children in both villages.

The collective pilot data and our insights into them are still ongoing in the deployments in Ethiopia. The children of Wonchi and Wolenchiti have given us a never expected petri dish for literacy and a still unfolding story. It is, we believe, a new chapter in our society's collective understanding of what literacy and child-driven learning mean in the life-course of a young human being, wherever and whatever the circumstances.

IV. Next Directions

The leitmotiv of this chapter, and indeed of all our work, is that literacy can open the mind of a person to a potential lifetime of knowledge in all its varieties, and, in the process, to creativity, personal growth, and critical thought. Such forms of thinking in a society can fuel discovery, productivity, and innovation, which, in turn, can drive economic growth, public health, and the well-being of that society. What we do not know is whether we can replicate the same early learning curve in children in different environments which may be equally difficult in some ways, but more hostile to learning itself. For example, the parents of the children in both villages could not have been more supportive. What of children in a Mumbai undercity, like those described so eloquently by Katherine Boo (2012), who have no such supportive families and whose basic goal must be to survive?

What of children who have schools, but schools which are so overpopulated and understaffed that 60 to 100 children may be taught in a single classroom by one insufficiently prepared teacher? And what of children in our own "backyard" in rural United States, where poverty and inadequate language environments render them at risk for school failure before they even enter the Kindergarten door?

To address these and related questions of generalizability, we plan or have begun new deployments in each of the above situations: in undercity populations in India; in settlement schools in South Africa; and in language-impoverished populations in rural Georgia and Alabama. Each of these deployments will bring unique challenges to our work and provide us with unique opportunities for increasing the utility of our platform for increased numbers of children.

To address the clear lacunae noted in app development, we are actively seeking funding towards the development of a more comprehensive set of new apps that will better target more components of the reading brain circuitry and that will also be more interconnected to each other. For example, we wish to be able to assess children's mastery of concepts and skills in the new and older apps and to help children move more seamlessly from one skill to the next with them. Towards those ends, we are working to combine the ideal app map with a new mentoring system that will connect the child's performance to a network of sequenced learning targets. This will allow for more dynamic learning by the child in a digital learning environment, and it will automatically connect one set of skills to multiple other related skills. In the process, the new system will highlight the relationships between lower-level knowledge like vocabulary learning with higher-level skills like comprehending written words, while still allowing the children to follow their own path to learning how to read. Thus, some children who spend less time in a particular area that represents a weakness (e.g., vocabulary), will be encouraged to select apps that provide a different form of interaction with vocabulary, one that can then lead to more progress in the more complex activity of decoding "harder" words. Other children may excel at learning vocabulary, but struggle to understand basic letter-sound relationships. They will be encouraged through the mentoring system along a different path with apps that enhance their weak areas, as they develop their strengths.

Such a system will allow us to monitor these children closely and ensure that the content remains engaging and fun for them, even though they may be having difficulty with some new skills. Ultimately, we want to be able to track children's use of every app, the amount of time engaged, and their performances, in order to build an adaptive, individualized learning system that will maximize their literacy development. .

A more global goal is to use our collective insights about apps to date to foster the development of more carefully constructed, language and literacy-relevant content on an international scale. This can be done by empowering app developers to work with experts in various domains on the creation of content directly related to language and reading development. Such a process, we believe, will enable teachers, researchers, and facilitators to contribute socially and culturally relevant material: For example, the development of photographs and picture collections that represent vocabulary in the local context, or the creation of local myths, fables, and stories that can be uploaded into interactive storybooks.

One can also imagine in some settings enlisting older literate children not only to interact with younger children on such apps as the TinkrBook, but also to write stories using particular vocabulary words that are automatically developed into apps for the younger children. This has several benefits beyond providing content that is contextualized and relevant to the local population. It creates a community of creators that keeps evolving the material over time, allowing the system to react to the growing and changing population of users. It also allows the project to cross-pollinate different populations.

As one present example in our most recent deployment, we hope to inspire children in the rural US to create material for vocabulary and stories that can be sent to Ethiopia, and vice versa in an exchange. This would not only expand and reinforce their understanding of the vocabulary by showing variations in new physical and social contexts, but, just as importantly, it fosters curiosity and understanding about another culture. We believe that these children will become far better prepared to understand and empathize with other children from all over the world, and will have a new perspective on who is "other". Thus the development of apps for literacy to us is, in fact, a potential vehicle for the conceptualization of a far broader learning experience that can embody principles of ethical and character development.

Indeed, based on our ongoing work to date, we envision three primary vehicles for how ethical development curriculum could be extended within the present platform in the near future: 1) weaving aspects of character and ethical development into future language-literacy curricula through stories that portray empathy and leadership qualities among characters, as well as that provide moral problems and dilemmas to solve; 2) leveraging the connections between different learning communities to inspire greater understanding and connectedness with people outside children's immediate environs; and 3) adapting and/or developing specific apps in ethics curricula for older ages (Note: an ongoing area of work in the Dalai Lama Center for Ethics and Transformative Values) for use with younger populations.

The ultimately envisioned platform is conceptualized as a global hub to foster a new, intellectual/technological movement in which an international community of users, developers, technologists, scientists, education practitioners, policy makers, and families work together to create a place where the digital assets, findings, and methods of best practice can be shared by all to help all children have their best chances to reach their potential. We think of this future entity as a kind of place where "Wikipedia" meets "Grameen Bank" – where interactive educational content can be deployed on mobile devices to any corner of the globe, and become an investment in all the individuals and communities reached

.

Summary

If our combination of a theoretically based, digital-learning experience and child-driven learning can be successful across such diverse cultures and settings, we estimate that 100 million children could have the potential to become literate in the next generation. The implications of such an advance in literacy and its sequelae would be extraordinary, beginning with decreasing poverty and mortality rates, and extending to increased understanding and connections across vastly different cultures. Literacy does not insure a conflict-free world; but its absence almost assures the existence of conflicts between the literate and the non-literate.

At the most basic level, literacy changes the brain of every literate person through new circuitry, which allows new forms of thinking and learning. At the level of society, literacy rates translate into greater community involvement and civic participation. Further, each new generation of readers passes these skills and their accompanying expectations on to their children and grandchildren, thus potentially ending the cycle of illiteracy and, very importantly, changing its insidious correlate – poverty. Higher rates of literacy empower young women to seek greater educational, economic, and even entrepreneurial challenges, which, in turn, make them more likely to raise healthy, literate, economically independent children. With the most basic of tools, individuals with an adequate to advanced level of literacy can become full-fledged members of society and can become involved on an equal basis in social and political discourse. As the world around us changes the way information can become available to anyone with access and the ability to read and understand it, there is a potentially revolutionary leap forward possible for the citizens of our world, wherever and whoever they are. There has never been a time in human history when literacy has been more important to a child's future, or more possible.

Until we demonstrate that children in our villages can learn to read, our acknowledgedly bold hope at the time of this chapter's writing is that the unfolding story of a literacy initiative in two tiny villages in remote Ethiopia will inspire us all. We hope to bring to the collective consciousness around the world the profound, intellectual generativity that lies at the heart of reading and the great waste when children never enter the worlds of knowledge opened for them by literacy. From the start of our work to the still distant moment when we can give this work to others, our constant goal is to elicit in children everywhere a desire to use literacy to go beyond their own knowledge. We want the next generation to learn to read and to think in ways that render the new readers capable of the highest forms of creativity and reflective thought.

In so doing, we seek to release the potential of children who might otherwise be exploited, underutilized, or completely excluded from the ever-changing societies in our own world. If we achieve even some part of our goals, we predict that whole new forms of literacy will emerge that will increase connectedness among children and individuals around the world and, in the process, usher in new dimensions of empathy and compassion for human beings they would never otherwise have encountered in their lives in Mumbai, Wonchi, Wolenchiti, Bangladesh, Uganda, urban Los Angeles, and towns in our own rural backyards, like Blakely, Georgia and Roanoke City, Alabama.

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A Digital Educational Environment in Poor Populations

Antonio M. Battro

We are facing an education emergency and we need to take urgent measures to ensure the right to education. Millions of children around the world are excluded from a proper education as a result of dramatic conditions of poverty and social inequity but, for the first time in history, we have the tools to bridge this intolerable gap. In fact, the formidable expansion of the digital environment is covering the whole world and can be used to the benefit of education. And education is the way to overcome poverty. We need to proceed as epidemiologists and cover very large populations, close or remote, to prevent ignorance and to unfold in the child the required neurocognitive skills to become an educated person in our century. In this sense digital tools are rapidly scalable and may reach millions in a short time. Recent digital deployments that cover marginal communities are showing ways to improve education even in extreme situations without schools or teachers. I will offer several successful examples of a large spectrum of digital deployments and educational interventions in poor communities, based on eight years of international experience by OLPC, The One Laptop per Child Foundation and Association.

Emergencies in education

The notion of "emergency" is not a frequent term in education, it defines instead a whole discipline in medicine. Physicians are trained for emergencies, educators are not. And this lack of conceptual tools and of practical means is not helping in the case of the enormous challenges we face in education today. The Millennium Goals of the United Nations stated that by 2015 every kid should attend elementary school. Unfortunately we are still far from this objective (Battro, 2007b). We are facing an emergency: millions of children are not educated because of the lack of schools and teachers or access to them. How can we proceed? We cannot wait for another generation to eliminate ignorance. We need a kind of "vaccine" to prevent it and a sound "epidemiological" strategy. Jonas Salk in his remarkable essay *Man unfolding* made a thoughtful analogy between immunology and education (Salk, 1972, Battro, 2009a). I quote: "It is possible to induce a temporary effect of immunity by transferring antibodies from one host to another; but long-term immunizing effects can be induced only by the active participation of the host in developing his own antibodies as a consequence of his own interaction with the antigen. This phenomenon is not dissimilar to the effect observed in the individual who acts passively in response to what he is told but who has not, through engagement, learned in a way that would result in understanding and hence in more durable effect of active experience" (p. 26).

Incidentally, following Salk's analogy between immunology and learning we have recently observed the effects of "passive learning" on the student brain during a sequence of questions proposed by the teacher in the demonstration of a theorem of geometry. To our surprise, this classic procedure, a Socratic dialog, is not always helping the student to "understand" the problem, but we could predict, using online brain images of both student and teacher, who will be the student that really understands the problem in a "durable" and constructive way (Goldin *et al*, 2011, Holper *et al*, 2013). This is a promising neurocognitive experiment that opens new ways to understanding the complexities of how teaching and learning interact in an educational setting at the brain level. The problem is to find the best pedagogy available and we have proposed a "Teaching Brain Consortium" to contribute to this objective (Battro *et al*, 2013a). Perhaps in the future we can dream of brain/computer interfaces that will facilitate the work of the educator, also in the most remote and deprived communities. In fact, the urgent search for a sound strategy to educate in the absence of schools and teachers is envisioned by the recent proposal of the Global Literacy Initiative (see Maryanne Wolf, this volume, 2013). At the moment, the digital tools are the only "vaccines" we can imagine to combat ignorance at a very large scale in deprived communities, in particular with mobile equipment of very low cost using alternative sources of energy.

The "One to One Model"

Nicholas Negroponte presented the idea of a low-cost laptop for the education of poor and deprived communities in November 2005 at the joint meeting of the Pontifical Academy of Sciences and the Pontifical Academy of Social Sciences on "Globalization and Education" (Negroponte, 2007). This idea became the core of *OLPC, the One Laptop Per Child Foundation and Association,* now active in 47 countries with a deployment of some 2,400,000 laptops. (www.one.laptop.org) See Figure.

A successful program must take care of all the components involved: in the first place a sound digital pedagogy in school and at home, teacher and family training, software, deployments, repairs, connectivity, maintenance, Internet, etc. OLPC follows five principles: the program starts at early ages

(today, with the new tablets, in pre-school), the laptops are owned by the user, all laptops are connected to the web, the software is free and open source, and the community is "saturated", every student and teacher has a laptop. From the point of investment the most difficult task is to support a sustainable plan that will permit the healthy growth of the entire system during the school years, in particular in the poor regions of the world. The unit of intervention is a whole "cohort" of students (some 6 years in primary schools). Not only do we need to provide good equipment and software, a sound connectivity network (Internet, wifi access, servers), give rapid solutions to repair or replace equipment, etc, but we also have to pay special attention to develop the required educational skills in teachers and students, by permanent courses, workshops, competitions, etc.

We already have some significant results of the effect of the one-to-one modality in education. A most important contribution of the digital environment is to add a new "longitudinal" dimension to the standard "transversal" evaluations provided by currents exams and tests. In fact, every student can be monitored day by day on his or her performance on the laptop and teachers may keep a continuous record of each student during all the school years, a record which is a veritable treasure of information to build a sound pedagogy and continuous intervention. Moreover the digital environment may also help in transversal testing. In one day, all (connected) students may be tested on a given discipline, there can be many thousands at the same time and the results are automatically analyzed, statistics are deployed and will immediately reach each institution for comparison. This is a formidable asset for the entire community and of very low cost in relation to common evaluations.

Quantitative and qualitative evaluations are regularly done and are published online. We can see a summary of these results in many OLPC current deployments in the world (http://laptop.org/map).

These results are very dependent on the scale of the deployment. Normally OLPC deployments start with small rural communities (Nicaragua) and towns (Paraguay) and increase by steps covering whole provinces (La Rioja, Argentina) and even whole countries (Uruguay). We observe in general that in the digital school OLPC environment drop-out rate decreases, families become more integrated with the school, children improve in mathematics and literacy, teachers create new pedagogical resources and students show amazing capacities for innovation in the arts and sciences (music, design, programming, robotics). And most importantly the community is increasingly involved and supportive. Thousands of hours of voluntary work make it possible to reach remote and poor populations.

A first question is always about the cost of this intervention, in particular in some developing countries where the budget of education is very small. It is clear that the required investment varies from country to country. Many think that computers are designed for wealthy communities; the poor instead need all kind of essential goods "before" reaching a sophisticated technology, bread before connectivity. The answer is that of course no education is possible without healthy nutrition, and many other conditions, but poverty can only be eliminated by education; and education today is to become "connected to the web". In fact, a digital environment can provide formidable resources at very low cost for education of the poorest communities.

In Latin America, Uruguay gives a solid example with an investment of 100 USD per child per year, that provides a connected laptop to all children and teachers of public schools (more than 500,000) with all related pedagogical services included (www.plan.ceibal.edu.uy). This amounts to only 5% of the annual governmental budget for primary and secondary schools. It is interesting to note also that some governments are taking their educational programs on digital innovation as a symbol for the modernization of their country. Rwanda, for instance, has deployed more than 200,000 laptops among teachers and students and has recently printed a new 500 franc bill with a picture of children using their laptops at school to celebrate this initiative (http://wiki.laptop.org/go/Rwanda). But private institutions are also greatly helping their communities, in particular the most deprived and poor. A good example is the Zamora Terán Foundation in Nicaragua (www.portaleducativofzt.org) that has provided over 40,000 laptops to poor communities and has developed an extended program on Health and Nutrition supported by the digital platform. Another successful "one to one model" is offered by the Paraguay Educa Foundation (www.paraguayeduca.org) that gave some 10,000 laptops to all children and teachers in public and private schools of the city of Caacupé, with a strong emphasis on teacher training and community innovation.

The process of digital deployment, however, is not simple because the new technologies frequently challenge the established pedagogy and may find great resistance. In our experience at OLPC, we have sometimes observed that a first burst of enthusiasm towards the "modernization" of education introduced by computers into the old structures of schools may evolve towards disappointment and even skepticism. Machines get broken, electricity and connectivity fail, teachers are not receiving sufficient support to become empowered in the new digital environment, students are not acquiring the necessary cognitive skills to thrive in the formidable world of opportunities offered by the digital systems. Accordingly, each OLPC team must deal with local political issues and with basic technical problems but the essential issue is always about pedagogy. We can affirm that "pedagogy defines the culture of a community" and we should now construct the new pedagogies of the digital era.

At the same time, the variety of cultures we contact at OLPC is a source of inspiration for all of us and opens a horizon of hope for education. We are experimenting the unfolding of a very rich array of new pedagogies. Moreover, many local initiatives in different languages and cultures are starting now to collaborate at the international level with the exchange of ideas and technologies, scholarships and common projects, working groups and seminars.

The details of the ongoing activities, evaluations, etc, may be checked on line and can be of great help. In particular, the impact of the digital environment to overcome poverty is great. A poor family with several children may now have several laptops at home, and this means a significant "expansion" of the school, without limits of time or space. Connectivity is also expanding in many poor regions, and of course schools are among the first institutions that take advantage of this accessible digital environment. Thousands of resources in the arts and sciences, books in many languages, and the possibility of social networking are new dimensions that were completely inaccessible only a decade ago (Battro, 2002, 2004, 2007a, 2007c, 2009a, 2009b, 2013b, López Rosenfeld *et al*, 2013). Education is always about values, the values of truth, good, and beauty. We have the great responsibility of helping the new generations to construct and share these values that are the treasure of humanity in every community around the world.

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La desnutrición infantil genera la única debilidad mental que se puede prevenir y revertir, la única creada por el hombre

Abel Albino

1. El problema

El cerebro es el órgano que más rápidamente crece. Cuando el niño nace, el cerebro pesa del 1 al 2% de su peso corporal, alrededor de 35 a 70 gr (6 monedas de un peso para arriba). A los 14 meses, cuando camina, 900 gr (150 monedas de un peso), el 80% del peso definitivo, ya que en el adulto llega a 1.200 gr (200 monedas de un peso), por lo tanto el crecimiento gigantesco lo hace en el primer año de vida: 1 cm por mes. En efecto el niño nace con 35 cm, de perímetro craneano – que es la medida del canal del parto que todos hemos atravesado al nacer – y a los 12 meses tiene 47 cm. O sea que en el 1º año, creció 12 cm. ¿Cuántos centímetros crece en el segundo año? Solamente dos centímetros: 1 cm en el 1º semestre en el que se cierra la fontanela anterior y el cráneo pasa a ser "una unidad sellada", y 1 cm en el 2º semestre. Lo hecho, hecho está! Las posibilidades de maniobra se van agotando; si queremos accionar sobre ese cerebro debemos hacerlo

Neurona de un niño normal, de dos años de edad que murió en un accidente de auto. Es un árbol florido fundamentalmente en el 1º año de vida que es la etapa de la primavera del sistema nervioso central; después de la primavera, vendrá el verano, el otoño y el invierno; pero nunca más tendrá primavera. Es por eso que el Prof. Mönckeberg, destaca que el primer año de vida marca la suerte de ese individuo, de ese pueblo, de esa nación.

Neurona de un niño desnutrido. Es un terreno quemado

¿Por qué es tan importante el primer año de vida? Cada neurona – de los 100 mil a 140 mil millones que tenemos en los 3 milímetros de espesor de la corteza cerebral – 3 rayitas de un centímetro – emite entre 5.000 y 15.000 cables. ¿De qué depende que emita 15.000 cables, en vez de 2.000, 3.000 ó 5.000? De la buena alimentación 50%, y de la buena estimulación 50%. Si se lo alimenta adecuadamente y estimula adecuadamente, tendrá un cerebro cableado, estos cables luego se interconectan entre sí, dándole al individuo la memoria, la capacidad de relación, asociación, experiencia, etc. Ese cerebro cableado, maduro, intacto, con muchas interconexiones interneuronales podrá ser educado. La educación es una semilla maravillosa, pero toda semilla para fructificar necesita un sustrato, y el sustrato anatonomofisiológico anatomofuncional donde se siembra la educación, es un justamente un cerebro intacto. Si no tenemos cerebros intactos, no hay qué educar.

La desnutrición es el resultado final del subdesarrollo, genera pobre cableado neurológico y su consecuencia es la debilidad metal, la única que se puede prevenir, la única que se puede revertir, la única que es creada por el hombre. Ese niño estará condenado de por vida, no tendrá posibilidades de aprender y por ende, estará condicionado al desempleo y subempleo, repi-

Mujer lavando. El Agarrobal, Mendoza, Argentina

tiendo el ciclo de miseria, pobreza desocupación y subdesarrollo del cual fue víctima. El daño es individual y social!

Ahora bien, este vertiginoso crecimiento, insisto, no sólo depende de una buena alimentación, sino también de una buena estimulación afectiva. El papel fundamental lo cumple la familia, la única escuela de humanidad que existe. En efecto ¿dónde aprende un varón a ser varón sino es mirando a su padre? ¿Dónde aprende una mujer a ser mujer, sino es mirando a su madre? ¿Dónde, a respetar a un anciano sino se tuvo un abuelo, a un bebito o a un enfermo sino se vivió en familia? Es allí donde somos queridos y respetados, no por lo que tenemos sino por lo que somos.

El niño que se cría en un ambiente chato y gris, con ausencia de colores, de música, de alegría, con figuras maternas o paternas desdibujadas, cuando no ausentes; ese niño sufre deprivación afectiva. Esta deprivación impacta en el desarrollo cerebral del niño, reflejándose entre otros parámetros, en una disminución de su capacidad intelectual, que más tarde lo va a afectar negativamente en el proceso de aprendizaje (repitencia, deserción, etc.). Pobreza y desnutrición temprana frecuentemente coexisten, por lo que ambos factores potencian su acción negativa sobre el desarrollo cerebral. Ello es una observación constante en países subdesarrollados, donde gran parte de la población infantil sufre el retraso del crecimiento y también del desarrollo cerebral.

El desnutrido es más difícil de querer y expresarle afecto, un desnutrido causa distancia instintiva es flaco, feúcho, maloliente, pasivo, poco deman-

Tablas comparativas en dos niñas de 5 meses de edad, una de ellas desnutrida

Transiluminación del cráneo. a. - Una fuente potente de luz (flash) se aplica a la superficie externa del cráneo, y simultáneamente se toma una fotografía. b. - En un niño normal la luz penetra el cráneo y transilumina el líquido cefalorraquídeo que normalmente existe entre el cráneo y el cerebro, produciendo un pequeño halo de luz a su alrededor. c- en un niño desnutrido, el cerebro se ha atrofiado, creando un espacio entre él y el cráneo, que secundariamente se llena con líquido cefalorraquídeo. Como consecuencia de ello, la transiluminación es intensa. Con ello se pone en evidencia la atrofia del cerebro en el desnutrido.

dante, y por ende no dan ganas de abrazarlo, ni besarlo, ni mimarlo, causa cierto rechazo. Todo esto hace que experimente soledad y abandono y a que se desencadene una progresiva depresión que lo debilitará a la hora de reclamar el afecto que necesita y merece. Generalmente sus madres son menores de edad, solteras y el afecto y estimulación que brindan a sus hijos es muy escaso. Sin lugar a dudas que todo ello, junto con la desnutrición, constituye un grave stress crónico, que podría explicar las alteraciones observadas en los mecanismos de defensa inmunológicos. Este hecho se ha podido comprobar durante la recuperación. Si además del tratamiento nutricional se agrega un intenso programa de estimulación psíquica y afectiva, mejoran los mecanismos y disminuyen las enfermedades infecciosas.

2. La solución

La solución sólo la encontramos focalizando en los orígenes del problema: realizando un abordaje integral e interdisciplinario de la problemática social que da origen a la extrema pobreza, involucrando a la madre como primer agente sanitario y figura principal en la vinculación con su hijo.

Para revertir este mal, debemos trabajar en prevención y recuperación de la desnutrición infantil, centrando el accionar en tres pilares: Docencia, Asistencia e Investigación, como venimos haciendo desde hace más de 20 años en la Fundación CONIN con resultados asombrosos: 0% de mortalidad infantil. Estos centros cuentan con servicios y programas destinados al niño y su familia, gracias a un equipo interdisciplinario (pediatra, nutricionista, estimuladora temprana, psicopedagoga, fonoaudióloga, asistente social, maestras de nivel inicial, talleristas, etc.) que aborda al niño desde sus múltiples necesidades y entrena a la madre para que sea ella la artífice de la recuperación de su hijo.

Centros de Recuperación Fundación CONIN – Mendoza, Argentina

Centros multidisciplinarios de Prevención de la Desnutrición Fundación CONIN - Mendoza, Argentina

La desnutrición es el resultado final del subdesarrollo, de nada sirve que alimentemos a un chico, si lo devolvemos al ambiente hostil del que proviene; a los 15 días lo estamos alimentando nuevamente. Si queremos quebrar la desnutrición, debemos hacer un abordaje integral de la problemática social que da origen a la extrema pobreza. Buscamos dar respuestas concretas a cada problema concreto: docencia y asistencia al niño, su mamá y entorno familiar e investigación para validar el trabajo que realizamos

Para certificar el daño neurológico que produce la desnutrición y extrema pobreza trabajamos en fonoaudiología y otología con la Fundación Latinoamericana de Enfermedades Neurológicas Infantiles (FLENI): se detectó que el 85% de los niños desnutridos graves no tienen procesamiento auditivo, esto quiere decir que si bien escuchan, no comprenden el mensaje, pues el círculo vicioso de miseria, pobreza e incultura en el que se encuentran sumergidos ha determinado ya un daño cerebral. Nuestra temprana intervención es importantísima, ya que se revierte este problema, logrando que el niño pueda tener éxito en la educación formal, disminuyendo la deserción y la repitencia escolar significativamente

Los comedores infantiles, y el reparto de cajas de alimentos, constituyen una obra muy loable en cuanto obra asistencial y si bien contribuyen a la subsistencia física de los niños y a la riqueza ética de quienes solidariamente realizan esta tarea, sería inadmisible que tales repartos constituyan la meta suprema de una política social de salud impulsada por el Estado, es más, de ser así, quedaría en evidencia la ignorancia e incapacidad de los funcionarios de turno para prevenir o curar la desnutrición infantil.

No cabe duda que los comedores infantiles son útiles en determinadas emergencias – terremotos, guerras, inundaciones, etc. – pero una vez superado el conflicto agudo, el niño debe retornar a su casa para comer en fa-

Mujer cocinando. El Agarrobal, Mendoza, Argentina

milia. La responsabilidad de la educación de los hijos, es de los padres, y se educa con el ejemplo. Si bien las palabras conmueven, es el ejemplo el que, arrastra y se concreta en la convivencia. La responsabilidad de alimentar a los hijos, también es de los padres, puesto que nadie en el mundo está capacitado antropológicamente para hacerlo mejor que ellos (especialmente en la etapa de la nutrición posparto).

Es legítimo que el Estado colabore en esta tarea, pero el mayor deber estatal debe contribuir a que los progenitores estén capacitados para asumir ellos mismos la responsabilidad que les compete, lo cual es substancialmente distinto a facilitar a quienes trajeron hijos al mundo, deleguen dicha responsabilidad en organismos estatales o sociales; por lo tanto, el objetivo ha de ser que el padre logre con su trabajo el pan, que la madre (aun la que trabaja fuera del hogar), pueda hacerse cargo de la cocina, y que toda la familia pueda sentarse cotidianamente en torno a la mesa, para compartir la comida y dialogando sobre los intereses de cada uno de los integrantes.

El vínculo con la madre es fundamental en el desarrollo saludable del niño, tanto físico como intelectual y emocional. En los Estados Unidos, se analizó a un grupo de hombres que se habían alistado como voluntarios para ir a la guerra de Vietnam. Eran hombres psicológicamente equilibrados, tenían motivos para ir: amor a su patria, conciencia cabal del protagonismo de ese gran país en el concierto de las naciones, etc. Pero también tenían motivos para volver: sus padres, su novia, su esposa, sus hijos, su estudio, su empresa, etc. Muchos de ellos no volvieron, ni podrán volver nunca más: los mataron. ¿Cuál fue el rasgo distintivo de todos estos hombres, muchos de los cuales murieron sin disparar ni un solo tiro? ¿Cuál era el elemento común de todos éstos voluntarios que habían sido incapaces de matar? El Pentágono dio la respuesta: todos ellos habían tomado el pecho. Cuantos males de la sociedad violenta que hoy tenemos se evitarían si hubiese más madres y más padres, más familia, la única escuela de humanidad que existe. Más lactancia materna! "A de saber el hombre, que cuando una mujer da de mamar, tanto ella como su hijo están siendo más humanos".

Si queremos grandes naciones, tenemos que concretar 5 acciones que deberían ser políticas de estado que se mantengan en el tiempo, aunque cambien los gobiernos:

1. Estimular y alimentar al cerebro del niño adecuadamente en el primer año de vida y mejor aún, en el embarazo y primer año. En efecto la mujer embarazada debe ser objeto de todo cuidado y protección. Cada embarazada nos aporta un ciudadano más. Entre todos debemos lograr que ese niño pueda desplegar su potencial genético, para tener igualdad de oportunidades. Debemos procurar que cada niño tenga una escuela donde ir, un agente sanitario que lo asista y una dieta equilibrada que le posibilite un desarrollo físico y mental adecuado. Esto ya no depende de las posibilidades físicas o financieras. Esta es una cuestión de prioridad política!
2. Educar ese cerebro. La educación es una semilla maravillosa, pero como toda semilla, necesita un sustrato donde sembrarse, y el sustrato ideal para sembrar educación es un cerebro intacto, estimulado y alimentado adecuadamente. Hay que hacer de la patria una gran escuela, advertía Sarmiento hace 150 años y esa pasión, esa filosofía, llevó a la Argentina a ser el 1º país del mundo en quebrar el analfabetismo. "Hay que educar al soberano", decía Sarmiento hace 150 años y esa pasión, esa filosofía, llevó a la Argentina a ser el 1º país del mundo en quebrar el analfabetismo. "Hay que educar al soberano", decía Sarmiento. Tenía razón. Solamente un pueblo es soberano cuando es educado.

3. Cloacas. En esta oportunidad, debemos rescatar la opinión de quien fuera el Primer Ministro de Salud de la República Argentina, el prestigioso médico de Santiago del Estero, Dr. Ramón Carrillo quien decía "los hongos, los virus y las bacterias como causas de enfermedad son pobres causas, comparadas con el daño tremendo que causa la falta de saneamiento ambiental".

Letrina de rancho mendocino, Argentina

4. Agua corriente y ¡caliente! Nuevamente el ex Presidente Sarmiento nos advertía que el agua es como "la sangre de un cuerpo". Si el Estado impulsara como política social, no solo la provisión de agua potable sino también de agua caliente, modernizaríamos la consigna bajo la cual tuvo notable éxito el Imperio Romano: carreteras, agua y derecho. El agua caliente está estrechamente relacionada con la higiene: es fácil ser limpio cuando uno tiene todas las comodidades, distinto es cuando se carece de estos elementos que también constituyen derechos humanos.
5. Luz eléctrica. "La luz es como la vista, no hay derecho que una persona quede ciega después de las 6 de la tarde", decía Sarmiento. Cuando uno permanece dentro de un rancho nota que no tienen ventanas, pues de esa manera se protegen del frío y al no haber ventanas, tampoco hay luz al atardecer. Tampoco mesas donde los chicos pueden hacer sus deberes.

En fin, es muy triste la vida en la pobreza, los pobre no son vagos, son tristes. Tienen una tristeza profunda que linda con la depresión. Debemos ayudarlos a ponerse de pie, a sentirse importantes y queridos, de modo que renazcan en ellos, la alegría, la autoestima, la fe y la esperanza.

Debemos terminar con la eterna guerra del hombre contra el hombre e iniciar todos juntos, como hermanos que somos, la única guerra que vale la pena, la única en la que todos ganamos: la guerra del hombre contra el hambre.

Deseo expresar el gozo que para cada uno de nosotros constituyen los niños. Primavera de la vida, anticipo de la historia futura de cada una de las patrias terrenas actuales. Ningún país del mundo, ningún sistema político puede pensar en el propio futuro, sino a través de la imagen de estas nuevas generaciones, que tomaran de los padres el múltiple patrimonio de los valores, de los deberes y de las aspiraciones de la nación a la que pertenecen, junto con el de toda la familia humana. La solicitud por el niño, incluso antes de su nacimiento, desde el primer momento de su concepción y, a continuación, en los años de su infancia y de su juventud, es la verificación primaria y fundamental de la relación del hombre con el hombre. ¿Y por eso, que más se podría desear a cada nación y a toda la humanidad, a todos los niños del mundo, sino un futuro mejor en el que el respeto de los Derechos del Hombre llegue a ser una realidad plena en las dimensiones del 2000 que se acerca?

Juan Pablo II, *Asamblea Anual Naciones Unidas*, 1979.

Interventions to Achieve Nutrition Security

Biofortification: Progress Toward a More Nourishing Future[1]

Amy Saltzman, Ekin Birol, Howarth E. Bouis, Erick Boy, Fabiana F. De Moura, Yassir Islam, and Wolfgang H. Pfeiffer[2]

Abstract

Biofortification, the process of breeding nutrients into food crops, provides a sustainable, long-term strategy for delivering micronutrients to rural populations in developing countries. Crops are being bred for higher levels of micronutrients using both conventional and transgenic breeding methods; several conventional varieties have been released, while additional conventional and transgenic varieties are in the breeding pipeline. The results of efficacy and effectiveness studies, as well as recent successes in delivery, provide evidence that biofortification is a promising strategy for combatting hidden hunger. This review highlights progress to date and identifies challenges faced in delivering biofortified crops.

1. Justification

In the past 40 years, agricultural research for developing countries has focused on increased cereal production. Recently, there has been a shift: agriculture must now not only produce more calories to reduce hunger, but also more nutrient-rich food to reduce hidden hunger.[3] One in three people in the world suffer from hidden hunger, caused by a lack of minerals and vitamins in their diets, which leads to negative health consequences (Kennedy *et al.* 2003).

[1] This article originally appeared as: Saltzman, A., E. Birol, H.E. Bouis, E. Boy, F.F. De Moura. Y. Islam, and W. Pfeiffer. 2013. "Biofortification: Progress toward a more nourishing future". *Global Food Security* 2(1): 9-17. Tables and information have been updated as of October 2013.

[2] Howarth E. Bouis, Ekin Birol, Erick Boy, Fabiana F. De Moura, Yassir Islam, and Amy Saltzman are affiliated with the International Food Policy Research Institute, Washington, DC; Wolfgang H. Pfeiffer is affiliated with the International Center for Tropical Agriculture, Cali, Colombia. Please direct queries to the corresponding author: Howarth E. Bouis, HarvestPlus c/o IFPRI, 2033 K St NW, Washington, DC 2006, USA; email: h.bouis@cgiar.org.

[3] An important part of the overall solution is to improve the productivity of a long list of non-staple food crops. Because of the large number of foods involved, achieving this goal requires a very large investment, the dimensions of which are not addressed here.

Biofortification, the process of breeding nutrients into food crops, provides a comparatively cost-effective, sustainable, and long-term means of delivering more micronutrients. Biofortified staple foods cannot deliver as high a level of minerals and vitamins per day as supplements or industrially fortified foods, but they can help by increasing the daily adequacy of micronutrient intakes among individuals throughout the lifecycle (Bouis *et al.* 2011). Note that biofortification is not expected to treat micronutrient deficiencies or eliminate them in all population groups. No single intervention will solve the problem of micronutrient malnutrition, but biofortification complements existing interventions to sustainably provide micronutrients to the most vulnerable people in a comparatively inexpensive and cost-effective way (Bouis 1999; Nestel *et al.* 2006; Pfeiffer and McClafferty 2007; Qaim *et al.* 2007; Meenakshi *et al.* 2010).

Biofortification provides a feasible means of reaching malnourished rural populations who may have limited access to diverse diets, supplements, and commercially fortified foods. The biofortification strategy seeks to put the micronutrient-dense trait in those varieties that already have preferred agronomic and consumption traits, such as high yield. Marketed surpluses of these crops may make their way into retail outlets, reaching consumers in first rural and then urban areas, in contrast to complementary interventions, such as fortification and supplementation, that begin in urban centers.

Unlike the continual financial outlays required for supplementation and commercial fortification programs, a one-time investment in plant breeding can yield micronutrient-rich planting materials for farmers to grow for years to come. Varieties bred for one country can be evaluated for performance in, and adapted to, other geographies, multiplying the benefits of the initial investment. While recurrent expenditures are required for monitoring and maintaining these traits in crops, these are low compared to the cost of the initial development of the nutritionally improved crops and the establishment, institutionally speaking, of nutrient content as a legitimate breeding objective for the crop development pipelines of national and international research centers.

Currently, agronomic, conventional, and transgenic biofortification are three common approaches. Agronomic biofortification can provide temporary micronutrient increases through fertilizers. Foliar application of zinc fertilizer, for example, can increase grain zinc concentration by up to 20 parts per million (ppm) in wheat grain in India and Pakistan, but only in the season it is applied (Zou *et al.* 2012). This is nearly the full target increment set by nutritionists and sought in plant breeding (further described below). About half the target increment can be realized in rice; in maize, foliar application resulted in only a small effect (Phattarakul *et al*. 2012; Kalayci *et al*. 2011). This approach could complement plant breeding efforts but further research is needed.

Biofortification can be achieved through conventional plant breeding, where parent lines with high vitamin or mineral levels are crossed over several generations to produce plants that have the desired nutrient and agronomic traits. Transgenic approaches are advantageous when the nutrient does not naturally exist in a crop (for example, provitamin A in rice), or when sufficient amounts of bioavailable micronutrients cannot be effectively bred into the crop. However, once a transgenic line is obtained, several years of conventional breeding are needed to assure that the transgenes are stably inherited and to incorporate the transgenic line into varieties that farmers prefer. While transgenic breeding can sometimes offer micronutrient gains beyond those available to conventional breeders, many countries lack legal frameworks to allow release and commercialization of these varieties.

Implementing Biofortification

For biofortification to be successful, three broad questions must be addressed:

– Can breeding increase the micronutrient density in food staples to target levels that will make a measurable and significant impact on nutritional status?

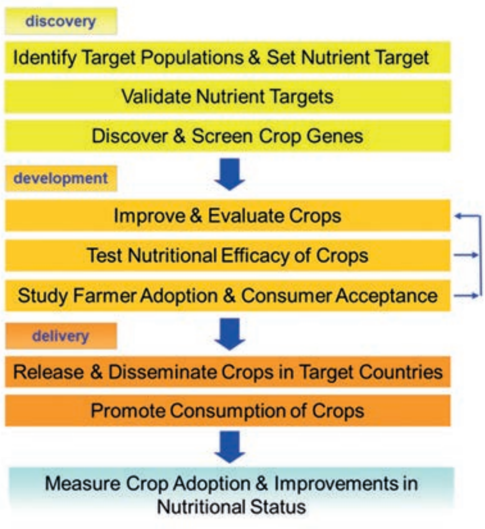

Figure 1. HarvestPlus Impact Pathway.

– When consumed under controlled conditions, will the extra nutrients bred into the food staples be absorbed and utilized at sufficient levels to improve micronutrient status?
– Will farmers grow the biofortified varieties and will consumers buy/eat them in sufficient quantities?

To answer these questions, researchers must carry out a series of activities classified in three phases of discovery, development, and dissemination. This impact pathway is illustrated in Figure 1 and discussed in greater detail in Bouis *et al.* (2011).

Discovery

The overlap of cropping patterns, consumption trends, and prevalence of micronutrient malnutrition, as well as *ex ante* cost-benefit analyses, determine target populations and focus crops. Nutritionists then work with breeders to establish nutritional breeding targets. These target levels take into account the average food intake and habitual food consumption patterns of target population groups, nutrient losses during storage and processing, and nutrient bioavailability (Hotz and McClafferty 2007).

Under HarvestPlus, breeding targets are set such that, for preschool children 4-6 years old and for non-pregnant, non-lactating women of reproductive age, the incremental amount of iron will provide approximately 30 percent of the Estimated Average Requirement (EAR), that incremental zinc will provide 40 percent of the EAR, and that incremental provitamin A will provide 50 percent of the EAR. Bioavailability of iron was originally assumed to be 5 percent for wheat, pearl millet, beans, and maize (10 percent for rice, cassava, and sweet potato), that of zinc 25 percent for all staple crops, and for provitamin A 8.5 percent for all staple crops (12 molecules of beta-carotene produce 1 molecule of retinol, the form of vitamin A used by the body).

Plant breeders screen existing crop varieties and accessions in global germplasm banks to determine whether sufficient genetic variation exists to breed for a particular trait. Initial research indicated that selection of lines with diverse vitamin and mineral profiles could be exploited for genetic improvement (Dwivedi *et al.* 2012; Gregorio 2002; Ashok Kumar *et al.* 2012; Velu *et al* 2012; Gomez-Becerra *et al.* 2010; Maziya-Dixon *et al.* 2000; Talukder *et al.* 2010; Jiang *et al.* 2008; Fageria *et al.* 2012; Menkir 2008; Beebe *et al.* 2000; Monasterio and Graham 2000; Menkir *et al.* 2008). Genetic transformation is an alternative method to incorporate specific genes that express nutritional density.

Development

Crop improvement includes all breeding activities. Initial product development is undertaken at international research institutes to develop varieties with improved nutrient content and high agronomic performance, as well as preferred consumer qualities. When promising high-yielding, high-nutrient lines emerge, they are tested by national research partners and the best-performing lines then selected to submit to national governments for release. The formal release process varies by country, but in general requires that a variety be grown and evaluated in several different locations (called multilocational trials) for at least two seasons, and its performance compared to other candidate and widely released varieties, before the national government approves the variety for dissemination. The breeding, testing, and release process can take 6 to 10 years to complete.

Parallel to crop improvement, nutrition research measures retention and bioavailability of micronutrients in the target crop under typical processing, storage, and cooking practices. Initially, relative absorption is determined using in vitro and animal models and, with the most promising varieties, by direct study in humans in controlled experiments. Randomized, controlled efficacy trials demonstrating the impact of biofortified crops on micronutrient status and functional indicators of micronutrient status (i.e. visual adaptation to darkness for provitamin A crops, physical activity for iron crops, etc.) provides evidence to support biofortified crops as alternative public health nutrition interventions.

Economics research on consumer and farmer evaluation of biofortified varieties, as well as varietal adoption studies, further informs crop improvement research during the development phase.

Dissemination

Biofortified crops must be formally released in the target countries prior to their delivery to the target populations. Economists lead consumer acceptance, varietal adoption, and seed and grain value chain studies to inform effective, efficient, and targeted delivery and marketing strategies to maximize adoption and consumption of these crops.

2. Current Status of Biofortified Crops

HarvestPlus leads a global interdisciplinary alliance of research institutions and implementing agencies in the biofortification effort. The Bill and Melinda Gates Foundation-funded Grand Challenges 9 is developing several transgenic crops. Progress made with key crops is reviewed, summarized in Figure 2.

CROP	NUTRIENT	TARGET COUNTRY	LEAD INSTITUTIONS	FIRST RELEASE YEAR
Banana/Plantain	Provitamin A Carotenoids	Nigeria, Ivory Coast, Cameroon, Burundi, DR Congo	IITA, Bioversity	Unknown
	Provitamin A Carotenoids, Iron*	Uganda	Queensland University of Technology, NARO	2019
Bean	Iron (Zinc)	Rwanda, DR Congo	CIAT, RAB, INERA	2012
		Brazil	Embrapa	2008
Cassava	Provitamin A Carotenoids	DR Congo	IITA, CIAT, INERA	2008
		Nigeria	IITA, CIAT, NRCRI	2011
		Brazil	Embrapa	2009
	Provitamin A Carotenoids, Iron*	Nigeria, Kenya	Donald Danforth Plant Science Center	2017
Cowpea	Iron, Zinc	India	G.B. Pant University	2008
		Brazil	Embrapa	2013
		China	Institute of Crop Science, YAAS	2015
		India	DBT	Unknown
Pearl millet	Iron (Zinc)	India	ICRISAT	2012**
Pumpkin	Provitamin A Carotenoids	Brazil	Embrapa	2015
Rice	Zinc (Iron)	Bangladesh, India	IRRI, BRRI	2013
		Brazil	Embrapa	2014
	Provitamin A Carotenoids*	Philippines, Bangladesh, Indonesia, India	Golden Rice Network, IRRI	2014
	Iron*	Bangladesh, India	University of Melbourne, IRRI	2022
	Iron	China	Institute of Crop Science, CAAS	2010
Sorghum	Zinc, Iron	India	ICRISAT	2015
	Provitamin A Carotenoids*	Kenya, Burkina Faso, Nigeria	Africa Harvest, Pioneer Hi-Bred	2018
Sweet potato	Provitamin A Carotenoids	Uganda	CIP, NaCCRI	2007
		Mozambique	CIP	2002
		Brazil	Embrapa	2009
		China	Institute of Sweet Potato, CAAS	2010
Wheat	Zinc (Iron)	India, Pakistan	CIMMYT	2013**
	Zinc (Iron)	China	Institute of Crop Science, CAAS	2011
	Zinc (Iron)	Brazil	Embrapa	2016

For projected releases, "first release year" refers to the first country listed.

* Denotes transgenic variety

** Denotes commercialization year; official release in subsequent year

( ) Denotes secondary nutrient

BRRI: Bangladesh Rice Research Institute; CAAS: Chinese Academy of Agricultural Sciences; CIAT: International Center for Tropical Agriculture; CIMMYT: International Maize and Wheat Improvement Center; CIP: International Potato Center; DBT: Department of Biotechnology; IAR&T: Institute of Agricultural Research and Training; ICARDA: International Center for Agricultural Research in the Dry Areas; ICRISAT: International Crops Research Institute for the Semi-Arid Tropics; IITA: International Institute of Tropical Agriculture; INERA: Institut National pour l'Etude et la Recherche Agronomiques; IRRI: International Rice Research Institute; NaCRRI: National Agricultural Crops Resources Research Institute; NARO: National Agricultural Research Organisation; NRCRI: National Root Crops Research Institute; RAB: Rwanda Agriculture Board; YAAS: Yunnan Academy of Agricultural Sciences; ZARI: Zambia Agriculture Research Institute.

Figure 2. Biofortified Target Crops and Countries-Release Schedule.

2.1 Conventional Breeding

Orange Sweet Potato (OSP)

After screening identified varieties that twice exceeded the target level of 30 ppm of provitamin A, varieties were improved by the International Potato Center (CIP) and National Agriculture Research and Extension System (NARES) scientists to suit local tastes and agronomic conditions.

Nutrition research indicated that provitamin A retention was greater than 80 percent after boiling or steaming and at least 75 percent after solar or sun drying, typical types of preparation (van Jaarsveld *et al.* 2006; Hagenimana *et al.* 1999; Wu *et al.* 2008; Bechoff *et al.* 2010; Bengtsson *et al.* 2008; Kimura *et al.* 2006). Provitamin A from OSP is highly bioavailable and its consumption can result in a significant increase in vitamin A body stores across age groups (Haskell et. al 2004; Jalal *et al.* 1998; Low *et al.* 2008; van Jaarsveld *et al.* 2005).

Mozambique and Uganda released high-provitamin A varieties in 2002 and 2007, respectively. Biofortified varieties are now being introduced in many parts of Africa and South America, as well as China. In 2009, CIP launched its Sweetpotato for Profit and Health Initiative (SPHI), which seeks to deliver OSP in Africa to reach 10 million households by 2020. The project focuses on empowering women farmers, expanding market opportunities, diversifying the use of sweet potato, and enhancing the breeding pipeline for OSP varieties. Helen Keller International (HKI) has integrated biofortification into its programs to combat vitamin A deficiency, promoting OSP through nutrition education coupled with homestead food production. HKI works with CIP on the Reaching Agents of Change project, which seeks to leverage increased investment in OSP across Africa.

Maize

Provitamin A maize breeding is led by International Maize and Wheat Improvement Center (CIMMYT) and International Institute of Tropical Agriculture (IITA) in conjunction with NARES in southern Africa. Germplasm screening discovered genetic variation for the target level (15 ppm) of provitamin A carotenoids in temperate maize, which was then bred into tropical varieties. Recent developments in marker-assisted selection technology have increased the speed and accuracy of identifying genes controlling the traits of interest in maize. Varieties that can provide 25 percent of the EAR for adult women and preschool children were released in Zambia (3 varieties) and Nigeria (2 varieties) in 2012. In South America, Embrapa of Brazil (www.biofort.com.br) has released a maize variety that contains similar levels of provitamin A. Varieties that can provide 50 percent of the EAR are in development.

African food processing and cooking methods result in provitamin A losses below 25 percent (Li *et al.* 2007). Storage stability studies with the varieties released in 2012 are not yet complete; a previous study of different varieties showed 25-60 percent decay of provitamin A after drying and four months of dark storage at 25° C (Burt *et al.* 2010). Bioavailability (the conversion rate of beta carotene to retinol) was originally assumed to be 12 to 1, but nutrition studies have found more efficient bioconversion rates of 3 to 1 and 6.5 to 1 (Muzhingi *et al.* 2011; Li *et al.* 2010). Nutritional efficacy studies in Zambia have concluded and results are expected to be published in 2014.

Cassava

Biofortified cassava is being developed for Nigeria and the Democratic Republic of the Congo (DRC). The initial breeding target was set at 15 ppm provitamin A. Screening research identified source germplasm from cassava populations in South America, and IITA and the International Center for Tropical Agriculture (CIAT) improved these varieties to be suitable to the African environment and resistant to cassava mosaic disease. Three varieties with sufficient provitamin A to provide 25 percent of the EAR for women and preschool children were released in Nigeria in 2011. Screening identified a variety with a similar level of provitamin A that was released in the DRC in 2008; it is now being disseminated to farmers. In South America, 3 varieties with up to 9 ppm provitamin A have been developed by Embrapa and released in Brazil.

As with maize, the bioavailability of provitamin A is much better than assumed; conversion of beta-carotene to retinol has been measured at 3.8 to 1 and 4.3 to 1, with and without added oil, respectively (Liu *et al.* 2010; LaFrano *et al.* 2012). Existing literature on the stability of provitamin A in cassava through traditional cooking processes highlights high losses (65-80 percent) associated with the most common form of cassava consumption in Nigeria, gari (Chavez *et al.* 2007; Thakkar *et al.* 2009). Given that retention is in part determined by cassava variety and great variability in processing methods exists at the household level, a study of retention during gari production and storage with recently released varieties was commissioned to confirm the tentative revision of the breeding target to 10 ppm. Results indicated an average retention of 40 percent of beta-carotene in freshly made gari, with further degradation during storage. According to the results, 50% of the vitamin A EAR can be supplied by gari that has been stored for up to 15 days for a child 3-5 years of age or up to 45 days for a woman of childbearing age. A nutritional efficacy trial is underway, with results expected in 2014.

Rice

In many Asian countries, rice provides up to 80 percent of the energy intake of the poor. High-zinc rice varieties for Bangladesh and India are developed by the International Rice Research Institute (IRRI) and the Bangladesh Rice Research Institute (BRRI). The initial breeding target has been revised to 28 ppm zinc in polished rice, an increment of 12 ppm above the baseline zinc concentration of commercially available rice. High-yielding varieties with more than 75 percent of the target are in official registration trials in India; the first high-zinc rice variety was released in Bangladesh in 2013. A high-zinc rice variety was identified in Brazil and released in 2012 by Embrapa, and a high-iron rice variety was released in China in 2011; research to incorporate the high-zinc trait into this Chinese line continues.

Retention studies showed that the zinc content of rice is not significantly reduced by parboiling and less so by milling relative to iron, as zinc is distributed more homogenously throughout the brown rice grain (Resurreccion *et al*. 1979; Liang *et al*. 2008). Controlled studies conducted by the Bangladesh Rice Research Institute quantified the loss of zinc from rice during milling and washing before cooking. Approximately 10 percent of the zinc in the milled grain was lost during washing prior to cooking (Juliano 1985). When rice is boiled in an excessive volume of water, which is discarded prior to serving, another 10-14 percent of the zinc may be lost (Dipti 2012). There is neither bioavailability nor efficacy evidence thus far for zinc-biofortified rice. Demonstrating efficacy of a food-based intervention to improve zinc intakes is challenging due to poor sensitivity of serum zinc concentration in response to relatively low amounts of additional zinc intake. More sensitive biochemical indicators of zinc status are needed, and more research is required to assess the impact of zinc interventions on human health.

Wheat

The development of high-zinc wheat for India and Pakistan is led by CIMMYT. The initial breeding target for whole wheat was revised to 37 ppm zinc, an increment of 12 ppm above the baseline zinc concentration. It is expected that adoption of high-zinc wheat will be driven by its improved agronomic properties compared to current popular varieties, and breeding has focused on both zinc content and resistance to new strains of yellow and stem rust. Multilocation trials are underway in both India and

Pakistan; commercialization of varieties with 75 percent of the zinc target level will begin in India in 2013. A wheat variety with zinc concentration of 44 ppm, well above the target level, was released in China in 2011 (www.harvestplus-china.org).

In general, wheat mineral losses are directly proportional to the duration and intensity of milling, but bioavailability increases due to simultaneous phytate reduction. The Punjab Agricultural University is assessing iron and zinc losses associated with traditional milling and cooking methods. An absorption study among women in Mexico showed that total absorbed zinc was significantly greater from the biofortified variety of wheat as compared with non-biofortified wheat (Rosado *et al.* 2009). Additional zinc absorption and efficacy research in 2013 will validate this result for genotype-specific variations in phytate concentration, as phytates have an inhibitory effect on iron absorption.

Pearl Millet

Pearl millet is a regionally important staple in the Indian states of Maharashtra, Rajasthan, Gujarat, and Uttar Pradesh, the target area for biofortified pearl millet. The breeding target was set at 77 ppm iron, an increment of 30 ppm above the baseline. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) carries out the pearl millet breeding research in collaboration with NARES and the private sector. The popular open pollinated variety (OPV) ICTP 8203 was improved to create the first biofortified variety, called ICTP 8203-Fe, which contains 100 percent of the iron target. ICTP 8203-Fe was commercialized in 2012 and officially released in 2013. Hybrid varieties with up to 100 percent of the iron target are in the development pipeline.

Human bioavailability of pearl millet iron is low (Guiro *et al.* 1991). A recent study comparing mineral absorption between a biofortified and control pearl millet variety in children 2–3 years of age in India found a significant difference in total iron absorbed in favor of the biofortified variety (Kodkany *et al.* 2013). Additionally, the iron absorption from ICTP 8203-Fe pearl millet when consumed as porridge was higher (7 percent) than initially assumed for setting breeding target levels (5 percent). A subsequent study validated these bioavailability results in women of child bearing age in Benin (Cercamondi *et al.* 2013).

Beans

The target countries for high-iron bean are Rwanda and DRC, and CIAT and the Rwandan Agricultural Board (RAB) lead the breeding process to reach the initial breeding target of 94 ppm, 44 ppm above the baseline. Several "fast track" lines with more than 60 percent of the target level of iron are in delivery. Five varieties of biofortified beans with higher iron levels were released in Rwanda in June 2012. The breeding pipeline includes both large-seeded bush lines and mid-altitude adapted climbing beans. In South America, three varieties with 80 ppm iron have been developed by AgroSalud and released in Brazil.

Background nutrition research suggests that bean consumption in Rwanda is about 10-20 percent lower than assumed when setting the target, a finding that is currently being validated. Apparent iron retention after cooking is close to 100 percent, as beans are not presoaked before cooking and none of the water used in cooking is discarded (USDA 2007). In general, single meal studies show iron bioavailability to be low (3-5 percent); there is some evidence now that these test meal studies may underestimate bioavailability over longer periods of time, as there is adaptation to high levels of polyphenols (Petry *et al.* 2012). Further research testing the hypothesis that human iron absorption adapts to high levels of dietary phytate is underway in Rwanda and the United States.

Lentil, Cowpea, Banana, Sorghum and Potato

Additional crops are being conventionally bred for higher micronutrient levels, as detailed below. In general, target levels as a percentage of EAR have not been determined, and more research is necessary to provide nutrition evidence for the efficacy of biofortification in these crops.

The International Center for Agricultural Research in the Dry Areas (ICARDA) leads research seeking to biofortify lentils with higher levels of iron and zinc. Multilocation testing began in 2009, and varieties have been tested in Bangladesh, Ethiopia, India, Nepal, and Syria. In Bangladesh, mineral-dense varieties identified in early screening are already promoted for wide-scale cultivation. In Nepal, a candidate variety (ILL 7723) was released in 2012.

Cowpea research is led by G.B. Pant University of Agriculture and Technology, Pantnagar, India. Two early-maturing high-iron and zinc cowpea varieties, Pant Lobia-1 and Pant Lobia-2 were released by the Uttarakhand Government in 2008 and 2010, respectively. These varieties have now entered the national seed multiplication system and seed is available to farmers. Brazil also released three varieties of high-iron cowpeas, developed by Embrapa, in 2008 and 2009.

Banana/plantain varieties providing up to 20 ppm provitamin A have been identified through germplasm screening in Nigeria, Ivory Coast, Cameroon, Burundi, and DRC by IITA and Bioversity. In Nigeria, planting materials have been disseminated. Planting materials of several varieties are currently being multiplied for dissemination to farmers.

Zinc- and iron-dense sorghum hybrids developed at ICRISAT will enter multilocation testing and on-farm adaptation trials in India in 2013. If competitive mineral-dense hybrids emerge, commercialization can be projected for 2015.

High-iron potato clones have been developed at CIP. After production of virus-free in-vitro plantlets, these clones are now being introduced to Rwanda and Ethiopia for testing for local adaptation.

Country Programs

Country programs in Brazil, China, and India work to biofortify a wide array of staple food crops. This "food basket approach", favored particularly in Brazil, is useful for addressing micronutrient deficiencies in populations that consume smaller amounts of several staple crops, rather than deriving most of their nutrition from a single staple crop.

BIOFORT Brasil is coordinated through the Brazilian Agricultural Research Corporation (Embrapa) and is developing nutrient-rich varieties of eight crops: rice, sweet potato, bean, cowpea, cassava, maize, wheat, and pumpkin. Ten varieties have been released: three each of cassava (up to 9 ppm provitamin A); beans (up to 80 ppm iron and 50 ppm zinc); and cowpeas (up to 77 ppm iron and 53 ppm zinc); and one sweet potato variety (up to 115 ppm provitamin A). Furthermore, a provitamin A maize variety (up to 7.5 ppm) was released in 2012.

China's biofortification program began in 2005 and research focuses on increasing iron, zinc, and provitamin A contents in rice, maize, wheat, and sweet potato. Released varieties include: a wheat cultivar, "Zhongmai 175", with 44 ppm zinc and 38 ppm iron; a rice variety, "Zhongguangxiang", with 6.5 ppm iron; and a sweet potato variety, "Nanshu 0101", with 93 ppm provitamin A. Additional promising provitamin A-rich sweet potato and maize varieties are in multilocational trials.

The Indian Government's Department of Biotechnology (DBT) and the Indian Council of Agricultural Research (ICAR) have joined efforts to achieve high-quality research and accelerate the development of biofortified varieties in India. The India Biofortification Program, a long-term project of the DBT, focuses on rice, wheat, and maize. HarvestPlus is a collaborator in the development of these crops and also focuses on biofortified pearl millet and sorghum in collaboration with ICRISAT.

2.2 Transgenics

Transgenic biofortification is used when genetic variability for vitamin and mineral targets is too low to meet the desired target levels, or for crops that are very difficult to breed, such as banana.

Golden and High-Iron Rice

Golden Rice was first developed at the Swiss Federal Institute of Technology, and research was furthered by Syngenta as part of their then-commercial pipeline. Transgenic events with higher levels of provitamin A, up to 37 ppm in a U.S. variety (the GR2 events), were produced and were then donated for use by the Golden Rice Network when Syngenta decided not to pursue the trait as a commercial product (Al-Babili and Beyer 2005). Research on Golden Rice is currently led by IRRI. Starting in 2006, the GR2 events were backcrossed into varieties for the Philippines, Indonesia, India, and Bangladesh (Beyer 2010). Field-testing is currently ongoing.

Bioavailability testing has confirmed that golden rice is an effective source of vitamin A in humans, with an estimated conversion rate of beta carotene to retinol of 3.8 to 1 (Tang *et al.* 2009). Golden rice will be required to pass biosafety tests prior to release; the data for this safety assessment are expected to be submitted to Philippines's regulators in 2013 and in Bangladesh after 2015. An efficacy trial is planned in the Philippines after biosafety approval is granted.

Additionally, a transgenic high-iron rice variety has been developed by the University of Melbourne and IRRI that contains 14 ppm iron in the white rice grain and translocates iron to accumulate in the endosperm, where it is unlikely to be bound by phytic acid and therefore likely to be bioavailable (Johnson *et al.* 2011). Bioavailability trials are expected to begin next year, and release is projected for about 2022 in Bangladesh and India.

BioCassava Plus

The BioCassava Plus (BC+) program genetically engineers cassava with increased levels of iron and provitamin A. Additional traits addressed by BC+ include increased shelf life, reduced cyanide levels, and improved disease resistance. The first field trials for a provitamin A biofortified cassava began in 2009, followed by trials for high-iron cassava (Sayre *et al.* 2011). Delivery of the biofortified crops is expected in 2017. Retention and bioavailability of transgenic cassava are similar to the findings of HarvestPlus on conventional biofortification research indicated above (Failla *et al.* 2012).

Banana Biofortification

Queensland University of Technology and the National Agricultural Research Organization of Uganda are developing transgenic provitamin A and iron bananas for Uganda. Bananas with up to 20 ppm provitamin A have been developed and trials have commenced in Uganda (Namanya 2011). Provitamin A bananas are expected to be released in 2019. A human bioavailability study using transgenic provitamin A banana will begin in early 2013. High-iron bananas are not yet ready for use in human trials.

African Biofortified Sorghum

Africa Harvest and Pioneer lead a consortium of institutions genetically modifying sorghum. Transgenic sorghum has elevated levels of provitamin A (up to 21 ppm), reduced phytate (35-80 percent), and an improved protein profile. Transgenic plants are currently in greenhouse trials; release is expected by 2018.

Sorghum has lower relative bioaccessibility in transgenic varieties, but the higher levels of carotenoids in the grain increased the overall levels of accessible total and provitamin A carotenoids. Additional bioavailability studies have shown increased zinc absorption of 30-40 percent and increased iron absorption of 20-30 percent when phytate levels are reduced.

3. Delivery and commercialization experiences

Two factors influence the design of a delivery strategy: whether the biofortified trait is visible or invisible, and the availability of good infrastructure (including the presence of well-developed seed sectors and seed markets) for dissemination. Provitamin A crops are visibly different, while crops biofortified with iron or zinc are visually indistinguishable from their non-biofortified counterparts. Figure 3 offers a framework that helps to inform dissemination strategies.

From 2007 to 2009, HarvestPlus and its various NGO partners distributed OSP to more than 24,000 households in Uganda and Mozambique (HarvestPlus 2010; Hotz *et al*. 2012b). The pilot delivery project was new to Uganda but built on two previous CIP projects in Mozambique, *Towards Sustainable Nutrition Improvement* and *Eat Orange*. Because there were no markets for sweet potato vines in Uganda and Mozambique, planting materials were delivered through NGO partners. An operations research component monitored implementation activities, while a parallel impact evaluation team carried out a randomized control study. The impact evaluation component tested two delivery methods: an intensive method that included two years of planting material delivery and training, and a less in-

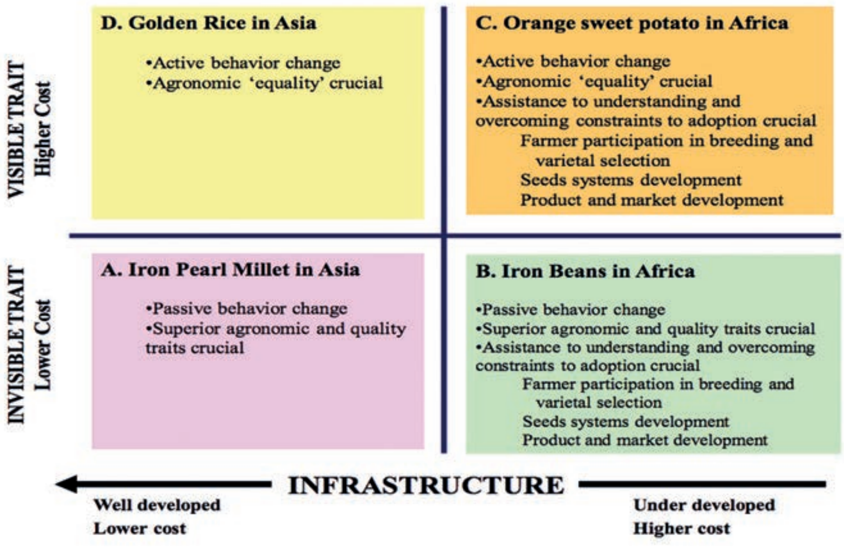

Figure 3. Delivery Framework.

tensive method that included only one year of planting material delivery and training. The less intensive model was shown to be as effective as the more intensive one; in both countries the project led to increases in OSP adoption and consumption by farm households. As a result, vitamin A intakes as much as doubled for both children and women, the primary target groups for this intervention.

Dissemination can also utilize the private sector. In India, HarvestPlus is taking advantage of the existing well-functioning seed sector for pearl millet, and has partnered with a private seed company, Nirmal Seeds Ltd., to market and deliver ICTP 8203-Fe. By partnering with a leading commercial entity in pearl millet seed sales in the target state of Maharashtra, HarvestPlus is increasing demand in an existing market and building a sustainable strategy for future delivery. Because the high iron trait is an invisible one, demand for the ICTP 8203-Fe will be driven by its superior yield performance compared to the earlier version. The marketing of invisible traits is informed by the delivery experience in Rwanda, where over 500,000 packs of high-iron beans have been distributed to 150,000 households since 2011.

4. Effectiveness of biofortification

The primary evidence for the effectiveness of biofortification comes from orange sweet potato (OSP). Effectiveness was assessed through a randomized control trial in both countries. The pilot delivery project described above resulted in a 68 percent increase in the probability of OSP adoption in Mozambique and a 61 percent increase in Uganda (Hotz *et al.* 2012a; Hotz *et al.* 2012b). OSP adoption resulted in substantial substitution of other sweet potato varieties in terms of area under cultivation; the project increased the share of OSP in total sweet potato areas by 59 percent in Mozambique and 44 percent in Uganda. Compared to intakes at baseline, vitamin A intake doubled for all three age/gender groups by project end in Mozambique, and in Uganda increased by two-thirds for younger and older children and nearly doubled for women. For the age group of greatest concern, children aged 6–35 months, OSP contributed 74 percent of the total vitamin A intake in Mozambique and 52 percent in Uganda (see Figure 4). In Uganda, the high prevalence of inadequate vitamin A intake among a subset of children 12–35 months, who were no longer breastfeeding, fell from nearly 50 percent to only 12 percent as a result of the

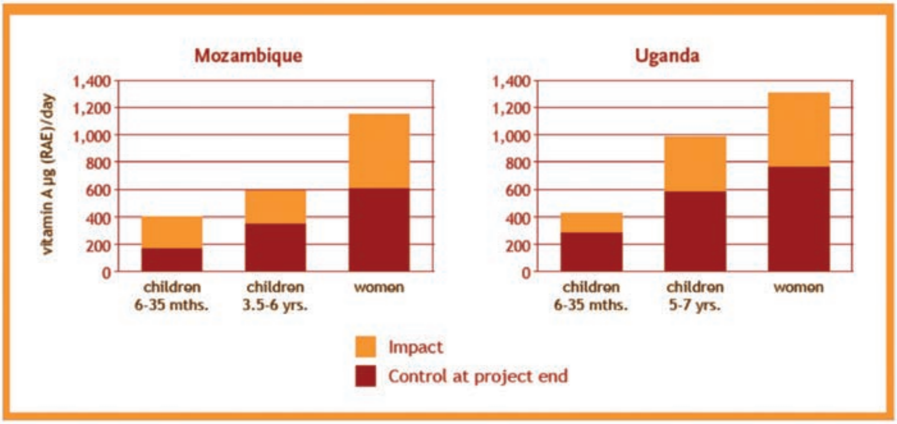

Figure 4. Impact of REU Intervention on mean vitamin A intakes (µg Retinol Activity Equivalents (RAE)/day), Mozambique and Uganda by age group.

Notes: *Estimates are mean vitamin A intakes at project end (2009) in both countries. Mean vitamin A intakes at baseline were not significantly different between project and control households within each age group. For younger children in both countries, separate groups of children were assessed at the beginning and end of the project. For older children and women, the same group was followed over time. Retinol is the active form of vitamin A found in the body. Beta carotene is converted to retinol by the body and the amount of retinol derived from beta carotene is expressed as retinol activity equivalents (RAE).*

project. Researchers were also able to measure a modest yet significant impact of eating OSP on the amount of vitamin A in the blood among children 5-7 years who had lower levels of vitamin A at the start of the project. At project end, researchers also found that women who got more vitamin A from OSP had a lower likelihood of having marginal vitamin A deficiency (Hotz *et al.* 2102a).

Disability Adjusted Life Years (DALYs) are a commonly used metric for measuring the cost-effectiveness of health interventions. For example, in Uganda, calculations suggest that the intervention cost US$15-US$20 per DALY saved, which by World Bank standards is considered highly cost effective (World Bank 1993; HarvestPlus 2010). An ex ante cost-effectiveness study by HarvestPlus estimated that consumption of OSP could eliminate between 38 and 64 percent of the disability-adjusted life years (DALYs) burden of vitamin A deficiency in Uganda (Meenakshi *et al.* 2010).

5. Promise and potential barriers for biofortified crops

Consumer Acceptance and Farmer Adoption

In the pilot delivery programs in Mozambique and Uganda, when beneficiaries were provided information (i) that consumption of orange sweet potato could protect their children from the consequences of vitamin A deficiency and (ii) that orange sweet potato varieties were just as high yielding as white varieties, these households produced and consumed orange varieties – commensurately lowering their production and consumption of white sweet potato.

Rural consumers want nutritious food and are willing to pay a price premium for it, indicating favorable valuation of and demand for staple foods with nutritional benefits. When given the same information as above under experimental conditions, "willingness-to-pay" studies for orange sweet potato, orange maize, and yellow cassava showed that consumers liked the sensory characteristics of the biofortified crops and will pay a higher price for high provitamin A varieties than for white varieties (Chowdhury *et al.* 2011; Meenakshi *et al.* 2012; Oparinde *et al.* 2012).

Consumer acceptance of crops biofortified with invisible nutrition traits (such as high-iron pearl millet) and the impact of branding/certification was also tested. In the case of high-iron pearl millet, it was found that even in the absence of nutrition information, the high-iron variety was preferred to the local variety (Banerji *et al.* 2012).

Varietal adoption studies inform efficient, effective, and targeted crop development and delivery strategies by providing information about current crop production practices, including currently popular varieties of crops, preferred agronomic and consumption traits, sources of information about new varieties, and sources of seed. Following the delivery of biofortified crops, HarvestPlus will study farmer adoption and diffusion, collecting feedback from farmers on agronomic and consumption characteristics and estimating the number of direct and indirect adopters.

Crop Performance

High mineral and vitamin density can be bred into the edible portions of staple foods while maintaining high yields, resistance to pests and diseases, and other desirable agronomic traits. Without desirable agronomic traits, farmers will not adopt biofortified staple crops; each variety released must be at least competitive with what is available in the market.

Transgenics

Several transgenic biofortified crops are currently under development that also have novel agronomic traits (e.g. disease resistance).

While transgenic approaches may reduce time-to-market, resistance to accepting transgenic crops remains high, particularly in Africa.

6. Conclusions

Major gaps in knowledge with respect to biofortification exist: more efficacy trials and effectiveness studies are needed to confirm and augment the promising evidence thus far obtained. Scientists must further refine indicators of individual micronutrient status and better understand the importance of cross-nutrient synergies. Additional delivery and marketing research will improve the effectiveness of delivery and marketing strategies in ensuring maximum adoption and consumption of biofortified crops.

Breeding can be made more cost-effective using marker-assisted selection to breed high levels of several minerals and vitamins in a single variety, and transgenic methods may prove to be more effective in accomplishing this than conventional breeding. To mainstream biofortified traits, agricultural research centers must adopt breeding for nutrient density as a core activity, investing in breeding pipelines at NARES. National varietal release committees should be encouraged to set minimum standards for nutrient densities in the crops that are released; currently only agronomic standards are considered.

Furthermore, biofortification is complementary to existing interventions, but the best mix of biofortification, supplementation, fortification, and dietary diversity must be considered for each target country, and the coordination of these programs must be improved.

Looking forward, a range of institutions must be convinced to endorse the biofortification strategy. Key actors in expanding dissemination globally and ensuring sustainability include the UN and related agencies, international and regional programs such as Scaling Up Nutrition (SUN) and the Comprehensive African Agricultural Development Program (CAADP), international NGOs, seed and food companies, and donor agencies. Only through broadening the biofortification coalition will long-term support for breeding and dissemination of biofortified crops be realized.

Concluding remarks

It is obvious, but sometimes forgotten, that agriculture and food systems will always provide most of the nutrients and compounds that humans require to sustain healthy and productive lives. Agriculture has several roles to play (e.g. also to provide employment and income), but this is surely its most important function. It is clear that agriculture has not performed this function well in developing countries – in the face of rapidly growing populations and land, environmental, human capacity, and institutional constraints. Biofortification is yet to be fully scaled up in a single country but much evidence and experience has been assembled to support its eventual effectiveness. Although the knowledge gaps and tasks ahead may seem daunting, investment in biofortification is a cost-effective approach to ensure a more nourishing future.

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Supplementation: An Effective Approach for Improving Nutrition and Health

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Introduction: The burden of micronutrient malnutrition

One of the major challenges to public health is that of quantifying the extent of micronutrient malnutrition in order to inform policy and program on effective response options. A study published in 2013 by Muthayya *et al*. (2013) represents a significant effort to collate the available data on key indicators of micronutrient deficiencies from national representative surveys. The major data sources were the World Health Organization's (WHO) Vitamin and Mineral Nutrition Information System (VMNIS), Demographic and Health Surveys (DHS) and Multiple Cluster Indicator Surveys (MICS).

Using these data, two hidden hunger index scores were created; the first index is based on national prevalence of iron deficiency anemia, zinc deficiency, and vitamin A deficiency, while the second is based on the Disability Adjusted Life Years (DALYs) attributable to micronutrient deficiencies. These index scores were used to create the hidden hunger index maps, which highlight hidden hunger hotspots around the globe. The maps highlight the significant burden of hidden hunger in Sub-Saharan Africa and parts of South Asia. They can be used as an advocacy tool to support the scale-up of micronutrient interventions, and as a surveillance tool to track progress towards reducing the burden of malnutrition in these areas of the world (Figure 1).

The study also examined the correlation between the hidden hunger index and the human development index, and found an association suggesting that hidden hunger decreases while human development index increases, and vice versa. This finding is of particular interest, as it indicates that in order for nations to advance prosperity, they must tackle malnutrition, a powerful message when advocating for increased action in the area of micronutrient malnutrition.

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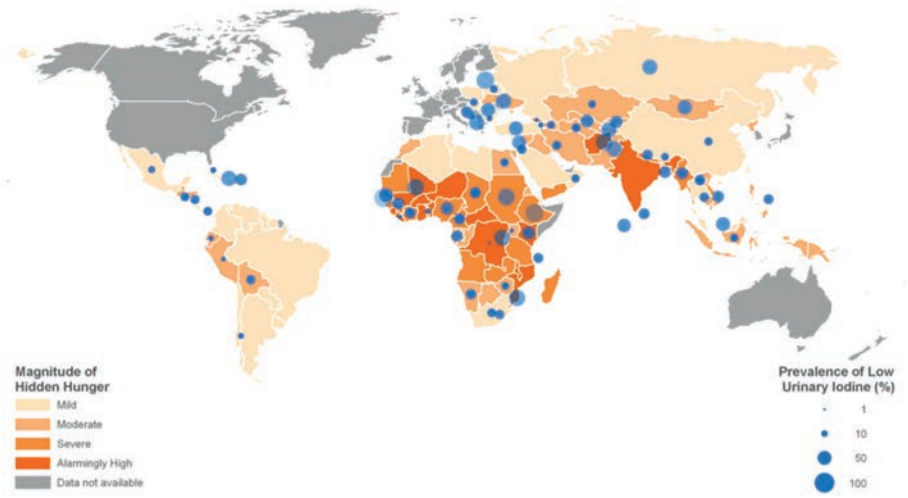

Figure 1. Global hidden hunger map (Muthayya *et al.*, 2013).

Strengthening evidence around the 1,000 days window

Since 2008, with the publication of the first Lancet Series on *Maternal and Child Undernutrition*, global consensus has been achieved that the period from a child's conception to his or her second birthday (often referred to as "the 1,000 days") represents a unique opportunity to ensure optimal outcomes on health and physical and cognitive development. When pregnant mothers and their infants and young children receive adequate nutrition in this critical period, they have a greater chance of surviving to their fifth birthday, and a lower risk of developing non-communicable diseases as adults. Some of the ways in which we can achieve good nutrition are through the use of micronutrient supplementation and fortification. As these interventions are relatively low cost to implement, they have the biggest returns on investment (see the chapter in this volume by Bjørn Lomborg on the Copenhagen Consensus).

Supplementation with micronutrient powders

Given that nutrient deficiencies usually coexist within the same populations, discovering innovative methods to tackle multiple micronutrient deficiencies simultaneously has been a priority for the nutrition field (Allen *et al.*, 2009). Since their original development in the late 1990s at the Hospital for Sick Children, Toronto, Canada, the evidence around micronutrient powders (MNP) has advanced quickly.

MNP is a mix of vitamins and minerals that can be added to food just prior to consumption in the home, which is why it is also referred to as "home fortification". MNP improves the quality of the typically plant-based complementary food in developing countries, which is given to infants and young children who have very high micronutrient needs. This is typically accompanied by key messages to support optimal infant and young child feeding and caring practices. The product formulations can differ in terms of the number of micronutrients included; however, standard formulations usually contain 15 vitamins and minerals which are essential for a child's development and survival. One sachet is equivalent to 1 Reference Nutrient Intake (RNI) – the amount which will fulfill the nutritional needs of 97.5% of the target population. Thus, when 180 sachets are provided per annum, 50% of the child's micronutrient requirements over that 12-month period will be met by MNP.

A systematic review of complementary feeding by Dewey and Adu-Afarwuah (2008) found that the risk for anemia and iron deficiency was lower in children who received MNP, as compared to the controls [anemia OR: 0.54 (95% CI: 0.46-0.64); and that of iron deficiency was RR: 0.44 (95% CI: 0.22-0.86) for those using MNP compared with controls].

Subsequently, a Cochrane review conducted by De-Regil *et al.* (2011) found that MNP use was associated with a 31% reduction in anemia (RR 0.69, 95% CI 0.60-0.78) and a 51% reduction in iron deficiency (RR 0.49, 95% CI 0.35-0.67). It was noted that MNP was highly acceptable to mothers and children, there were fewer side effects with MNP than with iron drops, and the efficacy was not associated with the duration of the interventions (two, six or 12 months). However, both reviews suggested that more evidence was needed on the influence of MNP on malaria morbidity.

MNP and malaria interaction

Concerns about MNP use and malaria morbidity stem from the findings of a study conducted on the Island of Pemba, Zanzibar (Sazawal *et al.*, 2006). The community-based, placebo-controlled randomized trail provided prophylactic supplementation with iron and folic acid to reduce anemia risk. However, the study found an increase in both morbidity and mortality in the treatment group. Conversely, findings from Nepal providing the same supplements found no increase in mortality or morbidity in the treatment group (Tielsch *et al.*, 2006).

Following these studies, the WHO released a statement, which noted that untargeted iron supplementation is contraindicated, while targeted supplementation with concurrent protection from malaria and other infections was safe (WHO, 2007). Fortification programs and food-based approaches were deemed as being safe, but at that juncture home fortification with MNP held an unknown risk. However, in 2011 a revision of the evidence stated that MNP was safe for use (WHO, 2011).

Home fortification technical advisory group

The Home Fortification Technical Advisory Group (HF-TAG) is a global network comprised of organizations implementing or supporting the scale-up of home fortification programs. Comprised of United Nations (UN) agencies, non-governmental organizations (NGOs), manufacturers of home fortification products, and academic institutions, HF-TAG is an important platform for evidence gathering and technical information sharing on home fortification. This includes not only evidence collected from research settings, but also vitally important lessons from field studies, which are key to informing the continuing scale-up of MNP interventions. Moreover, expert members of the HFTAG have also been instrumental in analyzing negative results from MNP trials and providing an interpretation for donors, policy makers, and implementers.

The *Home fortification with micronutrient powders (MNP)* 2013 special edition published by HFTAG, which is freely available online, provides a summary of the successes and challenges around MNP programs in a variety of settings, such as refugee camps, schools, and market-based distribution (HF-TAG, 2013).

MNP program scale-up

In 2011, 14 million children aged six to 59 months were reached in 22 countries worldwide, and large-scale MNP programs have been implemented or planned in more than 40 countries. This success has been driven by a number of factors; an expanding evidence base has allowed nutritionists to advocate for programs scale-up, and has provided donors with the confidence to invest in MNP programs. Improved product formulation and packaging have been developed, while manuals, programmatic guidance briefs, and statements have facilitated the scale-up of national programs.

Vitamin A supplementation

Since the 1980s, decades of research in low-income countries provide substantial evidence that vitamin A supplementation (VAS) is an efficacious solution to reducing child mortality and morbidity. The first of these studies was conducted in Aceh, Indonesia and showed a 34% reduction in mortality in the one- to five-year age group (Sommer *et al.*, 1986).

By 1993, a total of 8 studies, conducted in Asia and Africa, had been published, showing a significant decrease in child mortality (Sommer, 2008). In 2010, a Cochrane review of 17 trials with 194,795 children of six to 59 months of age found a 24% reduction in the risk of all-cause mortality for those receiving VAS compared with controls at follow-up [RR 0.76 (CI) 0.69, 0.83] (Imdad *et al.*, 2010). Seven trials reported a 28% reduction in diarrhea-related morbidity in those receiving VAS [RR 0.72 (CI) 0.57, 0.91]. VAS was also associated with a reduction in the incidence of diarrhea and measles morbidity.

Coverage of VAS programs

Given the significant impact that VAS has on children's risk of morbidity and mortality, the WHO recommends that pre-school-aged children at risk of vitamin A deficiency receive vitamin A capsules. The United Nations Children's Fund (UNICEF) collects data on national VAS program coverage. Currently, program coverage – determined as the number of children of six to 59 months of age receiving two doses of Vitamin A per annum – is vastly different, depending on region and country. In Eastern and South Africa the rate is as low as 72%, while in East Asia and the Pacific coverage reaches 85%. In Somalia, program coverage is abysmally low at 12%, while Afghanistan and Mauritania report 100% coverage (UNICEF, 2013). Improvements in program coverage will likely come when we improve access to program services; his requires a careful assessment of how programs are designed and implemented to reach the most vulnerable.

DEVTA Study: A case for delivery science

The Deworming and Enhanced Vitamin A (DEVTA) study was a cluster-randomized trial conducted in Northern India in the state of Uttar Pradesh under usual program conditions. The program provided periodic VAS in an area where children are known to be at risk of VAD (Awasthi *et al.*, 2013). With one million children in the study, it has been described as the largest drug trial ever to examine the impact of VAS on child mortality. The study, however, found a non-significant 4% reduction in child mortality among those children who received the vitamin A capsules.

Compared to the established evidence, the contradictory findings of the DEVTA trial have raised many questions about the methodology employed in the study. These points were addressed in a commentary by Sommer *et* *al.* (2013), who suggested that the trial was not conducted in a manner rigorous enough to be deemed an efficacy trial, some of the issues being that children were not enumerated, consented, formally enrolled, or carefully followed up for vital events. Habicht and Victora (2013) and Habicht and Pelto (2014) raised a number of other issues relating to the program assessment design. In large-scale programs, the causal chains are long and complex, and documentation along the whole chain and process is essential to understanding the results (Habicht and Victora, 2013). In the DEVTA study, these questions were only answered in a non-random opportunistic sample of 2,106 children; furthermore, these children were likely to be easy to reach, and thus received both annual doses of vitamin A. The authors conclude that program assessments require more complex designs than randomized control trials.

Turning knowledge into action: Implementation research

Scientific advancements have provided public health nutritionists with the tools and products to tackle malnutrition. From earlier works involving micronutrient supplementation, such as the case of VAS discussed above, to new innovative methods such as MNP, it is largely recognized that we have the knowledge to tackle malnutrition. The next major challenge for the nutrition field is to take these interventions to scale, with our future success inextricably linked to our ability to deliver high quality programs to many people, particularly to those most difficult to reach.

So the major question is: How will this be achieved? There are a number of challenges that must be addressed. Delivering high quality supplementation programs is complex and requires an urgent investment in implementation research to elucidate the critical intervention and implementation components. Yet implementation research receives only 3% of research funds (Habicht, 2012). Improving program delivery requires program managers to systematically use a range of strategies across the program cycle, such as formative research, behavior change communication, market-based research, and robust monitoring and evaluation frameworks. Understanding the value of this process is the key to successful program implementation, and we need practitioners with skills in not only nutrition, but also social science, and who have strong management and leadership skills. At present, this is a major roadblock.

Another significant bottleneck to improving program delivery is a usable set of tools for frontline workers, especially for those implementing interventions within large-scale programs in health, agriculture, education, and social protection. A systems approach could help public health professionals understand the complexities of delivering nutrition intervention across multi-sector platforms.

Conclusions

The examples ofVAS and MNP show how supplementation can be used as an effective front line tool in the battle against micronutrient malnutrition. It is essential that, while acknowledging previous successes in the nutrition field, we move forward with scaling up nutrition interventions to reach those most in need and to ensure they will have the maximum benefit. We need to think beyond nutrition, and look over the fence to incorporate other disciplines to implement our programs more effectively.

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Consequences of the Anti-GMO Campaigns

Robert Paarlberg[1]

Genetically modified crops have long been opposed by a wide range of not-for-profit nongovernmental organizations (NGOs). Because these NGOs are not seeking profits in the marketplace, in contrast to the private companies that sell GMO seeds, they frequently enjoy greater social trust. Some of these organizations present themselves as advocates for social justice, some as advocates for the rural poor, some as advocates for the environment, some as opponents of corporate-led globalization, and some primarily as advocates for alternative farming methods, for example organic or agroecological methods, which reject the use of GMOs.

Much of this NGO opposition to GMOs has been led by European-based organizations such as Greenpeace Internatioenal, and Friends of the Earth International, both headquartered in Amsterdam. Yet significant numbers of United States and Canadian-based NGOs join in these campaigns; for example, the current campaign to mandate the labeling of foods with GMO content in the United States is led by a Washington, D.C. based legal action and advocacy organization called the Center for Food Safety. Anti-GMO organizations from rich countries often support local counterparts, sometimes with money and networking support and sometimes simply with information.

The campaigns these organizations have been conducting for almost two decades now have been remarkably successful, particularly in blocking the planting of GMO food crops. GMO wheat, GMO rice, GMO potato, and nearly all GMO fruits and vegetables have been blocked from commercial planting, even in the United States. GMO food animals and GMO fish have also been kept entirely off the market. Nearly all of the GMO crops being planted today are used primarily for industrial purposes or as animal feed. For example, the three biggest GMO crops in the United States are soybeans, corn, and cotton, and roughly 98 percent of our soybean meal goes for animal feed, while 88 percent of the corn is employed either for animal feed or as a feedstock for making ethanol. Cotton is almost purely an industrial crop.

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Thus, while NGO critics like to depict private companies as somehow forcing GMO foods down the throats of consumers, nothing could be farther from the truth. Judging from actual outcomes so far, it is the NGO critics who are strong and the private companies that are weak. The private biotechnology companies have so far lost nearly every battle when it comes to food crops.

Even in the United States, the nation that has gone the farthest in permitting the commercial use of GMOs, one transgenic food crop after another has been kept or driven off the market by anti-GMO campaigners. GMO wheat seeds were first field-tested in the United States in 1994, but in 2004 Monsanto decided it could not put them on the market because activists both at home and abroad had persuaded consumers they might not be safe. GMO rice has never been commercialized for similar reasons. GMO potato was actually grown on 25,000 acres in the United States and widely consumed between 1999-2001, but cultivation was then voluntarily suspended when food service chains told farmers they did not want to be accused by activists of selling GMO French fries. GMO tomatoes were also cultivated commercially in the United States between 1998 and 2002, but then cultivation stopped in response to intentionally inflamed consumer anxieties. GMO melons capable of resisting a virus have been successfully tested in the United States since 1989, but never planted commercially. The only GMO fruits and vegetables grown in the United States are Hawaiian papaya, plus a tiny share of summer squash and sweet corn.

In the rest of the world as well, government regulations now block the planting of nearly all GMO food crops. GMO food crops are not legal for planting anywhere in Central or Latin America. In all of Sub-Saharan Africa, only the Republic of South Africa allows the cultivation of a GMO variety of white maize for direct food consumption. No GMO food crops are legal to plant anywhere in South Asia or Southeast Asia. India and Pakistan permit cotton, and the Philippines permits yellow corn for animal feed, but nothing else. China permits cotton, but it does not allow commercial farmers to plant GMO wheat, rice, corn, or potato.

Food crops are not the only GMOs being blocked from use. In most of the world beyond the Western Hemisphere, national governments have also failed to approve the planting of GMO animal feed or industrial crops. In fact, only three of the 47 countries of Sub-Saharan Africa have made it legal for farmers to plant any GMO seeds at all: Burkina Faso (which allows cotton only), and Sudan (again, cotton only), and the Republic of South Africa (cotton, maize, and soybean).

Surprisingly, this considerable worldwide blockage of GMOs does not reflect any malfunction of the seeds or crops themselves. Critics talk endlessly of risks, but they should acknowledge that even in Europe the most prestigious national academies of science and medicine have found no new risks either to human health or the environment from any of the genetically engineered crops so far in existence. This remains the official position of the Royal Society in London, the British Medical Association, the French Academy of Sciences and Medicine, and the German Academies of Science and Humanities. In 2010, the Research Directorate of the European Union (EU) produced a report that went so far as to state, "biotechnology, and in particular GMOs, are not per se more risky than e.g. conventional plant breeding technologies" (EU 2010).

The single most powerful explanation for this continuing blockage of GMOs has been an energetic NGO campaign of disinformation, led and financed mostly by individuals from well-fed countries who do not need the technology themselves. These individuals take what they believe to be a virtuous position on the issue, but since they are not poor farmers, and may have never even met a poor farmer, they fail to appreciate the advantages GMOs can give to the poor who need better ways to protect their crops against disease, insects, weeds, and drought. Occasionally, individuals who have participated in this anti-GMO campaign have a change of heart. Patrick Moore, a Canadian ecologist who headed the Greenpeace Foundation in Canada, concluded in 2006 that poor farmers in developing countries "need genetically engineered crops". Moore announced his support for Golden Rice in particular, as a means to prevent vitamin A deficiency in poor countries (Prakash 2001). Just this year, a UK environmentalist named Mark Lynas took the unusual step of apologizing for his earlier role in helping to launch the anti-GMO campaign in the 1990s. He characterized this campaign as the most successful he had ever been involved with, but admitted now that it had been misguided. Taking a longer look at the science, he now sees GMOs as a "desperately needed agricultural innovation" that is being "strangled by a suffocating avalanche of regulations which are not based on any scientific assessment of risk" (Lynas 2013a). Moore and Lynas are exceptions, however. Most anti-GMO campaigners remain certain of the wisdom and virtue of their cause.

Explaining NGO Influence

The success of the anti-GMO campaign is a puzzle, given the absence of any documented new risks from the technology, and an abundance of evidence that farmers have found it to be a good way to reduce chemical inputs and save labor costs. Superficially, the success of the campaign draws heavily from an anti-corporate narrative. There is considerable evidence to support a critique of transnational corporate power abuse in other areas, such as international banking, financial services, labor-intensive manufacturing, or energy and raw material extraction. Yet in the specialized arena of agricultural crop seeds, international corporate control is actually quite weak in the developing world. Partly this is because corporate patents cannot be claimed in this area in most developing countries, since the governments in those countries have opted not to recognize patent claims on plant seeds. In addition, this area is distinctive because for crop seeds to perform well they must be developed close to the place they will be planted, by local plant scientists and seed companies testing them under local soil, water, and growing season conditions. Seed development programs of this kind will be vulnerable at many stages to blockage from host country government regulators, influenced by anti-GMO campaigners.

In part, international NGO campaigns against GMO foods have succeeded in the developing world because they first succeeded in Europe. This success, in turn, was driven in part by a completely legitimate food safety scare that had nothing to do with GMOs. In March 1996 the Government of the UK finally acknowledged the existence of a potentially fatal human food safety risk from eating the meat of animals contaminated from bovine spongiform encephalopathy (BSE), better known as "mad cow disease". The Government had earlier assured consumers it was perfectly safe to eat this meat. By coincidence, March 1996 was precisely the month that European officials approved the first import of a GMO food, herbicide-tolerant soybeans from the United States. Activist NGOs in Europe such as Greenpeace, Friends of the Earth, and the European Consumers' Organisation (BEUC), saw no consumer benefit from GM foods that might justify even a hypothetical safety risk, so they began warning citizens away from GM foods and crops, simply on "precautionary" grounds. Efforts by European officials to reassure consumers about the soybeans had no impact, since the BSE case had destroyed their credibility a guardians of food safety. NGO activists ignored the reassurances and instead staged street demonstrations and mobilized efforts to block the unloading of ships carrying GMO soybeans (Bernauer and Meins 2003). European supermarket chains then began removing known GM products from their shelves to avoid being targeted by activist demonstrations.

Anxieties nonetheless grew, so in June 1997 the EU decided under citizen and activist pressure to require that all GM food sold in Europe carry an identifying label. Instead of reassuring consumers, this step seemed to validate the growing impression that GM foods must indeed be dangerous. By 1998, political anxieties had grown so intense that EU regulators felt obliged to place an informal moratorium on any new case-by-case approvals of GM crops.

Once this European victory was in hand, the NGO campaign shifted into the global arena, specifically targeting an effort then underway, under the 1992 Convention on Biological Diversity (CBD) of the UN, to negotiate an international protocol (the Cartagena Protocol) governing the transboundary movement of living GMOs (LMOs). Once they were given access to the protocol negotiation process, anti-GM organizations such as Greenpeace, Friends of the Earth International, and the Third World Network spread scare stories about the risks GMOs and advocated that the new Protocol be modeled around a 1989 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes. GMOs that had been developed at considerable expense and approved by regulators for safe use were thus compared to hazardous wastes. This was a bizarre and inappropriate framing, but it was accepted by the environmental advocates from Europe who dominated the protocol negotiation, and it was sold to Africans and to delegates from other developing countries as something the UN had to do in order to protect their rich biodiversity.

Many African delegates originally came to the protocol negotiations fearing not that GMOs were dangerous, but that they might work so well in rich countries as to leave African agriculture farther behind. These Africans were quickly turned around by NGO scare stories. As explained by Bas Arts and Sandra Mack, "Generally, many developing countries had only a limited knowledge on biosafety issues because of lack of financial and scientific resources. It was the NGOs which made them aware of the (potential) negative consequences of the transboundary movement of GMOs for their countries, particularly for their rich biodiversity, traditional agriculture and indigenous people" (Arts and Mack 2007, p. 53). Since the negotiation had been framed as an international environmental agreement, most developing countries deputized officials from their environmental ministries to handle the job, and these individuals were easily influenced by Europe's better-established environment ministries. The final Cartagena Protocol that emerged in 2000, modeled after the Basel Convention, thus required that anyone seeking to export GMO grain as living seeds must provide warning label, and if the seeds were intended to be planted rather than processed or consumed, the exporter would first have to secure the informed consent of an officially designated biosafety authority in the importing country.

Once these rules had been incorporated into an international treaty, NGO activists could begin attacking the United States for its longstanding food aid practice of delivering GMO corn and soy in bulk shipments to poor countries. Under the new Protocol, the kernels of GM corn contained in these shipments were classified as LMOs, meaning the importing country was entitled to a warning label. The United States Government resisted providing such as warning, reasoning that the corn in these shipments was approved as safe in the United States and was identical to what Americans had been buying and consuming for several years without any warning labels, and without any ill effects.

The NGO community seized upon this American resistance to label, and in 2001 (led primarily by Friends of the Earth International), the NGO community began depicting unlabeled GM food aid from the United States as part of a stealthy scheme to dump surplus quantities of unhealthy American foods onto the vulnerable poor. Friends of the Earth first distributed test kits to its field offices to document the presence of the GM products in U.S. food aid shipments, finding GM corn and soybeans in some food aid shipments from the U.S. to Bolivia, Colombia, and Ecuador. This was then presented and publicized as evidence of "GMO contamination around the world", setting the stage for an important rejection of GM food aid by African countries in the year that followed (FoE 2001).

Africa's Rejection of GMOs

In Zimbabwe in May 2002, the government in Harare decided to turn away a 10,000-ton shipment of U.S. corn for fear that the shipment was "contaminated" with GMOs. Officials worried that if any of the GM maize kernels were planted by farmers, the nations biosafety regulations would be violated and future commercial export sales of hybrid maize could be put at risk. Zimbabwe eventually agreed to accept GM maize as food aid if the kernels were milled prior to delivery, so they could not be planted. The rejected shipment of whole kernel maize was then diverted to Zambia, which had routinely accepted GM food aid shipments in the past. Yet criticism from the NGO community was making this more difficult by 2002. European NGOs critical of the technology had cultivated influential allies within Zambia's policy elite. By 2002, Dr. Mwananyanda Lewanika, the executive director of Zambia's National Institute for Scientific and Industrial Research (NISIR), had developed a close relationship with a European NGO, Norway's Institute for Gene Ecology, which gave him reason to advocate against accepting the food aid. At a public meeting in August 2002, Lewanika presented the technical case against accepting GM food aid in Zambia. He said, without presenting any evidence, that GM foods could increase cancer risks and were contributing to a growing public health danger in the form of antibiotic resistance to infections (Phiri 2002).

The most impassioned public speaker against GM food aid at this important open meeting in Zambia was Emily Sikazwe, executive director of a local NGO called Women for Change (WFC). She told her fellow Zambians how important it was to say no to GM food aid: "Yes, we are starving, but we are saying no to the food the Americans are forcing on our throats" (Phiri 2002). Sikazwe's own local NGO had earlier been spun off from a Canadian NGO (Canadian University Services Overseas, or CUSO) that had engaged in "biotech teach-ins" against GMOs back in Canada, in partnership with Greenpeace (CUSO 2001). Sikazwe's local NGO received its funding from a number of Canadian church and peace organizations, the Swedish embassy in Lusaka, the Norwegian embassy, and the Danish foreign Assistance agency DANIDA (WFC 2007).

Two religious NGOs in Zambia headed by expatriate Jesuit priests from the United States also joined in the attack against GM food aid. The Jesuit Centre for Theological Reflection (JCTR) and the Kasasi Agricultural Training Centre, both located in Lusaka, had begun proselytizing against GMOs in 2000, and earlier in 2002 that had jointly commissioned a research paper titled "What is the Impact of GMOs on Sustainable Agriculture in Zambia?", recommending that Zambia's policy regarding GMOs should follow the precautionary European approach (JCTR 2002). These two Jesuit organizations embraced a doctrine – never endorsed by higher church authorities – that all living things, including plants, should enjoy a God-given right not to have their "genetic integrity" altered (Lesseps 2003). Commercial interests were also at play. Trainees from the Kasasi Centre were employed by Agriflora, an expat-owned company that was growing organic baby corn for export to Europe. Training fees at the Kasasi Centre were financed by yet another European NGO, the Swedish Cooperative Centre (FAO 2001).

American officials tried to reassure the Zambians about GM maize by inviting a delegation of government experts on a fact-finding trip to visit America, but this approach backfired when the seven-person Zambian delegation also traveled to Europe to gather facts, and met with representatives of Greenpeace, Friends of the Earth, the UK Soil Association, an NGO named Genetic Food Alert, and Norway's Institute for Gene Ecology. Greenpeace warned the visiting Zambians that their organic produce sales to Europe would collapse if the nation accepted the new technology, and Genetic Food Alert warned of the "unknown and un-assessed implications" of eating GM foods. A UK NGO called Farming and Livestock Concern warned the Zambians that GM maize could form a retrovirus similar to HIV (Daily Telegraph 2002). Upon returning home, the spokesperson for this Zambian expert group asserted that his own anxieties about GMOs had only been confirmed by the trip (Government of Zambia 2002).

Having helped turn Zambia against GMOs in the summer of 2002, the NGO campaigners (including by now a number from North America) shifted their attention to the September 2002 World Summit on Sustainable Development (WSSD) nearby in Johannesburg. In anticipation of this UN event, a San Francisco environmental advocacy group, Earth Island Institute, had organized an unofficial "World Sustainability Hearing" running parallel to the summit. A number of internationally prominent GMO critics from wealthy countries spoke at this forum. Three NGOs, Friends of the Earth, the Institute for Agriculture and Trade Policy (IATP), and the World Development Movement, also managed to persuade 140 local African civil society representatives and organizations in Johannesburg to sign an open letter to the World Food Programme and the U.S. government protesting shipments of GM food aid. This letter circulated widely on the Internet as the authentic voice of Africa on the issue of GMOs. It was filled with a number of alarming yet completely undocumented charges:

> The safety of GM food is unproven. On the contrary, there is sufficient scientific evidence to suggest it is unsafe. GM food can potentially give rise to a range of health problems, including: food allergies; chronic toxic effects; infections from bacteria that have developed resistance to antibiotics, rendering these infections untreatable; and possible ailments including cancers, some of which are yet difficult to impossible to predict because of the present state of risk assessment and food safety tests (Third World Network 2002).

The Johannesburg summit also gave international NGOs an opportunity to put anti-GMO words into the mouths of local African farm organizations. An organization called PELUM (Participatory Ecological Land Use Management), claiming to represent 160 civil society organizations in Africa, organized what it called a "Small Farmers' Convergence" on Johannesburg that included a four-day caravan by 120 farmers that set out from Lusaka. Funding for this pilgrimage came from HIVOS and NOVIB in the Netherlands, FOS-Belgium, MISEREOR in Germany, and Find Your Feet in the UK. At a press conference in Johannesburg at the end of their walk these farmers announced, "We say NO to genetically modified foods" (GFAR 2002). PELUM's chief African organizer for this march was not a farmer himself, nor was he well informed regarding the technology. He told interviewers he didn't like GMOs because he had learned that, if eaten, they would change the genetic composition of the human body (IMM 2002).

These inflammatory and unsubstantiated charges against GMOs in Johannesburg eventually provoked a response from USAID administrator Andrew Natsios, who lost has patience after being asked by one African minister from a Muslim country "if it was true" that GM maize contained pig genes (Natsios 2006b). At this point Natsios spoke out, calling the NGO efforts against GMOs "revolting and despicable". Having baited Natsios into the arena, the NGOs were more than happy to amplify the dispute. A Greenpeace spokesperson replied that the United States was being "arrogant to tell the Zambians what food they must accept", and Peter Rosset from Food First (an American NGO) said he thought the Africans should "tell the U.S. to go to hell" (Martin 2002).

Building on their efforts in Zambia and Johannesburg, the NGO campaigners later took their message to a number of other African countries. In Kenya, a collection of NGOs had organized themselves into a Kenya GMO Concern Group (KEGCO), and in 2004 two of its foreign-funded members, PELUM and ActionAid, led this coalition in a media campaign against passage of a draft biosafety bill, depicting this legislation as something that might lead to the planting of GMOs (PELUM 2004). For this campaign PELUM produced an article titled "Twelve Reasons for Africa to Reject GM Crops", a document that asserted without evidence that GM crops were a threat to human health. Also in 2004, Friends of the Earth launched an African regional campaign to "challenge the myth of GM crops as a solution to hunger and poverty", hoping specifically to dissuade Angola and Sudan from accepting GM food aid (FoE Africa 2007). The Angolan government went along with this advice, rejecting GM maize in an unmilled form as food aid, just when WFP was being forced to cut its normal feeding rations in the country due to funding shortfalls (Scott 2004). In Sudan, Friends of the Earth then led a group of sixty NGOs accusing the United States and WFP of coercing the country into accepting GM food aid (ACB 2004).

Friends of the Earth also worked against GMOs in West Africa, holding a 2005 conference in Nigeria that brought together GM food critics from nine different African countries to demand "a complete moratorium on GMOs in Africa until their safety for our environment, health, and socio-economic conditions is established beyond doubt" (FoE 2005).

These NGO campaigns had a cumulative effect on Africa's urban policy-making elites, many of whom – within a post-colonial mind-set – saw European practices as the best practices. The NGO campaigners were concealing the fact that all of the most important science academies in Europe had so far found no evidence of new risks from GMOs, so leaders in Africa leaders were left to conclude that the best thinking (i.e., European thinking) must require a rejection of GMOs. As one local Kenyan leader said in 2006, "Europe has more knowledge, education. So why are they refusing [GM foods]? That is the question everyone is asking" (Hand 2006). Actual smallholder farmers in Africa had little voice in the matter. The only farmers well organized to express an opinion those producing specialty crops for export, and from their viewpoint GMOs were risky because they could lead to lost sales in the European market.

The NGOs were not acting alone, of course. They linked their anti-GMO campaign to a well funded program by the United Nations Environment Program (UNEP) intended to help developing countries set in place adequate regulatory systems for GMOs, consistent with the new Cartagena Protocol. This Program led one African government after another down a path to stifling the technology with regulatory requirements that provided critics with multiple new points of delay. Of the 23 African governments that completed this Program between 2000 and 2006, 21 of the 23 had to adopted the most restrictive ("Level One") approach (UNEP 2006). Thanks to these restrictive regulatory approaches, it is still not legal, seven years later, to plant any GMO food or feed crops commercially in any of the developing countries of Sub-Saharan Africa. An industrial crop, cotton, was finally approved by Burkina Faso in 2008, and it proved to be a considerable success (the income of cotton farmers who switched to Bt increased by $62 per hectare), but no other developing country in Sub-Saharan Africa has yet followed Burkina's lead (Vitale, Bognan, Ouattarra, and Traore 2010).

NGO Campaigns Beyond Africa

The international NGO campaign against GM crops has of course had impacts well beyond Africa. In India, for example, NGOs in 2010 helped to block the commercial planting of a GMO variety of eggplant (brinjal), even though the benefits would have included higher income for farmers plus reduced use of environmentally harmful pesticide sprays that also bring both occupational health risks to farmers and food safety risks to consumers. India's environment minister blocked commercial planting at the last minute after a firestorm of protests led by international NGOs. In 2012, India's Prime Minister Manmohan Singh went so far as to complain in public about the role international NGOs had played in this case. He said, "Biotechnology has enormous potential, and in due course of time we must make use of genetic engineering technologies to increase the productivity of our agriculture. But there are controversies. There are NGOs, often funded from the US and Scandinavian countries, which aren't fully appreciative of the developmental challenges our country faces" (Hindustan Times 2012).

More recently in East Asia, NGO actions have further postponed any commercial planting of high-beta carotene "golden rice". In 2012, Greenpeace in China in made the sensational charge that 24 Chinese children had been used as "guinea pigs" in a golden rice feeding trial. In fact, the researchers were operating with parental consent, and most important no child had been harmed. Yet Chinese officials were so frightened by the media hysteria surrounding the charge that they decided to fire three of those from the Chinese Center for Disease Control and Prevention and the Zhejiang Academy of Medical Sciences which had coordinated the project, and were named in the Greenpeace report. This controversy reinforced a decision top officials had made earlier in response to NGO alarms, to suspend for the moment any plans to commercialize China's own home-developed varieties of GMO rice.

NGO actions have also slowed the commercial development of golden rice in the Philippines. In August 2013, a band of 50 or so activists broke down a fence then trampled and uprooted field of young golden rice plants. While claiming to be "farmers", the perpetrators had been organized by several Philippine NGOs including Kilusang Magbubukid ng Pilipinas (KMP), a radical left organization that promotes a conspiracy theory that golden rice is part of a corporate takeover of the Philippine rice market (ignoring the fact that golden rice is being developed by public sector organizations), plus MASIPAG, which has long been in the forefront of anti-GMO activities in the Philippines, joining with Greenpeace in various legal actions and campaigns (Lynas 2013b). MASIPAG's authenticity as a Philippino institution is undermined by the fact that for many years it has been receiving support from the Swedish International Cooperation Agency (Sida), through funds to the Swedish Society for Nature Conservation (SNF).

Conclusion

Nobody should criticize civil society campaigns, so long as these campaigns emerge from the societies that must bear the consequences. Unfortunately in the case of NGO campaigns against GMO crops, they typically emerge from rich countries while imposing consequences on poor countries. Well-fed citizens from Europe and North America, where farming is already highly productive, are understandably not attracted to GMOs. Most in these countries do not need this technology to increase their well-being; most of the benefits are captured by farmers, and farmers now represent perhaps only 1-2 percent of all citizens in these countries. Moral clarity is lost, however, when citizens from these rich countries project their dismissive opinion toward GMOs onto poor countries, where as many as 60 percent of all people are poor farmers and might stand to gain a benefit from this technology. Still more is lost when the anti-GMO campaigners from rich countries intentionally hide from developing country citizens the published conclusions of their own national science academies back home, that no convincing evidence has yet been found of new risks to human health or the environment from this technology.

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Lessons from Golden Rice

Ingo Potrykus

Micronutrient deficiency takes a daily toll of ca. 24,000 lives (see also H.K. Biesalski, this volume). Micronutrients such as vitamins, minerals, and essential amino and fatty acids are essential for vital molecular functions of the human body and have to be taken up with the diet (see also Klaus Kraemer, this volume). For those who can afford a diversified diet this is not a problem. However, those billons of poor who survive essentially on starchy staple food crops such as rice, which are poor in micronutrients, shortage in micronutrients can be lethal. The novel concept of "biofortification" – the improvement of the micronutrient content of especially starchy staple crop plants on a genetic basis – has great potential for low cost and sustained interventions for the reduction in micro nutrient deficiencies (see also Howarth Bouis, this volume). His presentation has demonstrated that biofortification on the basis of traditional breeding techniques can indeed lead to novel varieties enriched in micro nutrients and that their consumption can improve the nutritional status of those who consume them. The data already available after less than 10 years of experimentation establish proof-of-concept for this novel concept – an impressive progress within a short time period indeed!

Micronutrient deficiency not only has dramatic negative effects on health and wellbeing for infants and pregnant women, but also severely compromises brain development, thus leading to far reaching consequences for mental, educational, and social capacity (see Martha Farah and Sebastian Lipina, this volume). Interventions via "supplementation" of diets with industrial formulations of vitamins and minerals improve the micronutrient status, but can reach only a fraction of those who need it (see Klaus Kraemer, this volume). There is no doubt that supplementation of diets with industrial formulations has an important role to play, and represents a mature technology which just requires more support for wide-scale application. Biofortification offers in comparison the comparative and complementing advantages that it does not require recurrent investment and reaches those who are out of reach for supplementation programmes. Biofortification is to be seen as complementation for the established interventions, and progress is, in view of the magnitude of the problem, urgently needed. According to the Copenhagen Consensus, investment in availability of micronutrients has, in addition, the highest economic return for investment on interventions for development and is on top of a list of recommendations for policy makers by that renowned think tank of world-renowned economists (see also Bjørn Lomborg, this volume).

Biofortification can be approached via traditional breeding or via genetic engineering. The approach via traditional breeding is possible in cases where natural variation in the desired trait provides the necessary basis. This approach has the comparative advantage that this technology is widely accepted. "Genetic engineering" however, a technology which, in theory, represents the ideal technology for biofortification, is faced with and suffers from highly emotional opposition. The technology enables the targeted introduction of micronutrients at desired levels and specifically to those plant organs which are consumed. It further enables biofortification in all those cases, where traditional plant breeding fails because of lack of natural variation. And it allows for biofortification in those numerous cases where traditional breeding is inefficient because introgression of traits is difficult due to problems with crossbreeding. Considering those advantages the obvious question is: where are the expected examples of crops biofortified with the help of genetic engineering technology?

There is one very instructive example, which was initiated in June 1991, years before the concept of biofortification was developed, and which to date – 25 years later – and despite enormous efforts and support still did not reach the needy. This example refers to a novel variety of rice, dubbed "Golden Rice". This rice provides enough provitamin A to prevent vitamin A-deficiency from a daily serving of 40 grams, whereas normal rice does not contain any provitamin A and is one of the major causes for vitamin A deficiency. This "Golden Rice" was developed within the public domain throughout the entire progress in science, product development, and the regulatory process. It was advanced within the framework of a "humanitarian project" to be provided to subsistence farmers free of charge for the trait. This project is best suited to demonstrate the potential and the pitfalls of genetic engineering applied with the goal to contribute a public good for the reduction in micronutrient deficiency (for details please visit the homepage maintained by Humanitarian Golden Rice Board www.goldenrice.org).

Vitamin A-deficiency is one of the major public health problems of the globe. 190 million children and 19 million pregnant women are affected globally. It leads to 1-2.7 million deaths per year through immune response suppression. Ca. 500,000 children per year are blinded and ca. 600,000 pregnant women die annually at childbirth from VAD related causes. 23-34% reduction in preschool mortality can be expected from Vitamin A programs reaching children in undernourished settings.[1] A comparison of the global mortality data sets these figures in perspective with other, well-known public health problems: Global population mortality (in million): Vitamin A-deficiency – 1.9-2.7; HIV/Aids – 1.7; Tuberculosis – 1.4; Malaria – 0.75.

Vitamin A-deficiency is widespread in poor populations depending on rice as their major staple. Rice provides up to 80% of food calories, but is poor in micronutrients and does not contain any provitamin A (which the human body converts into vitamin A). The unavoidable consequence for hundreds of millions of poor who cannot afford a diversified diet is, therefore, vitamin A-deficiency, accompanied, of course, by deficiencies in other micro nutrients. In Bangladesh e.g. children obtain from their routine diet only 30% of the recommended daily intake, woman only 40%. The US Medical Council has established that 50% RDI is sufficient to prevent clinical symptoms of VAD deficiency. According to the concept of biofortification rice should, therefore, be altered in such a way that its content in provitamin A at least fills the gap to 50%. As rice contains zero provitamin A in the endosperm, there is no natural variation traditional plant breeding could use.

What can be done to develop rice with provitamin A in the edible part of the plant – the endosperm of the seed? Rice plants contain, as all green plants, large amounts of provitamin A in all green tissues. There is, however, nothing in the endosperm. Whereas provitamin A is vital in green tissues as protectant against irradiation, it does not make any biological sense in the endosperm. Four alternative approaches were at choice: 1) find a rice plant, or a plant related to rice, with "yellow" endosperm. If this "yellow" trait turns out to be "provitamin A" this would constitute the variation rice breeders could use to "biofortify" rice with traditional plant breeding (see Howarth Bouis, this volume). This variation was not found in more than 100 000 accessions from around the world and, therefore, does not exist. 2) In such a case it is possible to provoke variation by applying mutagenesis. This has been tried extensively applying all technical possibilities. Unfortunately this did not lead to yellow endosperm either. 3) The third possibility, which was considered the most promising one when we began our project, was to try to identify the "switch" the rice plant is using to turn off provitamin A biosynthesis in the endosperm. This project has funding since 1992, but the switch has not been found up to date. It must, however, exist and may be found one day. 4) This leaves us with the last possibility, which

[1] West KP Jr, Klemm RDW, Sommer A. (2010) Vitamin A saves lives. Sound science, sound policy. *World Nutrition* 1, 5: 211-229.

was judged totally unfeasible for numerous reasons: to engineer the pathway with the help of genetic engineering. This was a gigantic task because eight genes were involved and numerous cellular prerequisites were unknown. Together with my partner Peter Beyer from the university of Freiburg/Germany, we decided to give it a serious trial.

It took eight years with continuing uncertainties and with little possible checks in between until we saw the first yellow endosperms. When we published our results[2] this totally unexpected breakthrough electrified not only academia but also the media and gained us hundreds of articles including a cover story in TIME Magazine[3] and numerous academic recognitions. Fine, there was this welcome scientific success and this would normally have been the end of the work of scientists in an academic setting. However, to prevent vitamin A malnutrition, this scientific breakthrough had to reach the needy and it was obvious that the scientific breakthrough was only a first step towards this goal. It soon became clear that if we did not take care of this problem, nobody else would do so. In cases where scientific discoveries offer the chance for an economic success, e.g. in Medicine or Pharmacy, they will be taken up by the private sector which then has all the means to develop a product. In cases where the development of a public good is at stake, which does not offer a financial return to the private sector, there is nothing in the public domain to carry this on. We realised that we had to forget about our vision, or to take care of it ourselves.

And this was the beginning of a long and cumbersome odyssey. Neither we nor anybody else in the public domain had any idea what it meant to develop a GMO product within the public domain and deliver it to the needy. We had an established collaboration with the International Rice Research Institute in the Philippines. The most successful rice breeder so far, Dr. Gurdev Khush, was assuming that Golden Rice would be available for rice farmers from 2002 onwards. And this was everybody's expectation including our own. The fact that Golden Rice was a GMO, however, had the consequence that we had to invest an additional twelve years of work and enormous financial resources. "Golden Rice" is a scientific reality since February 1999. If it hadn't been a GMO, it would have been in use since 2002 and would have saved millions of children from blindness and death. Being a GMO, it will not be available to the farmers before 2014 – with a 12-

[2] Ye, X., Al-Babili, S., Klöti, A., Zhang, J., Lucca, P., Beyer, P., Potrykus, I. (2000). Engineering provitamin A (b-carotene) biosynthetic pathway into (carotenoid-free) rice endosperm. *Science* 287, 303-305.

[3] TIME cover, July 31, 2000 www.time.com

year delay. Twelve years with all their consequences which have to be blamed on regulation and opposition. As it was impossible to achieve our goal within the public sector, we struck a deal with the private sector: transfer of the rights in our invention to the private sector for commercial development in return for support of our humanitarian project. The architect of this "public-private-partnership" was Dr. Adrian Dubock, than Syngenta, who later became our "Humanitarian Golden Rice Project Manager".[4]

The outstanding challenge for the humanitarian Golden Rice project was GMO-regulation. It delayed deployment for more than ten years! There is no scientific justification for any of those requirements! There is scientific consensus that GMO-crops are at least as safe for the environment and the consumer as the traditionally bred ones we consume without regulation and hesitation. Numerous academies have published that there is no GMO-specific risk associated with the technology, e.g. the Swiss National Science Foundation 2012, the Pontifical Academy of Sciences 2010 (6), the European Commission's Scientific Advisory Panel 2008, the International Union of Food Science and Technology 2005, the Royal Society in London, the US Natl. Acad. Sciences, the Brazilian Academy of Sciences, the Chinese Academy of Sciences, the Indian Academy of Sciences, the Mexican Academy of Sciences, the Third World Academy of Sciences 2004, the GM Science Review Panel UK, 2003, etc. Transgenic plants have been planted for more than 12 years on over 170 million hectares in 23 countries and used by more than 17 million small-scale farmers with not a single documented case of harm to the consumer or the environment. Despite this unprecedented safety track record of the technology, the Golden Rice project had to follow all the established rules and regulations set up for work with transgenic plants and had to collect all the data required for a regulatory dossier. The time required by these unjustifiable requests did not sum up to 19 years, because some tasks could be approached in parallel. Socio-economic ex ante studies have shown that e.g. in India Golden Rice could prevent death and blindness of nearly 40,000 children per year. A delay in deployment is, therefore, not just an economic loss, but responsible for dramatic social consequences!

Deletion of selectable marker:	2 years
Screening for streamlined integration:	2 years
Screening for regulatory clean events:	2 years
Protection against liability problems:	1 year

[4] www.goldenrice.org homepage of the Humanitarian Golden Rice Project.

Trans-boundary movement of seeds:	2 years
Obligatory sequence greenhouse-field:	1 year
Permission for working in the field:	2 years
Requirement for one-event selection:	2 years
Experiments for the regulatory dossier:	4 years
Deregulation procedure:	1 year

And it required additional financial resources, compared to the development of non-GMO varieties, of ca. USD 32 million. The regulation-caused GMO-specific costs wherewith ca. USD 32 million: so high that they are prohibitive for any comparable GMO project of the public sector.

Once authorised for deployment by national biosafety authorities, Golden Rice will be free for use according the "humanitarian" concept: agronomically optimized and locally preferred varieties are developed by public rice research institutes in countries where vitamin A-deficiency is a severe public health problem and rice is the major staple crop. Once released by national biosafety authorities, seeds will be available to farmers free of costs for the trait.[5] They are from then on the owners of the seeds, can use them in their traditional production systems, do not need any additional agrochemicals and can use part of the harvest for the next sowing. There are no new dependencies whatsoever. The entire technology is in the seed. All patents are covered by free licenses. The only conditions in this humanitarian project: local trade is permitted, export is not allowed; profit beyond USD 10,000 is not considered humanitarian. This limitation will not affect anyone from our target population – subsistence farmers and local traders. It is the consequence that in our agreement for the public-private-partnership we had to define "humanitarian" versus "commercial" and this figure was a safe borderline for our intentions.[6]

Prohibitive regulation and aggressive anti-GMO politics have a strong negative impact on numerous further projects on consumer-oriented traits from public sector scientists[7] such as

[5] www.irri.org/goldenrice Golden Rice on the homepage of the International Rice Research Institute which leads product development for the Philippines, Bangladesh, and Indonesia.

[6] I. Potrykus and K. Ammann (eds) (2010) Transgenic Plants for Food Security in the Context of Development. Proceedings of a study week of the Pontifical Academy of Sciences. *NewBiotechnology* 27 (5).

[7] Biotechnology for Enhanced Nutritional Quality in Plants. Ayse Ozgur Uncu, Sami Doganlar, and Anne Frary. *Critical Reviews in Plant Sciences*, 32:321-343, 2013.

Protein modifications
e.g. essential amino acids

Carbohydrate engineering
e.g. inulin, amylose

Fatty acid modification
e.g. omega-3, polyunsaturated

Vitamin engineering
e.g. vit. A, E, C, B6, B9

Antioxidant engineering
e.g. lycopin, astaxanthin

Mineral content modification
e.g. iron, zinc

Reduction of plant allergens
e.g. in rice, soybean, wheat

Reduction of toxins
e.g. linamarin in Cassava

Zinc biofortification for rice is possible to the required target level via traditional plant breeding approaches because natural variation is good enough for that purpose (see also Howarth Bouis, this volume). However iron biofortification, desired for nearly 3 billion needy, most probably will not reach target levels from natural variation and will, therefore rely on genetic engineering, which has already achieved proof-of-concept. Product development and deregulation will suffer from the same delay and require the same amount of financial input as just described for Golden Rice. And the same is true for most of the other traits indicated above.

Biofortification of rice is in progress on several fronts. Besides provitamin A rice which is close to deployment (see IRRI homepage), there is "high iron rice" where, thanks to genetic engineering, the target level of 14 micrograms/gram has been reached (Howarth Bouis, personal communication). For this case as for all the following more than ten years of product development and deregulation will have to follow, just as it has been the case for Golden Rice. "High zinc" rice has been reached without genetic engineering and product development, therefore can be expected to be much shorter (see Howarth Bouis, this volume). Biofortified "folate rice" was published in 2007,[8] however to the authors' knowledge, product development had problems in attracting funding. In the context of "high quality protein rice" (for provision of "essential" amino acids which our body cannot synthesise) the example of the gene from "Winged bean" (*Psophocarpus tetragonolobus*) is a perfect illustration of the irrationality against GMOs. Winged bean is a popular vegetable consumed for centuries by hundreds of millions in Southeast Asia. It contains a storage protein high

[8] S. Storozhenko *et al.* Folate fortification of rice by metabolic engineering. *Nature Biotechnology* 25, 1277-1279 (2007).

in lysine. The gene was isolated and transferred into rice where it produced the storage protein in desired quantities. Product development was blocked by regulatory authorities when Prof. Samuel Sun, Hong Kong, proposed to combine this trait with Golden Rice. The reason for refusal was a short stretch of hypothetical allergenicity. Although the protein was and is consumed at large scale from the bean without any problem, it is not acceptable as an identical protein in rice[9] (personal communication by Prof. Samuel Sun, Hong Kong). Of course, if it could be crossed in, this would be a welcome improvement! As those deficient in one micronutrient are normally deficient in several micronutrients (see also H.K. Biesalski this volume) the long-term goal of biofortification is the simultaneous improvement in several micronutrients. The combination of "provitamin A" with "high iron" and "high zinc" in rice is a realistic option for the near future, and folate could be added as well. To facilitate deregulation it is advisable to combine the traits after deregulation. The combination would be done via traditional breeding.

The "high quality protein" topic may also serve as example of the potential of genetic engineering technology. Our body requires ca. 20 amino acids for protein biosynthesis. Ten of those it can synthesise; the remaining 10 have to come from the diet. An "ideal" storage protein should contain, for that purpose, the 10 essential amino acids in the desired ratio. Such a protein does not exist in nature. But it can be approached by the construction of a "synthetic gene" coding for the 10 amino acids in the desired relative quantities. Jesse M. Jaynes, a talented protein chemist from DEMEGEN USA, constructed the gene, arranging the triplet codes for the amino acids in the desired quantitative ratio in such a way that the protein would consist of stretches of amino acids with a positively and negatively charged surface on both sides. Adding a few beta turns led to a protein with the key functions of a storage protein. My laboratory inserted this gene into rice and demonstrated that the protein was produced, though at low concentration in this first experiment. This exiting approach was no longer followed up because it was just before my retirement and such a synthetic gene and synthetic protein would have had little chance to pass regulatory requirements.

There is a host of evidence that GMO technology has the potential to contribute substantially to food/nutrition security – and that the public sector is highly motivated to explore this potential for public good. However as long as the media, politicians, churches, and our society prefer to

[9] ssun@cuhk.edu.hk email address of Prof. Samuel SM Sun.

listen to self-serving activists instead of scientists, GMO technology will not be able to substantially contribute to food- and nutrition security. Most of all, this exciting proof-of-concept work will *not* lead to products which are the prerequisite for reaching and helping the needy. Golden Rice may still represent an exception because it received, as a "pioneer" project, unusual financial support. Millions of poor are taken hostage in an ideology-driven fight for political power and campaign money – applauded by brainwashed Western societies.

The bottlenecks for public good research and development in the area of genetic engineering with plants are all related to product development and deregulation. There are no specific hurdles as far as basic research is concerned, although financial support even for basic research in the area is drying out.

Conclusion

1. There are no public funds available for product development and deregulation.
2. The financial requirement is more than 10 times higher compared to that for proof-of-concept work.
3. There is little competence for product development and deregulation within the public sector.
4. Intellectual property rights and Material Transfer Agreements which can be ignored as long as work for basic research is progressing are becoming severe hurdles as soon as work for product development begins. Free licenses depend totally upon goodwill of the patent holder and Material Transfer Agreements may become prohibitive because of fear of putative liability problems.
5. Nothing from all the work for product development has a chance to lead to publications, because there is no chance of "scientific novelty".
6. Therefore all this work is "highly toxic" for any academic co-worker and career. With Golden Rice we were fortunate that we could use the results from the work Syngenta invested in the development towards a commercial product using input from non-academic personnel.
7. There is no "bonus for public good" to be had from regulation. Public good GMO products must follow all regulations and provide all data as required for commercial products from the private sector.
8. Compared to the private sector the public sector has no means to protect GMO work against hostility and vandalism from the anti GMO lobby.

9. The very welcome financial support from altruistic sources changes "freedom to operate" and may come with "foreign micromanagement" and even "take-over".
10. The understandable desire for absolute protection against "liability" in case of the "unintended presence" of unauthorised GMO material is the overarching problem for the private sector partner in a public-private-partnership. This is understandable because there have been extremely expensive precedents of fines of hundreds of millions of USD.
11. Public-private partnership is in theory an ideal solution which, however, suffers from this situation.
12. The root cause for all these almost prohibitive bottlenecks is GMO-specific regulation maintained in the face of worldwide scientific consensus that there is no GM technology-inherent specific risk and consequently no scientific justification for GMO specific regulation.

Final Statement

Bread and Brain, Education and Poverty Final Statement

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The Complexity of the Problems

Hunger and childhood undernutrition remain a scandal in a world that could produce and make accessible enough healthy food and nutrition services for all.

Hunger violates human dignity. New insights suggest that nutritional deficiencies severely reduce cognitive capacities. The poor not only suffer from hunger, but their future potential is also undermined, and deficient education services further contribute to unfair exclusion. Related problems are worst in poor rural areas and in urban slums, which house over 1,000 million people that live in most adverse circumstances and in poor sleeping conditions that amplify health- and education-related problems.

Given the challenges, a working group was formed in the Pontifical Academy of Sciences by an unusually diverse assembly of scientists, coming from fields such as agriculture, biotechnology, nutrition, brain research and neuropsychology, public health, economics and education. The working group noted the state of nutrition and education problems and identified a set of actions.

Understanding the Relationships among Nutritional Problems, Cognitive Potential, Education, and Health

The problem of hunger (deficiency in calories) is firmly established on the political agenda and reduction of hunger is one of the Millennium Development Goals. Nevertheless, "hidden hunger" (deficiency in micronutrients such as iron, zinc, iodine, and vitamins – in particular vitamin A, D and folate) is not yet widely recognized as a central problem and does not receive the political support it deserves, considering the magnitude of this public health problem affecting about 2,000 million people.

Deficiency in micronutrients is a major cause of many of these negative consequences on brain development, with all their dramatic and unfair social consequences. There was broad consensus that micronutrient deficiency also interferes with brain development and mental capacity building, and that damage is especially severe within the first thousand days from conception. Interventions to prevent hunger and hidden hunger are, therefore, critical during pregnancy and early childhood.

Based on emerging scientific insights and new technologies, the working group identified opportunities to improve food and nutrition. Actions were reviewed to counter the adverse effects of nutritional deficiencies to prevent related early neuronal damage, targeting not only nutritional needs but also providing affection and emotional and cognitive stimulation for healthy mental development and a sound education.

Recognizing the Inadequacy in Educational Services

"Bread and Brain" problems are most visible in the plight of education. Millions of children are excluded from education and are not receiving their fair share of available knowledge or a sound pedagogic approach to the values of truth, goodness and beauty that make us human and that should support the new generations in a globalized society. The Millennium Goals will not be attained if we don't take a great leap forward and create new pedagogies that can reach even the most remote and deprived areas of the world.

What Can Be Done? Priority Actions for 'Bread and Brain'

Successful programs already in place were presented and discussed in detail by the working group, including actions for improved micronutrient nutrition, new digital technologies for use in poor and isolated communities, and early age and child immigrant education, as well as better shelter for poor neighbourhoods. The working group felt that such actions need to be combined in order to achieve the required synergies.

We want to share our conviction that hunger, malnutrition and extreme poverty can be overcome by 2030, if appropriate scaling up of joint efforts is combined with application of the best technologies available.

We noted that addressing food and nutrition security comprehensively requires an agenda for productivity, well-functioning markets, and social protection with direct interventions to facilitate improved nutrition. We also received an overview of the efforts of the International Agricultural Research Centres to keep up with increasing demands for nutritious food.

We learned about the Copenhagen Consensus – a think tank of economists – that identified the most profitable investments of available financial resources, along with the highest possible development impact for improving micronutrient availability. Of the various possible interventions for that purpose we noted the established potential of interventions by "supplementation" (supplying the missing micronutrients in optimized formulations of minerals and vitamins as a substitute for an incomplete diet), which need substantially more support.

Many poor, however, are out of reach for such interventions and depend predominantly upon starchy staple crops. These are excellent calorie sources, but are unfortunately very poor in micronutrients. An ideal "diversified" diet consisting of animal products, fruits and vegetables in addition to energy-rich staple crops is not accessible to hundreds of millions of poor. Therefore, we found the novel concept of "biofortification" – the genetic enhancement of micronutrients in staple crops – very promising, where data have become available demonstrating the efficacy of this concept, such as the enhancement of provitamin A in Sweet Potato.

We reviewed and discussed the prominent role biotechnology can play to enhance biofortification, such as the example of "Golden Rice" which, in half a cup of rice, provides the missing vitamin A that normal rice does not contain. Lack of vitamin A, for example, leads to blindness and an impaired immune system, causing 500,000 children to be blind and 2 million deaths. Iron deficiency, a problem for ca. 3,000 million people, not only leads to anemia but impairs brain development and has a strong negative effect on intellectual, cognitive and mental capacity with all their social consequences. Deficiencies in vitamin A and D may also have a negative impact on brain development.

The real opportunity offered by plant biotechnology, however, is often blocked by anti-GM initiatives and over-regulation, both of which prevent its proper utilization. In the interest of those suffering from micronutrient deficiencies we call for support of research exploiting the potential of biofortification for public good, and for education and political support for the deployment of biofortified crops by farmers, which can benefit the poor.

Provision of micronutrients is absolutely essential for embryonic development, starting at the time of conception. During this period the only source of micronutrients is the pregnant mother. This strong dependence continues after birth for as long as the mother breastfeeds her baby. However, if the mother's vitamin stores are depleted due to poor nutrition or frequent pregnancies with a short birth interval, breast milk can become a rather poor source. Reliable provision of micronutrients is, therefore, of outmost importance for pregnant and lactating mothers.

We examined how the adverse effects of deep, concentrated poverty and stress factors compromise brain function, especially in the critical areas of language, executive function, and declarative memory, but also noted that, with positive reparative environments, certain brain functions can be recovered.

In low-income countries there are 72 million children with no schools, and 793 million human beings who cannot read. For these children new technological tools are promising, and information and communication technologies can make a strong contribution to improve educational opportunities, for instance by providing these children with computers.

In order to promote good, early childhood education it is crucial to overcome the sad reality of "poor schools for the poor" observed in many countries and to improve the basic professional training of kindergarten and primary schools directors and teachers around how to address the special needs of children in disadvantaged socio-geographic contexts.

In some contexts, children may take on new roles as teachers, as the place of learning migrates from "formal schools" to other contexts, etc. This is an area ripe for careful interdisciplinary empirical research and intervention.

Investments in early childhood education must be mindful of nutrition and environment, maternal literacy and ongoing teacher education. Once children enter the primary grades, school leadership (teacher/principal) and investments in school facilities have been found to make a difference.

What Do We Hope? Conclusions

The PAS working group concluded that, while food and nutrition security is a complex issue, there are sound context-specific opportunities to accelerate action. The consequences of nutrition deficiencies for human cognitive capacities must no longer be overlooked, but must motivate us to much faster and more significant actions that combine agriculture with nutritional interventions and innovations in education.

Outlook

The situation urgently demonstrates the need for a new way to bring all science communities related to food and nutritional security together in a permanent international platform for evidence-based advice to policy-makers and society.