THE BIOLOGICAL SCIENCES AND A THEORY OF DEVELOPMENT

"…for the general notion of development thus attained implies a method for studying any particular development."[1]

INTRODUCTION

What theory of development is currently operative in the minds of biological scientists? This essay will attempt to answer this question by examining the current notion of development implied in biological research and complementing that theory with a "method for studying any particular development".

The first section will provide an image of biological development. A second section will distinguish between description and explanation. A third section will distinguish between classical and statistical theory and discuss their complementarity. These two sections will provide the foundation for outlining, in the fourth section, the current notion of development operative in biological research. A fifth section will present principles of development and a theory of development called emergent probability. The conclusion discusses the possible relevance of emergent probability to both the biological sciences and the development of the researcher. In essence, this essay will present a theory of development worked out by Bernard Lonergan that would not normally be available to biologists.

Part One: An Image of Biological Development

In order to provide an image of biological development, we will begin with cellular processes. Cells are stabilized schemes of recurrence consisting of electro-chemical processes that function within the boundaries of classical laws. These processes within cells continue until their function is fulfilled or their process is interfered with by a non-systematic event. Most cells within the human body divide creating daughter cells some being duplicates; other cells are designed to differentiate for particular tissues or organs. Once certain populations of cells fulfill their function, they die (apoptosis). What occurs when a cell divides is a change in the combination of

[1] McShane, Philip, "Insight and the Strategy of Biology" in *Lonergan's Challenge to the University and the Economy*, University Press of America, 1980, p. 56. See also McShane, P. (1970) *Randomness, Statistics and Emergence*, Gill. and MacMillan Ltd., Dublin, Ireland.

classical laws within the original cell. In the process of division, the cell reproduces its DNA by taking in nutrients and energy and over a period of 30 hours or so. A cell divides between 40 and 50 times before apoptosis occurs. This reproductive process shortens the telomeres until the cell can no longer divide. Biologists are still unclear of all the processes involved in cell division but it is clear that the process is dedicated to the development of the organism. Once the telomeres in a cell become shorter, a change in the particular combination of classical laws occurs. Exactly what that change is are unknown. A cell cannot re-establish the original combination of the classical laws or any systematic recurring cycle and that distorted combination eventually brings about the end of that cell's existence. This process is linked to the genome, in other words, there are specific genes related to division and the programmed death of a cell. Other cells such as cardiac cells remain for the life of the organism. These cells do not reproduce daughter cells so their combination of classical laws remains intact as long as no external event disturbs their cyclical routine.

The cyclical routine of processes within a cell is called a scheme of recurrence. Once cells conjoin to form tissue and organs, new schemes of recurrence emerge with their own combination of laws leading to a function. Organs then function in relationship to each other to maintain the life of the organism. This too is a routine cyclical scheme of recurrence. Once the genome of an organism is fixed this routine pattern of development recurs with each new fertilization if there are no inhibitions such as genetic mutation or environmental change initiating adaptation. Emergent probability, which eventually brings about the developed organism over long periods, is the result of leaps in adaptation brought on by non-systematic events that rearrange the combination of the classical laws, which in turn creates new schemes of recurrence.

When a non-systematic event occurs and interrupts a cyclical scheme of recurrence within a cell different possibilities emerge. A new scheme of recurrence emerges from the former, the routine scheme of recurrence may be changed, the scheme may reject the process or the event may bring to an end that scheme of recurrence causing irreparable damage leading to the possible extinction of the cycle and, in some cases, eventually the organism. If the non-systematic event combines with the scheme of recurrence, a new scheme of recurrence emerges. It produces a new combination of classical law activity. The new scheme of recurrence will modify the former scheme and this process can continue to modify earlier subsequent schemes that brought into process later schemes. The new scheme also integrates sufficient material from the former scheme. As the new scheme functions as an integrator it also functions as an operator in that it is open for new combinations of classical laws should a further non-systematic event occur.

When a new scheme of recurrence forms it strives to stabilize its processes into a routine scheme by restructuring the combination of classical laws until the new scheme is routinely cyclical. Schemes of recurrence are flexible in that they are open to change should a new non-systematic event come into contact with that scheme. Where the biologist seeks to understand cellular processes, the developmental biologist is seeking an insight into a sequence of schemes of recurrence. These schemes of recurrence that emerge are related and by grasping the relations between the schemes, the developmental biologist grasps the development of a particular organ or organism.

This description of cellular activity provides an image of cellular activity and function of systems as a solution to survival in a particular environment. This image of ever-increasing schemes of recurrence emerging from former schemes is data to be understood. This outline provides first an image and secondly the possibility of defining development as a verified theory that is beyond any common sense or nominal definition of development.[2] As well, principles of development can be formulated that can guide future research regarding the development of any, and all species. How such a theory of development can provide a method for studying any particular development will become clearer after discussing the present notion of development and then outlining the principles of development that are immanently intelligible in the relations between schemes of recurrence. What is paramount is the formation of the image of a sequence of emerging levels of new combinations of classical laws as data. Those emerging schemes are related and by achieving the appropriate insights into those relationships, the researcher is grasping a notion of the developmental process. From this grasp, one can develop a theory of biological development that has implications beyond the biological. To adequately provide an introduction to a better understanding of development, the next two sections discuss scientific procedures and methods as further steps towards understanding development.

[2] McShane, (1980) p. 49-50.

Part Two: Description and Explanation

Description is a necessary precursor to scientific explanation. The distinctions between describing and explaining need to be differentiated according to the different cognitive operations that occur within the scientists own mental performance to ensure that the two different processes are not blended or blurred and to expose the relations between the two different activities.[3] Describing physical data, processes, and events is a process by which the scientist determines the characteristics of the data in relationship to his or her senses. This procedure includes breaking down a whole into its components, measuring the size and weight of a particular part, its color, its density, naming the individual parts, until all the sensible characteristics are accounted. It provides a baseline for relating the description of one particular datum to the description of other similar datum. Such a baseline assists in revealing anomalies between similar data on the descriptive level.

Should the frontal lobes of one brain appear larger or smaller than the size determined by a series of previous descriptions, the question "why" emerges. At this point, the scientist moves from description to explanation. Explanation involves different mental operations. In order to explain the occurrence of an anomaly the researcher has to be able to advert to understanding the normal processes of development, which would provide a baseline of understanding. Where description relates data to our senses, explaining relates things to things or processes and functions to other processes and functions. Description is then an intermediary between the data as presented to our senses and an explanatory account of the processes, functions and relationships occurring within a cell, an organ or an organism.[4]

The distinction between description and explanation provided above lays the groundwork for a discussion of a theory of development by helping to distinguish between the data of sense and the data of consciousness. Expressed in more technical terms, explanation assists the researcher in overcoming the epistemological issues involved with a rigid empiricism. As one advances in understanding, the descriptive characteristics fade into the background in terms of their relevance. Such confusion of these issues can often relegate the notion of development to descriptive rather

[3] Lonergan, Bernard, (1992) Insight: A Study of Human Understanding, CWL 3, University of Toronto Press, Chapter XI "Self-Affirmation of the Knower".
[4] Lonergan, op. cit., p. 368-69.

than explanatory procedures.[5] Once a researcher begins to be involved with explanatory procedures, he or she is operating on a different cognitional level and such procedures require that one know what one is doing cognitionally if the results are to explain accurately the developmental process.[6] Explanation reveals that insight is the central act of knowing and that its integral nature is the prime analogy for a notion of development.[7] The generation of questions as the activator of the heuristic order of cognition, orchestrates a mediating direction towards the developing understanding of data or an event. Just as the heuristic character of cognitional activity exercises an increasing intelligibility into one particular effort to explain one event, so would not a sequence of explanations require a similar intelligible method to orchestrate an increasing intelligibility upon that sequence?

Furthermore, description does not provide a foundation for a theory of development. It does provide a platform for explanation. Explaining one level of process and its relationship to an emerging process provides a foundation for developing a theory of development. The key lies in the relationships of explanations, not in the description of changes that occur through adaptation. Part Five will discuss this procedure.

Part Three: Classical and Statistical Theory

In the last section, distinctions between description and explanation were discussed to provide a background for a discussion of the distinction between classical and statistical method. Description is relevant in both of the early procedures of classical and statistical methods. Relating data to our senses is the first step in recognizing data as relevant to a particular research project or question in either classical or statistical methods. Where classical method seeks and anticipates an explanation of an event, statistical method seeks to know how often an event occurs and anticipates an explanation of the rate of occurrence of a sequence of events. Their complementarity is necessary in order to provide a full account of any biological process. In

[5] *Human Evolution through Developmental Change*, edited by Nancy Minugh-Purvis & Kenneth McNamara, John Hopkins University Press, Baltimore, 2002. The focus is on changing morphologies of skull structures and changes in dentition in order to ascertain leaps in development. The text does not address development as a sequential series of related schemes of recurrence. See Part Five of this essay.
[6] Henman, Robert, (2016) *Global Collaboration: Neuroscience as Paradigmatic*, Axial Publishing, Vancouver, BC, Canada. See Chapter 1 for a discussion of the cognitional process in neuroscience.
[7] Lonergan, op. cit., Chapter I, Sections 1 and 2 on “Insight as Activity”.

order to achieve a full account of a biological process one must account for both the non-systematic and the systematic. Such events require distinct methods to understand the frequency of the non-systematic, the cause of the systematic and their relationship.[8]

In world process and in biological processes both the non-systematic and the systematic are functioning. The distinction and relationship between classical and statistical theory serve to highlight a central feature of a theory of development that is common throughout the sciences. Concretization of a theory of development, which must encompass both an understanding of statistical and classical laws, requires an advertence to self-attention or reflection on performance when one is involved with statistical or classical research. Such a reflection exposes the nature of the different types of data, and the different types of insights that occur within the different methods of each theory.

In as much as the data of each method and the type of insight differ, the anticipation of intelligibility is common to researchers in both methods. It is this common anticipation and eventual verification of the different types of formulated insights that reveal the ground of the complementarity of the non-systematic and the systematic. Where the classical theorist seeks to formulate a law, the statistical theorist attempts to determine how often such a law or combinations of laws occur.[9] An understanding of the two processes provides further foundation for developing a theory of development, world process and a worldview.[10] Up to this point, the

[8] For an in-depth presentation of statistical techniques presently in use in genetic studies, see; "Statistical methods in neuropsychiatric Genetics" by K. Nicodemus and F. Zhang in *The genetics of cognitive neuroscience* edited by D. Weinberger and T. Goldberg, 2009, The MIT Press. The authors highlight the difficulty in "unraveling the complex web of gene-gene, gene-environment, and environment-environment interactions that underlie neuropsychiatric traits" relating to the cause of disease. Similar statistical methods and techniques are relevant to understanding development. These methods and techniques would benefit from the contextualization of a theory of development.

[9] For a more in-depth understanding of the distinction between statistical and classical theory I suggest the works of Lonergan and McShane. Lonergan, op. cit., Chapter IV: "The Complementarity of Classical and Statistical Investigations". See also McShane, op. cit., Chapter 5; "Statistical and Casual Explanation: Their Complementarity". What is described briefly above is sufficient for our immediate purposes. For the serious investigator of development, a deeper understanding of the complexity regarding the methodical distinction and relationship in developmental biology is necessary.

[10] Lonergan, op. cit., Chapter IV, Section 2, "Complementarity in the Known". This section outlines Lonergan's theory of evolution, which he calls "Emergent Probability". It is interesting to note as recently as 2011, Tassy has been quoted as stating; "we enter a world of non-systematic phylogenetics, a surprising oxymoron" Tassy, P. (2011) Trees before and after Darwin, J. Zool Syst Evol Res 49: 89-101. Lonergan outlined this method and its ramifications for evolution in his first edition of *Insight* (1957) Longmans Green & Co, London, UK. Philip McShane, (1970*) Randomness, Statistics and Emergence*, op. cit., also outlines the role of the non-systematic in evolutionary

focus has been on distinctions within scientific procedures. These distinctions and procedures provide the scaffolding for a discussion of the current understanding of biological development, which follows.

Part Four: The Current notion of Development in Biology

Let us now explore some of the notions of development expressed in present biology.

Over the past several decades, significant advances have been made in our understanding of the basic stages and mechanisms of mammalian brain development. Studies elucidating the neurobiology of brain development span the levels of neural organization from the macroanatomic, to the cellular, to the molecular. Together this large body of work provides a picture of brain ***development as the product of a complex series of dynamic and adaptive processes operating within a highly constrained, genetically organized but constantly changing context.*** The view of brain development that has emerged from the developmental neurobiology literature presents both challenges and opportunities to psychologists seeking to understand the fundamental processes that underlie social and cognitive development, and the neural systems that mediate them.

The processes that contribute to brain development range from the molecular events of gene expression to environmental input. Critically, ***these very different levels and kinds of processes interact to support the ongoing series of events that define brain development***. Both gene expression and environmental input are essential for normal brain development, and disruption of either can fundamentally alter neural outcomes. However, neither genes nor input is prescriptive or determinative of outcome. Rather brain ***development is aptly characterized as a complex series of dynamic and adaptive processes that operate throughout the course of development to promote the emergence and differentiation*** of new neural structures and functions***. These processes operate within highly constrained and genetically organized, but constantly changing contexts that, over time, support the emergence of the complex and dynamic structure of the human brain***.[11] (Italics and bold added)

I have highlighted particular phrases and sentences in the above quotation due to their relevance towards an understanding of the current notion of development as described by Stiles and Jernigan. The terms used in these sentences require explanation. What do the authors mean by the terms; ***dynamic, adaptive, changing context, emergence and differentiation***? By working out a theory of development that gives meaning to these terms, it will enable the researcher to develop a general notion of development that applies to any particular development.

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theory. This text was McShane's published doctorate thesis at Oxford, 1968. Following Tassy's work F. Doolittle & Tyler Brunet in their "What is the tree of life" (2016) PLOS Genetics Online Journal, Apr. 12 (4) quote Tassy to emphasize this new aspect of evolutionary methodology.

[11] Stiles, Joan & Jernigan, Terry, "The Basics of Brain Development" Neuropsychological Review, (2010) Online Journal, p. 327-348.

What do the authors mean by the term **dynamic**? A nominal definition of this term refers to something in motion or at least not static. In relationship to biological process, let us think of processes that are active in a manner that is functioning towards something more. What could this "more" be and why do biological processes function in this manner? The meaning of dynamic can be empirically understood as an openness or flexibility of each scheme of recurrence to non-systematic events that create new schemes of recurrence of greater intelligibility than the former scheme from which it emerged. New combinations of classical laws are possible and probable. This reach and openness to a greater intelligibility is a reach for finality.

Is that what the biologist means by dynamic? Furthermore, does the developmental biologist have an explanatory meaning of the term dynamic? In the quotation above, the terms are not defined, they are offered as descriptions within a definition of development. The problem emerges when no explanatory account is offered for the terms. The definition then offers the developmental biologist little idea of just what development is. The terms need to be explained through an understanding of the overall process: what is going forward in biological activity? Therefore, a description of biological processes does not explain the dynamism of the processes. An explanation of the sequence of processes exposes the dynamism and in that way, the dynamism is known as a result of the sequence of explanations. Only then can the biologist adequately define dynamism. The dynamism is exposed through the biologist's questions and explanations. What is going forward in the mind of the biologist? "The sequence of integrations is dynamic, where the meaning of dynamic is that associated, not with mathematical physics, but with finality."[12] Processes are driven to finality and the biologist's questions share the same trait. It is only in the linked sequence of verified explanations that the biologist arrives at an adequate definition of biological dynamism and a notion of development.

Because biological processes emerge from former processes, there is a sequence of related processes. In a similar manner, an adequate understanding of that sequence of processes requires that explanations need to be ordered in an intelligible sequence. A simple example is that of mathematics where the insight into addition, subtraction and multiplication are required before one can move on to division, or algebraic equations need to be understood before moving on to

[12] McShane, (1980), page 56.

calculus. Previous insights raise new questions and provide scaffolding for later insights. Later insights integrate the understanding inherent in former insights making possible the new and higher performance of intellectual procedures. The sequence of understandings that would adequately explain the development of an organism emerges in an order that expresses the very manner in which insights develop. Insights emerge from former insights and if the former have not occurred, the latter cannot occur. Biological schemes of recurrence emerge from earlier schemes.

In order to understand the nature of biological development there is required an understanding of how understanding develops. For it is, in the nature and order of the insights achieved in the mind of the scientist, that the order and relationships involved in biological development are revealed to the human scientist. One can achieve this empirically by self-attention, or reflecting on one's own performance when doing biology.

Part Five: A Theory of Development

I offer a definition that I take from the work of Bernard Lonergan. "...a development may be defined as a flexible, linked sequence of dynamic and increasingly differentiated higher integrations that meet the tensions of successively transformed underlying manifolds through successive applications of the principles of correspondence and emergence."[13]

I draw here on the work of Bernard Lonergan to outline briefly seven principles of development.

1. Principle of emergence: Processes invite higher integration.
2. Principle of correspondence: Different underlying processes require different higher integrations.
3. Principle of finality: Underlying manifolds are indeterminately upwardly directed dynamisms towards ever-fuller realizations. Static and dynamic higher integrations: Higher integrations systematize coincidental lower manifolds in two manners; the lower manifold is completely stabilized or the higher integration continues to add to the lower manifold until a new integration is introduced.
4. The Principle of development: The linked sequence of dynamic higher integrations.

[13] Ibid, p. 479.

5. The course of development is marked by an increasing explanatory differentiation.
6. The course of development is capable of minor flexibility inasmuch as it can pursue the same ultimate goal along different routes.
7. The course of development is capable a major flexibility that consists in a shift or modification of the ultimate objective.[14]

What method does the researcher use to study these sequences of emerging schemes of recurrence in biology? The study of biological development involves combinations of both classical and statistical laws. Development involves an understanding of the linked sequence of new combinations of classical and statistical laws. The notion of development is achieved by studying the transitional integrations from one scheme of recurrence to the next and discovering that the integration also functions as an operator, as a process open to higher and more complex combinations of classical laws.

This sequence of integrations, as previous illustrations show, is orderly but flexible. Each integration is related to preceding ones as higher to lower, for each integration manifests an increase in specification, in capacity for environment control. This continuous transition is achieved because each integration, is not only an integration but also an operator, where operator connotes such a systematization as makes way in positive fashion for its own replacement by a further integration. The sequence of integrations is dynamic, where the meaning of dynamic is that associated, not with mathematical physics, but with finality.[15]

The study of these related sequences is carried out be a scientific method Lonergan has called genetic method and it is to be noted that the name does not refer to the study of genes.

In general, a genetic method leads one to seek an understanding of a linked sequence of integrations through specifying of a linked sequence of integrations through specifying each integration as operator, as a source of transitions to further integrations.[16]

Conclusion

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[14] Ibid., pp. 476-79. This listing of the principles of development requires an understanding of each in relationship to an overall understanding of emergent probability and I refer the reader to the sections sited in this essay for a more detailed account.
[15] McShane, (1980), page 56.
[16] Ibid., p. 56-57.

There is a further aspect to this theory, which pertains to the development of the researcher. The "…emergence of genetic method is itself an instance of development, the development of human intelligence, and so its study calls for a further application of genetic method."[17]

How is this so? Genetic method is the study of the relationships between schemes of recurrence. Such study involves insight and since we are dealing with a linked sequence, we will be dealing with a sequence of insights if we are to understand development. This process manifests the nature and role of insight in the study of development. It is beyond the descriptive phase, touched on briefly earlier in this essay and beyond distinctions of classical and statistical laws in as much as it is the study of emerging new combinations of classical laws in relationship to the origins of that emergence, a former scheme of recurrence. In essence, genetic method as a study of development reveals the developmental aspect of the human intellect, specifically through an understanding of insight. Such understanding of insight is achieved, first by reflection on one's performance, and secondly by the study of the ordered linked sequence of one's insights into biological development. The heuristic scheme of recurrence of intellect, of raising new questions, to new insights, to verification stabilizes former schemes of the psyche and the biology. The reach for finality and stabilization of biological processes and psychological development is achieved through the emergence and activity of human intelligence.

My focus in this article has been to make available to evolutionary biologists and biological researchers in general the work of Bernard Lonergan on development and emergent probability. This community of researchers would not normally be familiar with his work. This article is brief and introductory in nature. For a detailed and explanatory account of Lonergan's work, I can only refer the reader to sections of his central work, **Insight: A Study of Human Understanding**. Lonergan's insights into the development of human understanding can assist in understanding biological development and evolution. By ordering and understanding the many schemes of recurrences and their relationships involved in normal development a baseline of understanding is provided that can assist in understanding any particular instance of development.

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[17] Ibid., p. 57. See Chapter Two "Interpreting Lonergan's Fifth Chapter of *Insight*" by Terrence Quinn in *Seeding Global Collaboration* (2016) edited by Patrick Brown and James Duffy, Axial Publishing. P. 42-43. Quinn explores the dilemma of development in contemporary physics by homing in on the neglect by the physicist of his or her own central image and experience of development, insight and its integral cumulative character as the foundational root of development.