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# Ripples of Newtonian Mechanics: Science, Theology, and the Emergence of the Idea of Development

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The field of developmental psychology has typically traced its history to Darwin or to changes in views about the nature of childhood. What has been generally neglected is how the core assumptions of contemporary theories were forged in the early history of modern science. In particular, the rise of Newtonian mechanics precipitated similar perspectives in geology and then biology. They all converged on a shared set of assumptions about the nature of change in the physical world. Theology also played a key role in this process, serving not only as a foil, but also as a source of important insights for the emerging scientific, and developmental, world view. The field of developmental psychology is a child of this complex and often stormy relationship between science and theology that has shaped Western thought.

Angels to apes. This is the transformation in our self-conception that Darwinian theory has wrought. A being created in God's image has been replaced by an animal shaped by physical forces; appeal to biblical text has been superseded by the analysis of biological data. This shift has resulted in the appreciation that current biological forms are to be understood by studying their origins and evolutionary history, that the past is the key to understanding the present.

The particular role played by Darwin's theory in the emergence of the field of developmental psychology is controversial. The debate centers on whether Darwin, or the derivative theories of Spencer, Haeckel, and other social Darwinians, provided the major impetus for subsequent theories in human development (Charlesworth, 1986; Richards, 1987). However, all of these approaches were relative latecomers, drawing on concepts about the nature of change already well established in other scientific disciplines (Toulmin, 1972; Toulmin and Goodfield, 1965).

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The rise of science carried within its genome many of the basic assumptions of modern developmental theory. The discoveries of seventeenth-century physics, culminating with Newtonian mechanics, revolutionized our understanding of the universe, replacing a static, immutable heaven with a dynamic, changing cosmos. Newtonian mechanics provided an impetus and model for reconsidering terra firma; it was discovered that the features of the earth were not given at Creation but had been shaped by geological forces that continue to change the surface of the earth. Thus, the earth and cosmos are not static, but undergo continual, orderly change. These discoveries prepared the way for biological theories of evolution and development.

The modern concept of development, as well as the history of science from which it emerged, is inextricably entangled with theology. Science emerged within the context of Judeo–Christian tradition; and from the onset, new scientific discoveries have proven to be problematic for religious doctrine. The relationship between science and religion has often been characterized as a war, and with some reason (White, 1965). However, recent scholarship indicates that the relation between science and religion is not simply one of a warring opposition but is also marked by interdependence (Lindberg and Numbers, 1986). While scientific discoveries have raised troubling theological problems, many of the assumptions that guide science, as well as those concerning change and development, originally were rooted in theological soil.

Developmental psychology emerged from the complex and troubled relationship between science and theology that has shaped Western thought. Unfortunately, the importance of this relationship has not been fully appreciated. This is a significant oversight, for it is important to understand that the field of developmental psychology is an integral part of this larger historical current that has shaped human history in the West. The aim of this essay is to detail how many of the core assumptions that guide contemporary theory about human development are a product of the relationship between science and theology from the seventeenth century to the time of Darwin.

## Cosmology and Development

The seventeenth century is generally believed to be one of the most revolutionary eras in the history of Western thought (Hazard, 1935/1963). Modern scientific thought emerged in full and robust form in this century with the discoveries of Kepler, Galileo, and Newton. They brought a radically new understanding to the dynamics of moving bodies and planetary motion, and their methods and results served as the paradigm for the other sciences (Funkenstein, 1986). These discoveries also raised new and troubling difficulties which centered on how these developments were to be reconciled with religious beliefs that had given a measure of order and certainty to European thought for centuries.

However, theology also played a formative role in the emergence of seventeenth-century science. Kepler, Galileo, and Newton were all pious believers, and their work was guided by theological considerations that were conducive to the scientific enterprise (Funkenstein, 1986). It was generally believed that there were two realms (or books) of knowledge: the realm of *nature* and the realm of *grace* (Cassirer, 1979; Funkenstein, 1986). The realm of nature was understood through reason, which was used deductively to ascertain truth from a priori first principles. Natural laws were any laws that could be ascertained by reason and that did not appeal to any other source of certainty. Thus, natural laws were not only those that applied to nature per se, but any laws that were derived solely through reason. The realm of grace was understood through the word of God, expressed most directly in the Bible. These two realms complemented each other, as the realm of nature led to, and was completed by, the realm of grace. Natural laws were thought to be the result of God, the supreme lawgiver, who provided the world with reasoned order. Humans could gain access to these laws through the divinely inspired faculty of reason and thereby acquire a greater knowledge of God through understanding his works.

This assumption guided Kepler's attempt to identify the underlying laws governing planetary motion. Kepler (1609/1991) first discovered the principles governing Mars and on the basis of these results postulated general laws of planetary motion. He presumed a God-given rational order would guarantee that any regularities that were discovered for one planet would also apply for all other planets. The important difference between Kepler and most of his predecessors is that he based his conclusions on detailed observations and not a priori deduction. Kepler sought a greater understanding of God's design, but his method produced results that ran counter to long-held beliefs that heavenly bodies closest to God would evidence their perfection in circular motion and uniform velocities.

Galileo also employed this approach, and his discoveries proved to be even more troublesome. In addition to his brilliant treatise on the dynamics of moving bodies, his observations through the newly invented telescope challenged Church dogma that there were only seven heavenly bodies (because seven was a perfect number) and that the earth must be the center of the universe. Galileo's famous trial by the Church centered on how to discern God's works. Galileo argued that humans cannot fathom the reasons for God's creation, and that a priori assumptions and teleological explanations of God's intentions are presumptuous and doomed to failure; we cannot know the "whys" of God's works. However, we can know the "hows," and this is achieved through observation. God's creation is contingent. There is no a priori reason why the earth should rotate in one direction rather than another, and only through observation we discover this fact. Furthermore, biblical text cannot inform about matters of Nature. The realm of the Bible is spiritual, not material (Galileo, 1615/1957).

What was most threatening about Galileo's views was the implication that the authority for truth was no longer the Church fathers, but scientific method. What was most significant for the emerging view of development was the separation of the material and spiritual worlds. The analysis of matter was no longer saturated with biblical and teleological explanations. Furthermore, Galileo's work provided the first scientific understanding of the dynamic properties of matter. This was a major breakthrough, bringing order out of flux; change was no longer seen as a consequence of errant deviation from the perfection of stasis, but a result of the lawful properties of motion (Cassirer, 1979).

What was hearsay for Galileo was the source of universal acclaim for Newton a generation later. Building on the discoveries of Kepler and Galileo, Newton provided mathematically articulated laws that governed a wide array of phenomena, from planetary motion to projectiles and collisions. The Newtonian world is one vast, lawful machine that obeys a rational order. The scope and precision of his laws are a testament to the power of scientific method for discovering truth. Nevertheless, theology provided the basis for Newton's metaphysical assumptions about the nature of the universe (Leibniz and Clarke, 1716/1956). His mechanistic perspective was a consequence of his belief that the world was made by God. Since God is the first cause and prime mover behind the world, matter itself must possess no inherent activity or direction; it must be inert, passive and atomistic. Furthermore, theological reasons led him to conclude that space and time are homogeneous and infinite and that the reasoned order of the universe is a reflection of God's handiwork (Newton, 1704/1952).

Despite the success of Newtonian mechanics, there were two problematic aspects of his theory, and both had a bearing on subsequent ideas about development. First, Newton hypothesized that matter is inert and without inherent force, yet his theory of gravity postulates that matter exerts a gravitational force that is proportional to its mass and is instantaneously felt over vast distances. What is the source of this force, if not matter? This was a very troubling metaphysical problem for Newton, who was unable to provide a satisfactory answer (Deason, 1986). The second problem concerned deviations in some planetary orbits. These deviations suggested that the forces of gravity and inertia in the solar system were not balanced. Gravitational force appeared to be slightly stronger, indicating that eventually the solar system would collapse on itself. This result was theologically unacceptable to Newton. He viewed the universe as having been created ex nihilo in its current form at Creation, and this slight imbalance of forces would require that God periodically intervene to readjust His clockwork (Leibniz and Clarke, 1717/1956).

Leibniz contested both of these points. Drawing on a different theological tradition whereby God was seen not as a Being apart from nature, but as immanent in nature, Leibniz argued that matter is inherently active and that gravity and other attractive forces are manifestations of this property. He also challenged Newton's belief that God has to periodically recalibrate His timepiece. Since this is the best of all possible worlds and God is infallible, he argued, then God does not need to intervene after the universe has been created. Consequently, the imbalance of gravitational and inertial forces indicates that the *solar system is evolving*. It was not given its present state at Creation but is developing in accordance with the laws and principles that are immanent in the material system itself. The solar system has a history, and knowing the features of its past is necessary for understanding its present form and future direction (Leibniz and Clarke, 1717/1956). This was one of the first developmental hypotheses within a modern scientific framework. It was based upon both empirical and theological considerations, reflecting the unique intermingling of science and religion in the early history of science (Funkenstein, 1986; Odom, 1966).

The subsequent history of this debate contains a curious admixture of Newton, Leibniz, and theology. Newton's equations proved to be astonishingly accurate in predicting a wide range of astronomical phenomena, and the force of this evidence established the preeminence of Newton's worldview (Hahn, 1986). Newtonian celestial mechanics reached its zenith at the beginning of the nineteenth century with the work of Laplace, who provided detailed calculations that accounted for imperfections and problems that had plagued predictions from Newton's theory. Laplace's work represented the crowning achievement of Newtonian mechanics, but a number of important aspects of Leibniz's perspective were also incorporated into Laplace's system (Koyre, 1958). First, gravity and other attractive forces were considered inherent properties of matter. Second, Laplace provided a detailed account of the evolution of the solar system from gaseous nebula. According to Laplace, this evolution is characterized by "a process of equilibrations through which an unstable structure was transformed, by the spontaneous play of physical interactions, into a more stable one" (Merleau–Ponty, 1977, p. 289).

Unlike Newton's and Leibniz's reasoning, Laplace's contained no theological considerations. According to Laplace, the evolution of the solar system results from purely material forces, and the justification for it is based solely on empirical evidence and Newtonian mechanics. Furthermore, this evolution moves toward greater equalibrium. About God, Laplace claimed, "I have no need for that hypothesis" (Hahn, 1986, p. 256). God was dismissed from the cosmos as a superfluous consideration. Evidence must be matched to theory without recourse to theology. A major consequence of this shift, one that was recognized at the time, is that knowledge ultimately turns on epistemological rather than ontological issues (Hahn, 1986).

The dismissal of theological issues, coupled with a systematic mathematical description of the dynamics of celestial phenomena, provided a compelling model for other emerging sciences. Geology and biology are two other sciences that had particularly formative influences on ideas about development. Both sciences had to grapple with evidence that suggested a dynamic, changing physical world. Their success in discovering laws and principles to account for change gave scientific definition and weight to developmental formulations. Earth science reached maturity first and provided a framework that made Darwin's work possible (Toulmin and Goodfield, 1965).

## Geology and Development

Prior to the seventeenth century, the earth was generally considered to have been given its present form by God at Creation. The earth was created for the benefit of humankind, who have peopled it since the time of Creation, and thus human history and the history of the planet are coextensive. Based on the chronology implicit in the Bible, scholars had determined that the Creation had occurred around 4000 B.C. (Hazard, 1935/1963). These beliefs about the origins of the earth were as important as the view that the earth was the center of the solar system. Both beliefs placed humans at the center of an immutable, divinely created universe. The solar system and the earth do not have a history but are merely the stage on which the crucial human drama of salvation and the Second Coming are enacted.

In the seventeenth century, as befits the spirit of that era, Hooke (1705) and Steno (1667/1950) attempted to augment biblical interpretation with empirical evidence. Unlike most of their contemporaries, both recognized that fossils are the remains of plants and animals and that they are clues to the earth's past. The evidence suggested that oceans once existed where there is now dry land and that there were life forms that are now extinct. These were radical suggestions, and Hooke and Steno attempted to reconcile these empirically based hypotheses with the biblical account of the Flood. Neither thought to consider the possibility of a long prehuman history or that the earth is an evolving physical system. They were too steeped in the prevailing theology to make such a radical break. Indeed, it would take a century and a half for these ideas to become accepted scientific wisdom (Rudwick, 1986).

Hooke's and Steno's discoveries prompted considerable investigation in the eighteenth century. There was a continued effort to use the growing evidence of the history of the earth to support biblical accounts, but these efforts became more and more problematic. It was discovered that some European mountains are the result of volcanoes and that the earth was originally molten rock that had cooled. However, there is no reference to such cataclysmic events in the Bible. Furthermore, calculations of how long it would take for the earth to cool and for volcanic mountains to take on their current form were enormously longer than biblical chronology allows (Toulmin and Goodfield, 1965).

Two main approaches were taken toward solving these dilemmas. One assumed that the earth was formed by the continuous operation of forces that have acted uniformly throughout the history of the planet. This approach meant that the biblical account was inaccurate and that the earth had a long history before humans appeared on the planet. Buffon (1749–1804) was one of the first to take this approach. Indeed, Buffon was one of the first modern developmentalists, and he attempted to explain all aspects of nature, from geology and cosmology to biology and human history, in terms of developmental processes that are the result of the operation of natural laws. While subsequent research at the end of the eighteenth century made the specifics of his earth theory obsolete, Buffon's naturalistic, evolutionary vision had great influence (Cassirer, 1979). A more mature version of this approach was advanced by Hutton (1795). Hutton provided a detailed account of how terrestrial forces interact to form a lawbound, self-regulating and self-preserving system of matter in motion. Hutton was careful to point out that the mechanical perfection of this system was evidence of God's design, and he argued that the purpose of God's efforts was to maintain the earth as a suitable habitat to minister to the physical and spiritual needs of humankind.

The second approach argued that God intervened in the history of the earth and was responsible for great cataclysmic events that shaped the earth. This view saved the theological account at the expense of the belief in the immutability of natural laws. Cuvier (1813) was the most forceful proponent of this approach, and he pointed out that there are major dislocations and discontinuities in many samples of rock strata. If the formation of the earth is one long continuous process, then how are these abrupt, cataclysmic changes to be accounted for? In addition, each type of strata contains its own unique types of fossils. Epochs are qualitatively distinct, suggesting that entire worlds, much different from our own, have been created and destroyed. Furthermore, the evidence indicates that the succession of environments is directional and progressive; once life appeared on the planet, it became increasingly more complex and diverse in each succeeding strata. Cuvier argued that these radical changes and the progressive development of the earth could be explained only by divine intervention in the earth's history.

While theology was a component in this dispute, the debate was largely a scientific one and turned on the interpretation of empirical evidence, not biblical text. The debate raised important development issues. The evidence gleaned from the strata of the earth was one of the first empirical substantiations in the physical sciences that development can be directional and progressive (Toulmin and Goodfield, 1965). It was also one of the early scientific efforts to address a problem that would also appear in developmental considerations in other fields, including psychology: How can the continuous operation of uniform forces account for the development of discontinuities and qualitatively distinct periods?

The debate in geology was resolved after the accumulation of new evidence that provided a greater appreciation of the magnitude of the destructive power of tectonic and volcanic forces (Lawrence, 1977). Lyell (1830–1833), drawing on this evidence, was able to account for the objections raised by Cuvier, settling the debate in favor of the uniformist perspective. Theology was eschewed in his account as unnecessary. Lyell did for geology what Laplace had done for cosmology (and, in fact, his theory was influenced by Laplace's) [Lawrence, 1977]; he provided a framework for understanding the formation of the earth that accounts for the existing evidence solely in terms of natural laws and causes. The laws govern a self-regulating, evolving physical system that progressively becomes more complex and diverse.

## Biology and Development

Lyell's theory not only represented the emergence of the modern science of geology, but it also had a very significant impact on Darwin. Darwin took the first volume of Lyell's work with him on his voyage on the *Beagle*, and when Lyell's second volume was published, Darwin had it sent to him in South America (Haber, 1968). Earth science had a direct bearing on Darwin's thinking. Analysis of strata involved examination of the fossil record, so when it was discovered that the time represented by the strata is immense, this implied that biological forms are also to be understood within this time frame. Lyell explained how the long evolutionary history of the earth can be understood in terms of a naturalistic, uniformist model. Only very slight changes in the earth's features are perceptible within a human lifetime, but over the vast reaches of time, these slow, incremental alterations have wrought dramatically different earth forms. This model enabled Darwin (1859) to explain how qualitatively different species can be accounted for by gradual changes produced by natural causes over the long epochs of geological time.

However, Darwin's theory is not simply the application to biology of Lyell's insights, since the specific nature of biological evolution, including the mechanisms of species change and adaptation, was yet to be identified. But the close association of geology and paleontology meant that Lyell's theory would have direct and immediate consequences for understanding life on the planet. Fossil evidence suggested that over time new species appeared and old ones died out. The evidence served as the impetus for temporalizing biology. This temporalization was a challenge to long prevailing theories about the nature of life, theories derived from theological considerations. It also was the beginning of a developmental understanding of biological phenomena.

Prior to the seventeenth century, theories of life held that God, in infinite wisdom, created all species in their current form at Creation. Species do not change or become extinct, nor are new ones created. The forms of life are fixed, and for it to be otherwise would imply that God had somehow blundered at the time of Creation. Species are created in a hierarchical order, stretching from the lowest forms to humans, in imperceptible gradations, forming a Great Chain of Being. The Great Chain of Being is a static hierarchy that does not change with time, but is part of God's design implemented at Creation. Life, in all its forms, is a divine gift provided through the grace of God (Bowler, 1984).

This view of life became problematic in the seventeenth century as the success of Newtonian physics led to attempts to conceptualize life in mechanistic terms. A major stumbling block in this approach was how a machine could possibly reproduce itself. Two approaches were taken that were similar to those adopted by Newton and Leibniz on cosmological questions. One approach suggested that passive matter is given life and the capacity for reproduction through preformed germs planted in matter by God at Creation (roughly paralleling Newton's cosmological view). The second was that the properties of life are a result of inherent forces in matter, similar to gravity, that organize matter into life structures (paralleling Leibniz's cosmology) [Roger, 1986].

Evidence accumulated in the eighteenth century gave increasing support to the second approach. It was discovered that muscle tissue disconnected from nerves will spontaneously contract when pricked, suggesting that life is inherently active. Further evidence of this was provided by the discovery that the freshwater hydra, when cut in pieces, regenerates into an equal number of new, living forms (Roger, 1986). The preformist ideas of development were undercut by research that indicates that embryotic growth occurs, not by the expansion of a preformed miniature, but by the systematic addition of parts, through epigenesis (Bowler, 1984). This evidence suggests that life is some sort of material process that is a consequence of the active properties of matter.

There was also a growing appreciation that life has the capacity to change form across generations. One source of evidence was the fossil record. A second came from Maupertuis, who discovered that traits can be transmitted by both parents. He formulated a theory that is remarkably similar to modern genetics and speculated that some inherited characteristics might become enduring features of a specie under favorable environmental circumstances (Glass, 1968).

This evidence suggested that life is an inherently active, material process that has the capacity to change across generations. Buffon and Herder were among the first to offer theories that attempted to address these issues. Buffon argued that life is a materially derived process and that migration and climatic conditions can produce morphological changes (Bowler, 1984). Herder temporalized the Great Chain of Being, arguing that God's plan is a dynamic one whereby life progresses from simple to increasingly complex forms over time. He also proposed a Great Chain of Cultures that follows a similar progression (Lovejoy, 1968). However, neither considered that biological change involves the evolution of complex species from simpler ones. Buffon allowed for environmentally caused variation but considered species to be fixed entities, while evolution in Herder's theory is achieved by a progressive unfolding, not an evolutionary transformation (Mayr, 1982). The beliefs of both Buffon and Herder in the fixity of species reflect the continued effects of an essentialism that was rooted in theology.

Lamarck is generally credited as being the first to provide a systematic theory of the evolution of species (Mayr, 1982). According to Lamarck, adaptation to the environment is accomplished through behaviorally developed habits. The needs and habits of an animal are altered as the environment changes, and these newly acquired habits are passed on to its progeny. In this way, species evolve and change in conjunction with the changing environment and habits of the animal. Lamarck also believed that species are not real biological entities, but are merely an intellectual abstraction for organizing the various forms taken by life. The material forces that comprise life have great plasticity for forming and transforming it; life seeks ever-increasing complexity and perfection, reflecting the working of the Supreme Author of all things (Mayr, 1982).

Darwin reconciled the two conflicting approaches to evolution. The first held that species are fixed and that evolution is progressive but not transformational. The second asserted that evolution is progressive and transformational but that there are no qualitatively distinct species. Both approaches were frequently imbued with theological considerations (Mayr, 1982). What Darwin provided was a way to understand how qualitatively distinct species can evolve through a natural process of gradual transformation. His argument conspicuously avoided any appeal to theological considerations and provided a completely physical and biological explanation of the evolution of life on the planet.

## Conclusion

Biology, geology, and cosmology share important historical parallels. Early scientific efforts in the seventeenth century attempted to understand God's design through empirical investigation. However, the resulting discoveries were not easily reconciled with theology. Growing evidence suggested that the world was dynamic and evolving, which conflicted with the biblical view of a static, immutable world. The crowning scientific triumphs occurred when science was completely separated from theology, and comprehensive developmental theories were provided that relied solely on material evidence and causes. Reason informed by observation replaced biblical interpretation guided by faith, and epistemological questions replaced ontological concerns.

By the middle of the nineteenth century, the physical sciences converged on a core set of assumptions about development, assumptions that are also at the center of contemporary theories of human development (Nisbet, 1969). First, it was assumed that change is a natural part of the world. The universe is dynamic, and while there may be points of stasis, these are the exception rather than the rule. Second, change has direction. It is not random flux of chance occurrences, but is organized and moves toward more advanced states characterized by greater complexity and stability.[1] Third, change is continuous. Qualitative stages can emerge, but they are the result of the operation of continuous change that leads to qualitative reorganization; nothing appears ex nihilo. Fourth, change is immanent. It is the result of some type of material or human force that is inherent in the system itself and is thereby capable of being understood through empirical analysis. Last, epistemology, not ontology, is the gateway to human knowledge and understanding.

The obvious points of conflict between science and religion have led to the common belief that religion has always been in opposition to, and at war with, science. However, this is an oversimplication. Recent scholarship suggests that theology has also played a constitutive role in the formation of science (Lindberg and Numbers, 1986). Almost all of the early scientists were pious believers, and the struggles were not between science and religion: "they were *within science* as men then conceived it — not struggles of progressive-minded scientists to overcome the obscurantism of an external authority, but internal struggles within the new and highly successful philosophy" (Toulmin and Goodfield, 1965, pp. 87–88). Furthermore, the theological assumptions that the world is governed by laws, are rational and, to some extent, accessible to human understanding, are critical assumptions of sci-

[1]There is controversy over the extent to which Darwinian theory can be considered as a progressive evolution theory. But whatever Darwin's intent, his theory was interpreted as progressive by most of his contemporaries and supporters, reflecting the pervasiveness and power of this assumption about the nature of change (Gould, 1989).

ence (Milton, 1981). In addition, the immanent properties that were imputed to matter by scientists parallel the properties ascribed to God by theology — that it has force, activity, organization, and rationality (Lindberg and Numbers, 1986). It has also been argued that the concept of development, with its assumption of progressive change, is derived from the secularization of Christian eschatology (Bultmann, 1962; Kaplan, 1983; Lowith, 1949).

By the mid- to late nineteenth century, this view of development, a product of scientific method and religious belief, dominated thinking about the nature of change. It was manifest not only in the physical sciences, but also in historiography, sociology, and economics as well (Nisbet, 1969). The field of developmental psychology was born at this time, in this milieu, with these presumptions about change and development. Biology had, perhaps, the most direct impact on the beginnings of the field, but the discipline owes much to the wider intellectual currents from which biology itself emerged. Indeed, developmental psychology is an outgrowth of this larger drama between science and religion that has galvanized Western thought for over three centuries.

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