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Rethinking Cells to Society

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Abstract

It is an exciting time to be a developmental scientist. We have advanced theoretical frameworks and developed ground-breaking methods for addressing questions of interest, ranging literally from cells to society. We know more now than we have ever known about human development and the base of acquired knowledge is increasing exponentially. In this paper we share some thoughts about where we are in the science of human development, how we got there, what may be going wrong and what may be going right. Finally, we offer some thoughts about where we go from here to assure that in the future we achieve the best developmental science possible.

Keywords

life span development; life course development; epigenetics; systems theory

It is an exciting time to be a developmental scientist. This is true of all disciplines focused on issues of human development, including for example, anthropology, biology, economics, medicine, psychology, and sociology (Cairns, Elder, & Costello, 1996). We have advanced theoretical frameworks and developed ground-breaking methods for addressing questions of interest, ranging literally from cells to society. More than ever before, we recognize the multiple levels and dimensions that influence individual development over time. At the micro level, we have access to techniques and technologies that allow us to examine cellular functioning and gene expression, observe the brain, and detail biological changes resulting from these processes. At the macro level, we can produce representative samples of societies at multiple levels (i.e., city, region, state, nation), thereby accurately reflecting the diversity present within (i.e., racial and ethnic, socio-economic status, age, etc.). We can reliably and validly survey their attitudes, values and beliefs. We recognize that environmental context and stressors can effect human development. With the availability of techniques such as geocoding and our ability to accurately assess environmental toxins, we can better understand the role of this context in human development. As a result of all of this, we know more now than we have ever known about human development and the base of acquired knowledge is increasing exponentially.

The knowledge and tools available to us are fundamentally redefining our science. There have been times in the study of human development when we believed that we were trying to discover *the* theory or *the* principle that was the only “correct” or “right” one. We once

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viewed the goal of developmental science to uncover the universal or absolute laws that governed developmental processes. The classic example is the nature versus nurture debate where developmental scientists argued for years about which was the defining characteristic or causal directive of development (Collins, Maccoby, Steinberg, Heatherington, & Bornstein, 2000; Garcia Coll, Bearer, & Lerner, 2004; Goldhaber, 2012; Rutter, 2002; 2006). But historically there have also been similar debates about instincts, learning, social relations, personality, and many other topics of interest. As more recent scientific evidence concerning the nature/nurture debate has taught us, development is flexible and complex, influenced by multiple factors, at multiple levels, and at various points in the life span (Antonucci & Jackson, 2010).

Our challenge, and we would argue our responsibility, is to ensure that our field remains open to the multiple potentials of all theories and methods, and recognizes that good quality science always has the potential to make a contribution. We make this point as a note of caution that our science not return to the aforementioned myopic approach that assumed one perspective, one technique, or one approach was the only ‘correct’ one. We propose that we be vigilant and cautious about how we embrace and utilize the new theories, tools, and information available to us.

Having said this, we do believe that in these exciting times developmental scientists now, and in the next generations, have the potential to achieve incredible advances that will fundamentally improve our understanding of and ability to optimize human development. Below we share some thoughts about where we are in the science of human development, how we got there, what may be going wrong and what may be going right. Finally, we provide some thoughts about where we go from here to assure that in the future we achieve the best developmental science possible.

Where Are We?

It is clear that we have made considerable advances in our understanding of human development. Perhaps most fundamental is our recognition of the links between micro and macro influences on human development (Brofenbrenner, 1977). As Figure 1 indicates, there are multiple levels of human development: cells, individuals, family/community, and society/culture. Each level represents an important aspect of development. We also now recognize that these multiple dimensions influence each other. Although our knowledge at each level is hardly complete, our understanding in these areas has advanced extensively. We recognize that cellular and molecular functioning are critical parts of human development. We are aware that cells are influenced by the broader environment and even more critically that growth and development are neither unidirectional nor fixed (Antonucci & Jackson, 2011). Further, we recognize that individuals grow and develop across the life span/life course and we gain much by understanding this intra-individual development. For example, we know that individuals develop with age and over time. This occurs simultaneously over multiple dimensions, e.g. cognitively, socially and emotionally; and across multiple levels, from the most basic fundamental levels to more complex and advanced levels. Hence, we have important research being conducted in areas that have

required new labeling in recognition of this cross-level and dimension influence. Examples include social cognition, emotion regulation, and cultural neuroscience.

At the same time, we have come to an entirely new understanding of the phrase ‘no man is an island’. Inter-individual development, in both the narrow and broad sense, is now seen to be critical to human development. It is widely recognized that individual development is fundamentally influenced by the specific individuals with whom one interacts, i.e., parents, siblings, family as well as the broader community, e.g. friends, neighbors, teachers, co-workers (Botts, 1957; Brofenbrenner, 1977, 1998; Cantor, 1979; Elder, 1999, 2000, 2009; Bowlby, 1969). It is worth reminding ourselves that at one point we assumed that individual development was predetermined, fixed and immutable. Family context and interaction did not matter, nor did community. Cognitive development or intelligence was thought at one time (and I suspect some people still believe) to be genetically pre-determined (Herrnstein & Murray, 1994). Intelligent people would be intelligent, no matter what opportunities their family or community had to offer them. This view has had to be modified in light of empirical evidence (Nisbett, 2009). It is now clear that enriched environments can enhance cognitive development and intellectual functioning whereas deprived environments can have the reverse effect and stunt intellectual or cognitive advancement (Kaler & Freeman, 1994). While it is generally agreed that there are individual differences in intelligence, many now feel that there is more intra- than inter-individual variation based on environmental experiences. Enrichment might include a supportive, loving, encouraging family or a community with inviting public spaces, safe neighborhoods and stimulating schools. The same has been shown to be true of every type of development we study.

At one point we believed society and culture had little effect on development. For example, it was initially believed that the Ainsworth Strange Situation would be the appropriate attachment assessment tool in all cultures. We later learned that societies, and by extension culture, influences the experience and hence the reactions of infants to their social world. It is now widely agreed that children can express secure attachment similarly, but also differently, across cultures (Cassidy & Shaver, 2010; Haywood, Miller, & Irizarry, 1995; Keller, 2012; Takahashi, O’Hara, Antonucci, & Akiyama, 2002). Thus, children reared in group settings react differently to strangers, whereas children who are never separated from their mothers are not easily comforted when separation does occur no matter how securely attached they might be (Takahashi, 1986; Van Ijzendoorn, 1990). Similarly, we have learned that for people who must recognize signs of danger in the wild, they are incredibly knowledgeable about clues with respect to predators and other dangers, whereas city dwellers might be able to navigate a complex metropolitan train system but have no clue about how to protect themselves in the forest.

Given what we now know about culture, it seems incredible that we ever believed that culture had little effect on development. Or even more unfortunate, and perhaps a good lesson in humility, is that it was once believed that if another culture differed from ours, ours was the more advanced or correct, while the other lagged behind. Certainly, how we think about development has changed. Below I provide two illustrative examples: life span/life course development and gene-environment interplay.

Life span and life course development

The study of life span and life course development has emerged from somewhat different disciplinary traditions (Fuller-Iglesias, Smith, & Antonucci, 2010). Life span development is most frequently associated with psychology. Paul Baltes (Baltes, 1987, 1997; Baltes & Smith, 2004) did much to advance this approach, although one could argue that the concept has been present either explicitly or implicitly in numerous other theoretical perspectives, e.g. Freud's psychoanalytic theory and Erikson's psychosocial stages theory (Erickson, 1950). Even learning theory suggests a cumulative effect of stimulus-response experiences, though this may not be the same as is usually meant by life span development. As noted above, the life span developmental perspective argues that individual development is cumulative and that one phase or stage affects the next. It is characterized by adaptivity and plasticity. Baltes argued that development was affected by biological and environmental factors as well as an interaction of the two, which he called bioenvironmental factors (Baltes, 1987). Further, anticipating later work, he argued that the major antecedent systems of change included ontogenetic age-graded change, evolutionary history-graded change, and non-normative factors which also influenced change in the individual's life span development. In later writings he spoke of these influences as the bio-cultural co-construction of development (Baltes & Smith, 2004). This perspective is now widely recognized at the theoretical level, but is also increasingly discussed at the empirical level.

One of the first examples is the consideration of attachment as a life span concept. While much of the work in attachment originally focused on mother-infant attachment, in fact, Bowlby argued that attachment should be considered a life span concept (Bowlby, 1979). He noted that early attachment relationships with mother and other primary caregivers would lay the groundwork for later child, adolescent and adult relationships. An early special issue of *Human Development* (Antonucci, 1976) elucidated this perspective and provided empirical evidence of attachment at different stages of life. Later, this proved to be a popular topic of both theoretical and empirical inquiry (Cowan, Bradburn, & Cowan, 2005; Hazen & Shaver, 1987; Main, Kaplan, & Cassidy, 1985; Mikulincer & Shaver, 2010).

Life Course Development theory is most closely associated with sociology. Glenn Elder (1974; Elder & Giele, 2009) did much to advance this approach, which argued that roles, community context, environment and historical events all influence development. The life course is also acknowledged to be influenced by age, cohort and period effects. These effects are cumulative, which means that equalities as well as inequalities can and do accumulate over time (Dannefer, 2003). Their effect can be either positive and enriching or negative and disadvantaging. The life course perspective is perhaps best illustrated by Elder's (1974, 1999) work on the *Children of the Great Depression*. Elder showed, not only that the Great Depression influenced an individual's entire lifetime, but that the prior experience and historical context of the historical event, i.e., the Depression, fundamentally altered the effect of that event on the individual. In the study of the Great Depression he identified two cohorts: one from the 1920s and a second from the 1930s. He demonstrated that children from the 1920s cohort who experienced childhood during an economically prosperous time and then experienced the Depression during adolescence were better able to rebound and recover from the depression. In most cases they managed to be quite successful

as adults. On the other hand, children from the 1930s cohort experienced childhood during the Depression and were hit much harder by the depression with longer lasting effects. These children were much less likely to recover, with their entire life trajectory negatively affected, resulting e.g. in significantly reduced educational and occupational attainment.

Elder and Conger (2000) replicated the finding with a study of farmers experiencing a similar economic downturn in the Midwest. The devastating effects of the farm recession affected the children differently depending on their age and gender when the farm crises occurred. Similar findings have been documented with the Civil Rights Movement in the United States (Gee, Pavalko, & Long, 2007). If individuals were young and could take advantage of new opportunities made available, e.g. education, individuals' life trajectories were changed, but if they were middle aged, the educational opportunities, though available, were not likely to change individuals' life course trajectories. In sum, the life span and life course perspectives emphasize that lives are linked to the past, to others, and to circumstances. These all influence individual life trajectories and pathways of aging. As developmental scientists we recognize that these are critically relevant influences on development.

Increasingly, researchers have argued that the life span and life course perspectives cannot reasonably be separated (Fuller-Iglesais et al., 2010). This has not always been the case (Settersten, 2009), and it is clear that specific researchers might still emphasize one over the other. However, researchers are increasingly recognizing that each clearly affects the other. In fact, much as the nature nurture debate has been replaced by a widespread understanding the both are influential, the same conclusion increasingly seems to be drawn with respect to life span and life course development.

Gene environment interplay

Advances in the study of genes were soundly heralded. The mapping of the human genome was greatly anticipated. It was assumed that many mysteries of human development would be solved. Many believed that with the complete identification of the human genome we would be able to identify the causes of most diseases and ultimately cure them or even preempt their manifestation. During this period, psychology and the behavioral sciences were increasingly seen as rapidly becoming irrelevant as most psychological problems and, indeed, optimal human development, would be resolved through genetic identification and perhaps even manipulation. No such future came to pass. In fact, it has become increasingly clear, first to our geneticist colleagues and then more generally, that even with the identification of the human genome, this would not be the case. It was soon discovered that few diseases were caused by a single gene and that most characteristics of interest could only be understood as a product of multiple gene influences and even more commonly as the product of gene environment interplay (Wanke, Partridge, & Antonucci, 2011; Antonucci, Birditt, & Ajrouch, 2011).

Gene-environment interplay refers to interconnections between genes and the environment, encapsulating both interaction and correlation effects. On the one hand, independent genetic and environmental factors interact with one another to modify outcomes. On the other hand, gene-environment correlation, referring to the fact that genetically influenced characteristics

may be correlated with environmental factors that are similarly influenced either by the same or other factors, also influences outcomes. Both gene-environment interaction and correlation influence outcomes in a way that suggests ignoring either precludes a full understanding of human development. Another recent advancement is the increased awareness and scope of epigenesis, i.e., the ability of non-genetic factors such as environmental or experiential factors, to actually modify gene expression. A recent study of alcohol use among Finnish teens highlights the importance of examining the influence of both genes and environment as well as the importance of considering issues over time. In this longitudinal study of twins aged 16 to 18 years old, there was a clear influence of genetic factors on alcohol use, which increased over time. However, an examination of rural versus urban living environments indicated a clear influence of context, with teens living in rural settings more likely to increase alcohol use than teens living in cities (Rose, Dick, Vicken, & Kaprio, 2001). This example is illustrative of the complexity of gene-environment interplay. For a developmental scientist this is truly exciting because it suggests that there is very little developmentally that is irreversible or, at the very least, not potentially amenable to change.

How Did We Get Here?

We want to reiterate how far we have come in addressing problems of contemporaneous importance, using the theories and methods available at the time, and building upon these as problems change, new tools become available, and confirming or disconfirming evidence accumulated. Consider the sample case of social relations.

Since social relations have been with us since recorded time, it is hard to know just how far back we should go, but for the purposes of this illustration, let us begin in the early 1900s. People noticed that some children seemed to thrive while others did not. Early studies of children who failed to thrive focused on maternal deprivation, targeting children who were separated from their parents due to death, economic hardship, or political conflict resulting from war. Explanations for why these children failed to thrive included separation from their biological mother/parents, undernourishment or unclean substitute environments, and under-stimulation (Spitz, 1945, 1949). Misguided views first thought that children could not thrive unless raised by their biological mother and that such children would never develop normally. In the cases of children without parents, this led to the belief that no intervention would help. In other cases, nutrition was improved and carefully monitored, which did lead to some improvement. At one point, concern that institutionalized children were not clean led to a notable improvement in the cleanliness of institutions that housed these children, but some of these interventions also included the elimination of stimulation and social interactions because it was feared this would expose the children to germs and unsanitary conditions. Thankfully, careful observation and natural experimentation has led us to understand that we need to maintain nutrition and cleanliness for children but that they also need social interaction and multiple forms of stimulation.

We have advanced a great deal in the study of social relations. For example, while recognizing that mothers/parents have critically important roles to play in the development of their children, we now know that children raised by non-biological mothers can thrive

while biological mothers can be a negative influence and have children who thus fail to thrive.

We have benefited from animal studies (Harlow, 1958; Meaney, 2001; Suomi, 2004; 2006). We briefly summarize some of this work to provide a flavor of what we have learned from what we call complementary science. The field of development science has learned quite a lot from Harlow's studies of terry cloth and wire mother monkeys, i.e., that infant monkeys would seek the comfort of terry cloth mothers even if the wire monkeys provided milk (Harlow, 1958). We have learned from Suomi's (2006) work with monkey's that both genes and environment influence behavior. He was able to show that while mothering style is transgenerational, i.e., transmitted across generations, cross-fostering can change this transgenerational transmission. As an example, infant monkeys of biological mothers with poor mothering styles, who were then cross-fostered with mothers who have good mothering styles not only were more secure themselves but engaged in more positive mothering styles when they themselves became mothers. In other studies, he found that infant monkeys raised by their mothers fared much better than those raised by peers. Similarly, Meany (Meany, 2001; Weaver, Meaney, & Szyg, 2006) has offered an interesting illustration of the relative effects of genes and environment by demonstrating that the negative effects of being born of a mother with poor maternal behaviors can be completely offset by having the rat pup reared by a mother with good maternal behaviors. Adding to the complementarity of interdisciplinary work, Meany is undergirding these behavioral interventions and observations with biomeasures indicating that the pups' biochemistry reflects their experiences and by specifically documenting the epigenetic effects of these experiences.

At the human level, many will be familiar with the theoretical writings of Bowlby (1969) and Ainsworth (Ainsworth, Blehar, Waters, & Wall, 1978) who developed and expanded upon the concept of attachment. Much of this work followed the concerns above, focusing on identifying the optimal conditions for child development. It has contributed to our understanding of adult parent-child relationships, dysfunctional and pathological adult attachment relationships, as well as romantic attachments and intergenerational transmission of attachment styles.

The study of social relations across the life span and research on convoys of social support is grounded in these early theoretical contributions and empirical findings (Antonucci, Ajrouch, & Birditt, 2014). This incorporates the study of both dyadic close relations such as parent and child or romantic partners, as well as other close and distal relations. To take one example of how this research has evolved, we have developed a corpus of research evidence documenting how social relations can make a person more vulnerable to stress or more resistant to the effects of stress (Antonucci, Ajrouch, & Janevic, 2003; Ajrouch, Abdulrahim, & Antonucci 2013). Using the new technologies available to us we are able to document how daily positive or negative social interactions influence daily mood (Birditt, 2013) and cortisol (Birditt, Nevitt, & Almeida, 2014), and how in the presence of the G-allele in a particular polymorphism (5H2TA-G1438A) an adolescent is more likely to engage in risky behaviors under certain, facilitative == i.e., tempting -- environmental circumstances (Burt, 2009). Gerontologists are using this work to develop environments for older people that will provide supportive circumstances that enhance independence, healthy

behaviors and reduce susceptibility to Alzheimer's disease. Interesting work by Fratiglioni, Paillard-Bong, & Winbald (2004) suggested that older adults who engage in social interactions are significantly less likely to develop Alzheimer's disease. These findings underscore the importance of recognizing the multiple levels from cells to society, or biology to social environments, that influence development including the health and behavior of individuals across the life span and over the life course.

It Is the Best of Times

New methods have played an important role in the advances achieved in every dimension and at every level of human development. For example, links across multiple levels, i.e., from cells and society, have been made possible by novel techniques such as Functioning Magnetic Reasonance Imaging (fMRI) and Functional Near-Infrared Spectroscopy (fNIRS). Both permit still somewhat crude but nevertheless exciting, access to brain reactivity. New tools in eye tracking allow detailed measurement of individual attention to stimuli presented either in natural or experimental settings. This has been shown to be useful in studies ranging from infant habituation, autism to student-teacher classroom interactions. We now have impressive tools for obtaining biomeasures in either experimental or field settings. In particular, these include cortisol and C-reactive protein, both of which make it possible to assess biological reactivity to stress. This has stimulated an entirely new level of exploration concerning the interaction and/or bi-directionality of psychological and physiological experiences.

In addition, we have been experiencing a period of incredible creativity in terms of new methods of data collection. The availability of new technologies permits data collection using devices such as Personal Digital Assistants (PDAs). This means that people can provide on-the-spot data, any time of the day or night. One can collect data at the exact moment an event occurs, such as, a pleasant or negative encounter with another or the experience of a stressful event or daily hassle. New methods have also been added to the arsenal of survey assessment. Daily dairies are now commonly used which, as the name implies, permit the collection of data on a specific topic or topics every day for a defined period of time. This allows for more immediate assessments both pre and post-event, thus providing more on-the-spot, real time data, as well as more numerous assessments which are less prone to inaccuracies of recall data.

The internet is now being utilized as a cost-effective, quick, and convenient means for collecting data. Moving from a frequent reliance on college students, which is limited both in terms of their representativeness and their accessibility, internet data collection opens a vast array of possibilities. Samples can now range in the thousands and data can be collected very quickly. Limitations are, of course, also evident in that these samples are usually non-representative and their accuracy or veracity is difficult to verify. However, as use of the internet continues to increase these limitations may addressed. Other approaches have combined several forms of data collection. This has the advantage of off-setting known limitations of various measures. Thus, a representative sample might be identified first and interviewed in the traditional manner, at which time an email, cell phone or internet address might be obtained or a PDA distributed for use in additional data collection. Similarly,

longitudinal data might be obtained weekly or monthly but then complimented by a burst of data collection which might be daily or even hourly.

Systems science

Systems science has made important contributions to how we think abouthuman development (Urban, Osgood, & Mabry, 2011). This approach derives clearly from both life span and life course theories, but also builds from several early theorists including Brofenbrenner's (1977; Brofenbrenner & Morris, 1998) bioecological theory, Thelen's (1992; Thelen & Smith, 1998) dynamic systems, Lerner's (2002) developmental contextualism, and Blumer's (1969) symbolic interactionism. Systems science takes a multilevel approach and utilizes new and emerging analytic tools. It permits the consideration of development as a dynamic system with multiple influences, on multiple levels, capable of evolving in multiple directions. It takes advantage of newly emerging methods such as complex multifactorial designs, network analysis, and agent-based modeling. In addition, computer science has offered new approaches that have proven useful to systems science. These include cyber-infrastructures, computational modeling, and the informatics superhighway. As ever more interesting and complex information becomes available to the study of human development, new tools and analytic strategies make it more possible to benefit from this information. Again these developments are new and exciting, offer much potential for the future, but also clearly build on the shoulders of previous carefully developed theories and empirical evidence. For example, a computer simulation of human behavior is only as good as the theoretical and empirical assumptions used in the programming.

With respect to advancing theoretical as well as empirical approaches, the newly evolving systems science is a fine illustration of advances in the field. We believe it will continue to do this in the future, as more and more people change the way they think theoretically and subsequently design experiments. It will also make another contribution to the study of human development in that it illuminates the benefits of collaborative approaches to human development. It is unlikely that we will be able to train any scientist to be an expert in all the areas\systems that we now recognize contribute to human development. Thus, it will be increasingly necessary for scientists to collaborate across disciplines. Depending on the focus of study, developmental scientists may find it profitable to work with anthropologists, biologists, engineers, economists, geneticists, mathematicians, physicians, sociologists and/or statisticians.

It Is (or Could Be) the Worst of Times

While we have made many important advances, the best of which, we would argue, have been made by building on the science of the past and working across disciplines, there are some who persist in the attempt to create a hierarchy of science. For instance, one may find some who believe biology trumps sociology, neuroscience trumps behavior, physical health trumps mental health. Similar hierarchies are being created with regards to methods. While, of course, one must always argue on the side of high quality science, it is also important to recognize that innovation does not always emerge at the top of the quality science hierarchy. Examples are numerous. When we first started using observation as a scientific method, we

often did so by observing an individual or individuals while in the same room or thru a one way mirror using a paper and pencil. There were problems resulting from the observer being in the room or the necessity of relying on an individual's instantaneous observation. Now, we are able to observe using highly sophisticated video equipment that allows one to observe in real time but also to review multiple times and with great specificity capturing second by second changes, using split screens to observe different members of a dyad simultaneously. In fact, with the internet and Skype, not only do we no longer need to be in the room, we can actually observe and record while many thousands of miles away. Observational studies have come a long way but we would have never been able to if we had not explored the benefits of the technique, even with all of their imperfections.

In other areas, similar hierarchies have been or are being created and we would argue have the danger of misdirecting our science. As noted above, anticipating the identification of the human genome led many to expect that genetics would replace behavioral science. This has not happened as scientists have begun to recognize the influence of environmental circumstances on gene expression and suppression. The field of epigenetics, indicating that environmental circumstances can influence gene expression both positively and negatively, has for many called a halt to this biologicalization of human development. Nevertheless, some still assume that a genetic explanation trumps all others, and we argue that we must be cautious of such assumptions.

We, as scientists, always seem to be infatuated with the latest technique, measurement, technology, or analytic strategy. This is fine. It is how we advance because we are open to change, to new approaches that offer new insights concerning questions of interest. Our concern, though, is the attitude that new is always better, and that new should replace the old. Yet, there are many examples when this was certainly not the case. It is rare that a new approach completely discredits an old approach. While there are many more such examples, our point is that we should both embrace the new but also be careful about rejecting the old. We should, as scientists, always give credence to high quality science, since it will undeniably be the best source of new and/or confirming knowledge. It is not always obvious what problems we will face, and consequently what knowledge we will need.

What seems to have gone wrong is that we seem to be making the same mistake about measures and methods that we once made about theory. It is not a question of nature or nurture but which contributes what and how and when. We need to remind ourselves to respect the contributions of good quality science as well as respect other and different types of science. We are in danger of not respecting the multiple dimensions, multiple approaches, and multiple methods that can be used to study questions of interest to developmental science. This is evident in the prominence in our research, our classrooms, our publications, and our funding of the latest and greatest idea without including complementary science. The result can be devastating. We need a healthy respect for other viewpoints and methods to best support and advance our science.

The tendency to create and argue for a hierarchy of science may also be related to the public and recent congressional hostility toward science. Recent efforts by Congress to judge the quality of science - especially social sciences, to selectively defund certain disciplines, and

to negatively interpret basic, as opposed to applied sciences, represent tendencies in this direction. Where scientists once were viewed as hardworking individuals interested in improving the health and well-being of all, somehow we are now painted as 'intellectuals' not aware of or helpful with solving the 'real' problems people face. This is not our view of science nor is it the view that should be perpetuated to others.

Where Do We go From Here?

We would argue that the basics of good science e.g. the scientific method, systematic investigation, high quality data, representative samples, are always the same and that we must appreciate good science, in its many forms. We must be eclectic and recognize the contributions of multiple methods. But that does not mean that one individual scientist has to do it all. We should recognize, respect, utilize, and incorporate relevant research being done by others. We are not sure it was ever possible, but it certainly is no longer possible for one individual to research the multiple levels of human development identified in Figure 1. Team science is an exciting and useful way to benefit from input on multiple dimensions.

It is also necessary to maintain the important role of science to critique itself - both good and bad, to be reflexive about the work we do (Kuhn, 2010). We can only improve our science by learning from it. We need to recognize the new, positive contributions being made, but we must also recognize the bad. With new knowledge there are new, in fact, increased, responsibilities. Of note is our fascination with new tools and technologies. There is danger that we will lose sight of the overall phenomena that we seek to understand, but rather redefine our goals to match the new tools available to us. We face the difficult task of being open to new approaches and what they have to offer, without being blinded by them. Furthermore, we need to be aware of the potential uses and misuses of good science. It is startling how little the general public understands the contributions scientists have, can, and will make to their lives.

Summary and Conclusions

Where does all this leave us? To reiterate the thoughts with which we began: It is an exciting time and a challenging time. We have new methodologies, new theories, and new technologies resulting in more, better quality and multiple levels of data ---all of which advance the study of human development. There is great potential for the future. Our goal is to challenge readers to think differently about all the questions that we ask. It is a time to reinvent the field to enhance our ability to understand human development. We urge you to think broadly; read and question widely; consider different perspectives and methods, and be open to innovation in these areas. Be informed by this to influence your thinking and your research. It is a time to re-invent the field to enhance our ability to understand human development and improve the world we live in.

One final note, whether we acknowledge it or not, as scientists we often play an important role in society. We must recognize our role as individuals, scientists, colleagues and citizens. We must do our very best to make sure that we are open minded and critical as we rethink human development, from cells to society.

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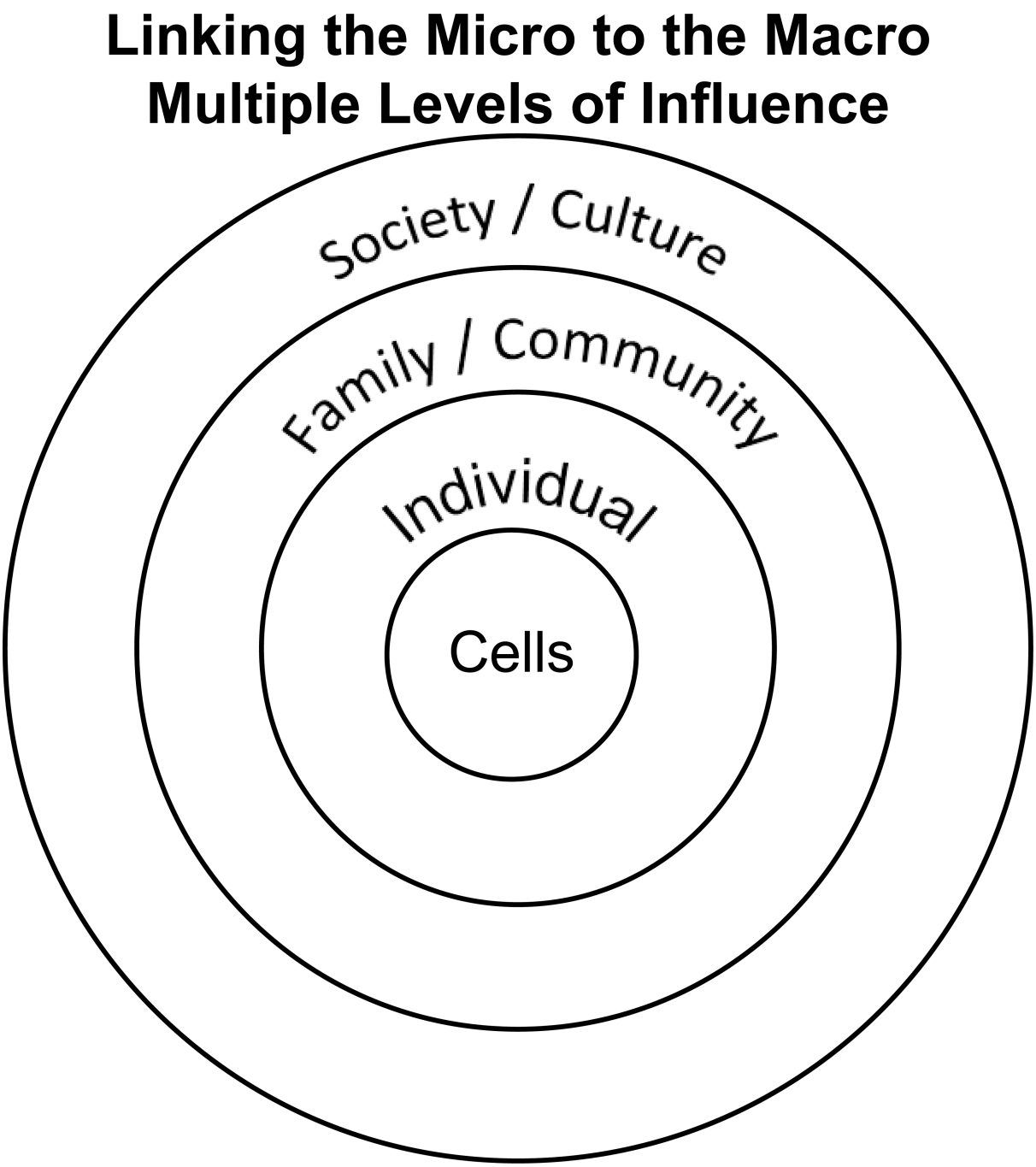

Figure 1.
Multiple Levels of Influence