The Place of Biology in Cosmology

Paula S. Derry, Ph.D.

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"Teleology is a lady without whom no biologist can live. Yet he is ashamed to show himself with her in public." E. von Bruecke, cited in W. Cannon (1968, p. 108).

Introduction

What is the place of humans in the cosmos? How we frame the question already reflects our ideas about the answer. To create transdisciplinary models, these implicit assumptions and orienting metaphors need to be examined. Cosmology can be defined as a subfield of astronomy that considers the nature and evolution of the universe. In this view, the origin and nature of matter and the forces impacting matter are the objects of study. Cosmology can also be defined as the study of cosmos, the universe as an orderly, harmonious system. In this view, the nature of underlying patterning is broader than that found in astronomy. Cosmology in its first sense is often taken to explain cosmology in its second sense. In this paper, I argue that cosmology as a subfield of astronomy is too limited a perspective to frame the discourse pertaining to cosmology in its broader sense. When we ask what the nature is of order in the universe, one thing that this question means is that we want to know our fundamental nature, and thus our place in this universe. To understand our characteristics as living beings and the important questions about order that need answering, we must look at biology as fundamental to our scientific understanding. Only then can we know what questions about cosmology as astronomy are relevant and important to address. That is, a scientific view of cosmology begins with looking at patterning in living systems. We need biology for our facts and observations, and hence core metaphors and assumptions about the nature of organisms and their environment. Only in this way can we know what the important features of the inanimate are as it relates to living things and the important questions to ask.

Cosmology As a Subfield of Astronomy

According to cosmology in its first sense, from the origins of matter in a "big bang," successively more complicated atomic elements and compounds develop. Impersonal physical forces underlie these developments. Somehow, when matter achieves a sufficiently high level of chemical complexity in organic compounds, life and its typical characteristics emerge. Thus, to understand human origins and evolution, to be "scientific," physics and chemistry are primary. It isn't simply that complex molecules are a part of the story; they are the key to the dynamic that explains life's origins and nature. However, this perspective contains no conceptual bridge across discontinuities between the dynamics of living and nonliving things. How to bridge that discontinuity thus become a difficult, even insoluble problem.

This viewpoint carries underlying assumptions for our examination of the place of humans in the universe. First, big-bang cosmology assumes that the starting point is crucial, the cause that sets everything in motion. Later developments follow in a cause-and-effect sequence from this beginning. We must understand the starting point and, more generally, development in cause-and-effect linear time sequences, in order to understand what is happening in the present. If we only see later points in the sequence, we will remain in the dark, because these later points are understandable only in relationship to earlier causes. This contrasts, for example, with understanding based on the nature of the patterning among parts in the present, a form of cosmology found, for example, in Chinese medicine. It contrasts, also, with an idea that origins are logical origins or a successive unfolding of meanings, as when an undifferentiated state transforms itself through series of distinctions. Again, in Chinese medicine, the one becomes duality, which then becomes multiplicity. Further, creation was something that happened "back then," not in the present. This contrasts with the idea that creation occurs repeatedly in the present through a process of actualization, with the rules by which that actualization occurs being important to understanding order.

Second, cosmology as astronomy tends to lend itself to a metatheory that physics is primary and thus a view of evolution and, more broadly, the life sciences that is reductionist and materialist. For example, the discovery of the physical structure of DNA has been hailed as telling us "the nature of life." Mapping the chemical structure of an individual's genome is supposed to tell us what is important about our health risks. Sociobiology embodies a radical materialism which assumes that promoting the propagation of one's DNA is a primary force in evolution. Describing the physical structure of neural nets is supposed to tell us about consciousness. In addition to a discontinuity between the dynamics of living and nonliving systems, there is no conceptual bridge to the nonmaterial. This contrasts, for example, with the idea that concepts not found in physics are also primary and scientific, concepts like anticipation, purposiveness, or a felt relationship with the physical and social environment as part of the creation of meaning.

Biology as Metatheory

Introduction

Biology offers many insights for the study of cosmology. The characteristics of living things are self-evidently different from those of nonliving systems. Helena Curtis (1975, pp. 27-31) suggested that "signs of life" include: living things are chemically complex and highly organized, take energy from their environment and change it from one form to another, are homeostatic, respond to stimuli, reproduce themselves, are adapted to their environment, and contain the information about all of these functions within themselves. Other biologists contribute additional experimental work and theoretical ideas about what are the characteristics of life. While there are many perspectives within biology, I would suggest that J. S. Haldane, Ragnar Granit, and Walter Cannon are all examples of eminent biologists whose work contributes much to our understanding of the underlying

organization of living beings. Haldane (1917), for example, examined the nature of interrelatedness between organism and environment. Granit (1977) examined the biological meaning of purposiveness. One aspect of Walter Cannon's (1963, 1939) research was the dynamics of homeostasis. Homeostasis is a key and important idea in understanding the patterning of living systems.

In this paper, I outline Cannon's work on homeostasis and the implications of this work for our understanding of cosmology. Walter Bradford Cannon, M.D., was the chair of the Department of Physiology at Harvard Medical School from 1906 to 1942, and president of the American Physiological Society from 1914 to 1916. His experimental research on a range of topics was substantial, spanning the physiology of digestion, the nature of traumatic shock experienced by wounded soldiers during World War I, the role of the autonomic nervous system and the endocrine system in responses to threat, the nature of emotionality and of psychosomatic processes. He coined terms that have become part of our culture's common language, like the "fight/flight" response to danger and "homeostasis." Cannon presented his ideas about homeostasis in the book, *The Wisdom of the Body* (Cannon 1963, 1939), which forms the basis for this paper; unless otherwise noted, all information and quotes are from this book. His autobiography, *The Way of an Investigator* (Cannon, 1961, 1945), was also drawn on.

Homeostasis

Homeostasis is the tendency of the body to maintain internal stability through the coordinated response of its parts to change. Many of our body systems must operate within a small range. For example, a diabetic has too much sugar in the bloodstream, but if we have too little sugar we experience first minor symptoms like fatigue and, finally, severe symptoms like coma. Large variations in blood sugar, along with variations in oxygen and other important bodily components, are avoided in healthy functioning because active mechanisms keep levels within a normal range. For example, if blood sugar levels start going up then the hormone insulin, which reduces these levels, may be secreted; if blood sugar goes down, as when we are exercising, then the liver may release additional sugar.

Homeostasis is sometimes described in textbooks as a mechanical process, analogous to a thermostat in a furnace. A particular variable is monitored, changes in its value are noted by receptors, control centers like the brain send out messages to nullify change. However, Cannon is clear that his concept is one that pertains to living beings rather than mechanical systems:

> The constant conditions which are maintained in the body might be called equilibria. That word, however, has come to have fairly exact meaning as applied to relatively simple physico-chemical states, in closed systems, where known forces are balanced. The coordinated physiological processes which maintain most of the steady states in the organism are so complex and so peculiar to living beings—involving, as they may, the brain and nerves, the heart, lungs, kidneys

> and spleen, all working cooperatively—that I have suggested a special designation for these states, homeostasis (p. 24).

Building upon Claude Bernard's concept of the "milieu interior," Cannon emphasizes that what must remain stable is the immediate environment surrounding the cells in our bodies. For our bodies to survive, the individual cells comprising them must survive. Individual cells are provided with nutrients and eliminate waste through their contact with fluid that surrounds them. The composition of this interstitial fluid in turn depends upon its communication with fluid in blood and lymph vessels. We require astonishingly small variation in the amounts of oxygen, carbon dioxide, acids and bases, etc. carried by the fluid matrix, that is, the fluid surrounding cells and within vessels, or else our individual cells will end up oxygen deprived, desiccated, or suffer other problems. Thus, the key to homeostasis is maintaining constancy in the "fluid matrix," and the mechanisms we observe ultimately are maintaining constancy here. For example, if we eat too little salt, our kidneys will excrete less; as a result, the percentage of salt in blood, lymph, and within cells can remain constant. Homeostatic mechanisms are active and purposive:

> In an open system, such as our bodies represent, compounded of unstable material and subjected continually to disturbing conditions, constancy is in itself evidence that agencies are acting, or ready to act, to maintain this constancy….If a state remains steady it does so because any tendency towards change is automatically met by increased effectiveness of the factor or factors which resist the change (p. 299).
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> Homeostasis is not accidental, but is a result of organized self-government (p. 300).

Yet the picture Cannon is painting is not one simply of constancy. Homeostasis involves the idea of maintaining a constant fluid matrix given ever-changing states, a balance in the present given dynamic change. The fluid matrix remains constant, but the body as a whole is not remaining constant. It is not simply accidents or adversity that produce disequilibrium. People are always changing, their bodies active, their physical movements organized so as to achieve goals, their bodies responding to changes in internal state like emotions. If a person moves, for example, s/he uses up greater amounts of oxygen and sugar than is the case when s/he is resting; breathing rate, release of sugar from storage in the liver, etc., therefore need to change to maintain homeostasis. Building on Cannon's language, we can say that homeostatic mechanisms make activity, purpose, or a variety of states, possible, and are fundamentally integrated with movement and change rather than a simple return to a predefined equilibrium. The fluid matrix is like a pivot point around which all else revolves.

What is the nature of these homeostatic adjustments? We can't make sense of them without referring to purposiveness. It is only by knowing the purpose that we can make sense of the mechanisms and when they are brought into play:

> The view that there are organic adjustments which promote bodily welfare, and consequently are useful, involves the conception that these activities are directed, i.e., that the parts operate teleologically for the good of the entire group of parts that constitute the organism. (*The Way of an Investigator*, p. 108).

> When a person is exposed to a reduced amount of oxygen in the air….the red blood corpuscles, which transport oxygen from the lungs to the shut-away tissues of the body, are increased in number. …It has been shown experimentally that because of adaptive changes…lower animals can continue living in an atmosphere that contains less than 10 percent of oxygen, i.e., less than half the concentration at sea level. In this connection it is pertinent to note that burning alcohol is smothered when the oxygen in the air falls from about 21 to 15 percent (*The Way of an Investigator*, p. 111).

Purposiveness helps to describe or explain how unrelated body systems, or different parts of the same body system, all work together to achieve an end. Homeostasis can't be understood by simply isolating individual mechanisms and adding them up. It relies on a large number of mechanisms that may exist in structures of the body distant from each other or in different body systems acting cooperatively in an organized manner. These mechanisms may be simultaneously mobilized, or any one of a number of mechanisms may alternatively be mobilized.

In addition to purposiveness, the mechanisms comprising homeostatic adjustments have other characteristics. One is anticipation. Mechanisms and feedback loops don't simply respond to deviations or breakdowns. They are brought into play prior to changes occurring that would create, or even threaten, a breakdown in homeostasis. Sometimes, they occur simultaneously with the conditions for which they are needed, as when the same nervous system mechanism that triggers voluntary movement also initiates the changes in heart rate, thus blood flow, that an increase in activity will require. Sometimes, mechanisms respond to indications of change or minor changes/precursors. For example, we feel thirst given small amounts of water deprivation, long before danger of changes in the composition of blood. Sometimes, physiological changes may occur in anticipation of an action. For example, when a seated person decides to stand up, the intention to stand up results in a rise in blood pressure even before activity starts, so that when s/he does stand, there is no drop.

A second characteristic of homeostatic mechanisms is the interrelationship of psychology and physiology. As noted, intentions like the decision to stand can initiate physiological changes. Drives like hunger are anticipatory. In addition, appetites, as when food is pleasurable because of its sight and smell, motivate eating before deprivation large enough to produce hunger occurs.

A third characteristic of homeostatic systems is that of a part acting for the benefit of the whole. Cannon, for example, discusses in detail the experience of thirst. Salivary glands moisten the mouth; when they don't secrete enough, this causes an unpleasant sensation called thirst. We can understand thirst in terms of local dynamics. Any condition that

causes rapid evaporation of moisture in the mouth or smaller production of fluid by the glands will results in this dryness and the experience of thirst, as when someone sings a lot or breathes dry air or feels anxious. Any condition that restores moistness in the mouth will ameliorate the experience of thirst, as when someone swishes fluid in the mouth or sucks a lemon. However, if we focus too narrowly on these local dynamics we will miss their significance to homeostasis. When there is too little fluid in the body, then fluid gets preferentially sent to crucial body parts like blood and away from nonessential parts like the salivary glands which then become dry. Salivary glands thus signal bodily need by causing an unpleasant sensation. The experience of thirst occurs when there is too little fluid in the body yet before the situation becomes critical; this is another example of the anticipatory quality of mechanisms. However, in addition, thirst is what Cannon calls a "sentinel," a local symptom that stands for/indicates a larger bodily imbalance. That is, in thirst an organismic state is experienced through a local indicator that communicates the state of the system; in alleviating thirst, the larger bodily imbalance is also addressed and balance restored.

A fourth characteristic of homeostatic mechanisms is redundancy and inefficiency. For example, when a person who is not moving breathes, a great deal of air sits in the lungs without being either exhaled or absorbed into the body, and a lot of blood in the heart sits there and doesn't get pumped. This may seem like a poorly designed, inefficient system, but it is the means by which flexibility is possible. If the person suddenly moves and needs more oxygen and blood, this can occur immediately as these stores are available to be used. In addition, for Cannon safety rather than efficiency is important to bodily organization, to allow for error, damage to an organ, and other problems. For example, redundancy is found throughout the body—pairs of organs like lungs or kidneys when only one is needed, intestines that are much longer than needed for digestion, multiple mechanisms that serve the same purpose as when saliva and the pancreas both release the same digestive enzyme. Conversely, in bodily organization one part often has multiple functions, as when connective tissue is also storage tissue for water and salt.

Finally, Cannon's work suggests that the body is a holistic system and that intelligence inheres in the body as a whole. The organization of the body varies with function of the overall body; for example, during muscular activity, arterioles and capillaries dilate in active muscle and constrict in the abdomen. Systems are interrelated; for example, constant blood acidity, crucial to the chemistry of individual cells, relies on control of carbon dioxide (which dissolves in blood as an acid) through respiration, but also relies on control of salts in blood through excretion by the kidney. Important as the brain and endocrine system are in organizing and coordinating bodily activities and functions, homeostatic mechanisms also inhere in local body systems, as when physical mechanics are important. For example, as muscles are being used, they push on blood vessels, which pumps blood along, which results in improved circulation to bring muscles the nutrients they need. As muscles are used, blood pressure rises which results in more rapid blood flow. However, rapid flow has a cost, since there is less time for the oxygen that the blood is carrying and that the muscles need to diffuse into cells from capillaries. However, active muscles produce heat and carbon dioxide which mechanically result in quicker oxygen diffusion.

Implications of homeostasis

The image of the body derived from Cannon's work is of a holistic system characterized by purposiveness, anticipation, the interrelationship of psychology and physiology, inefficiency and redundancy, a part representing the whole, and intelligence inhering in the body as a whole rather than localized in the brain and endocrine system. This image is a scientific image, based on experimental evidence and concepts derived from or accounting for experimental evidence.

This image differs from that derived from approaches to biology based on a materialist, reductionist viewpoint. For example, in sociobiology the propagation of the chemical DNA is at the heart of natural selection and the dynamics underlying evolution; for example, great importance is laid on how many women a man can impregnate rather than what it takes to successfully raise a child to reproductive age. A core image in sociobiology is that efficiency underlies biological organization, as in the assumption that there is a best trait that will be the object of natural selection (rather than that diversity, variety, or redundancy provide the best adaptation) or in the idea that adaptation is best understood as maximizing efficiency (as when asserting that men don't want to waste effort raising genetic young not their own). Sociobiology also assumes that in natural selection individuals pursue individual gain and that this somehow adds up to a whole that works; the social and physical environment are only the context within which individual activity occurs rather than forming a meaningful larger whole of which the individual is a part. Competition but not cooperation is considered a genetic given.

Cannon's viewpoint organizes biological observations and ideas into a different set of core assumptions and metaphors. By highlighting different facts and organizing them in a different set of images, it provides us with a different orientation in which we notice different aspects of reality and make different kinds of bridges and connections. Bridges exist between the nonmaterial and material, the psychological and the physical. For example, concepts like purposiveness explain observations and psychological motives are intertwined with physiological adaptation.

While he does not explicitly discuss spirituality, his concepts provide bridges to spiritual discourse. In scientific terms, we are characterized by activity, purposiveness, and meaning. These terms are also relevant to spiritual discourse. The idea that inefficiency and error are part of the natural course of things that allow for redundancy and variety has many resonances, for example to human imperfection and the imperfection of the world. In general, a spiritual world view that doesn't deny the space/time world but goes beyond it would be congruent with Cannon's images.

His ideas have many other interesting relationships to other systems. For example, Chinese medicine has a complicated system to describe underlying patterning in the body. In health, bodily energies are balanced; in illness, energies are out of balance. This balance reflects the internal state of the body and the person's interrelationship with the social and physical environment. While for us, a symptom is a problem to be treated, in

Chinese medicine a symptom is an indicator of an underlying bodily imbalance. Treatment consists of helping the body restore its ability to heal itself. All of these ideas resonate with Cannon: Homeostasis is a balance of bodily systems in which too much or too little create problems; signs like thirst signal an underlying imbalance; the body actively self-corrects to restore balance e.g. through behaviors like drinking water. Cannon (p. 242) states, with regard to medical treatment, that nature heals while doctors assist self-regulating mechanisms and help to make them more effective.

His ideas are also interesting when related to chaos theory, a theory which describes phenomena in the inanimate and biological realms. The cause-and-effect systems often studied by scientists characterize some but not the entire natural world. Other systems with other rules, for example chaotic systems, also exist, which can be mathematically described. Chaotic systems are deterministic but not predictable. They are dynamic, in constant movement, and they generate aperiodicity, therefore variety. It has been suggested that this aperiodicity, on a biological level, results in greater adaptability, as systems which are not locked in to periodicity have greater flexibility in responding to change.

Finally, these orienting images provide us with a different lens with which to regard astronomy. With regard to the universe originating in a big bang, we can note that the universe is all of one piece. The same laws apply everywhere. The universe is moving as a whole. Everything affects everything else, as in gravitational force. Physicists study forces and energies which are nonmaterial all of the time. Our relationship to the stars, as when we look at the night sky, reflects in part an intrinsic felt relationship to our environment.

Conclusion

Living things are composed of matter and conform to the laws of physics and chemistry. Hence, these laws contribute one layer to our understanding of cosmology. However, biological systems have different characteristics from nonliving systems. The idea that their characteristics are best understood as derived from or explained by the laws of physics and chemistry is an a priori, even scholastic, assumption, not a scientific fact. To understand cosmology, we must also look to biology for basic scientific facts and premises about the nature of living things, and hence our fundamental nature. Homeostasis, coordinated physiological processes that maintain steady states through self-righting adjustments, is a basic biological principle for mammals. It can only be understood as a purposive dynamic. It is not simply a process that keeps organisms static and unchanging. The fluid matrix must remain constant in order for cells, and hence the organisms that they comprise, to stay alive. Homeostasis pertains to the ability to maintain this crucial constancy as behavior and the environment change, a constancy that makes activity and a variety of states possible. The fluid matrix is like a pivot point around which all else revolves. The image of the body derived from Cannon's work is of a holistic open system with balance among a large number of interacting parts, characterized by purposiveness, anticipation, cooperation, the interrelationship of psychology and physiology, inefficiency and redundancy, a part representing and acting

for the good of the whole, and intelligence inhering in the body as a whole rather than localized in the brain and endocrine system. Our relationship to cosmology starts here.

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