

Consilience: The Unity of Knowledge

Edward O. Wilson

1998

Publisher = Alfred A Knopf

ISBN 0-679-45077-7

The greatest enterprise of the mind has always been and always will be the attempted linkage of the sciences and humanities. The ongoing fragmentation of knowledge and resulting chaos in philosophy are not reflections of the real world but artifacts of scholarship.

Literally a “jumping together” of knowledge by the linking of facts and fact-based theory across disciplines to create a common groundwork of explanation.

The belief in the possibility of consilience beyond science and across the great branches of learning is not yet science. It is a metaphysical world view.

What is the relation between science and the humanities, and how is it important for human welfare?

A balanced perspective cannot be acquired by studying disciplines in pieces but through pursuit of the consilience among them.

Occam’s razor, first expressed in the 1320’s by William of Occam. He said, “What can be done with fewer assumptions is done in vain with more.” Parsimony is a criterion of good theory.

Science, to put its warrant as concisely as possible, is the organized, systematic enterprise that gathers knowledge about the world and condenses the knowledge into testable laws and principles. The diagnostic features of science that distinguish it from pseudoscience are first, repeatability: The same phenomenon is sought again, preferably by independent investigation, and the interpretation given to it is confirmed or discarded by means of novel analysis and experimentation. Second, economy: Scientists attempt to abstract the information into the form that is both simplest and aesthetically most pleasing—the combination called elegance—while yielding the largest amount of information with the least amount of effort. Third, mensuration: If something can be properly measured, using universally accepted scales, generalizations about it are rendered unambiguous. Fourth, heuristics: The best science stimulates further discovery, often in unpredictable new directions; and the new knowledge provides an additional test of the original

principles that led to its discovery. Fifth and finally, consilience: The explanations of different phenomena most likely to survive are those that can be connected and proved consistent with one another.

Here is how reductionism works most of the time, as it might appear in a user's manual. Let your mind travel around the system. Pose an interesting question about it. Break the question down and visualize the elements and question it implies. Think out alternative conceivable answers. Phrase them so that a reasonable amount of evidence makes a clear-cut choice possible. If too many conceptual difficulties are encountered, back off. Search for another question. When you finally hit a soft spot, search for the model system-say a controlled emission in particle physics or a fast-breeding organism in genetics-on which decisive experiments can be most easily conducted. Become thoroughly familiar-no, better, become obsessed-with the system. Love the details, the feel of all of them, for their own sake. Design the experiment so that no matter what the result, the answer to the question will be convincing. Use the result to press on to new questions, new systems. Depending on how far others have already gone in this sequence (and always keep in mind, you must give them complete credit), you may enter it at any point along the way.

Herbert Simon, a Nobelist who has devoted part of his career to the subject, says of the complexity of concept formation: "What chiefly characterizes creative thinking from more mundane forms are (I) willingness to accept vaguely defined problem statements and gradually structure them, (ii) continuing preoccupation with problems over a considerable period of time, and (iii) extensive background knowledge in relevant and potentially relevant areas." To put that in a nutshell: knowledge, obsession, daring.

The greatest obstacle to consilience by synthesis, the approach often loosely called holism, is the exponential increase in complexity encountered during the upward progress through levels of organization.

THE GREATEST CHALLENGE today, not just in cell biology and ecology but in all of science, is the accurate and complete description of complex systems. Scientists have broken down many kinds of systems. They think they know most of the elements and forces. The next task is to reassemble them, at least in mathematical models that capture the key properties of the entire searchers acquire to predict emergent phenomena when passing from general to more specific levels of organization. That in simplest terms is the great challenge of scientific holism.

Complexity theory (the best expression, in my opinion) can be defined as the search for algorithms used in nature that display common features across many levels of organization.

Short-term memory is the ready state of the conscious mind. It composes all of the current and remembered parts of the virtual scenarios. It can handle only about seven words or other symbols simultaneously. The brain takes about one second to scan these symbols fully, and it forgets most of the information within thirty seconds.

Much of the input to the brain does not come from the outside world but from internal body sensors that monitor the state of respiration, heartbeat, digestion, and other physiological activities.

The common property of science and art is the transmission of information, and in one sense the respective modes of transmission in science and art can be made logically equivalent. A team of scholars-led perhaps by color-challenged Mary-has constructed an iconic language from the visual patterns of brain activity. The result resembles a stream of Chinese ideograms, each one representing an entity, process, or concept. The new writing-call it “mind script”-is translated into other languages. As the fluency of its readers increases, the mind script can be read directly by brain imaging.

From diverse vantage points in biology, psychology, and anthropology, they have conceived a process called gene-culture coevolution. In essence, the conception observes, first, that to genetic evolution the human lineage has added the parallel track of cultural evolution, and, second, that the two forms of evolution are linked.

Culture is created by the communal mind, and each mind in turn is the product of the genetically structured human brain. Genes and culture are therefore inseverably linked. But the linkage is flexible, to a degree still mostly unmeasured. The linkage is also tortuous: Genes prescribe epigenetic rules, which are the neural pathways and regularities in cognitive development by which the individual mind assembles itself. The mind grows from birth to death by absorbing parts of the existing culture available to it, with selections guided through epigenetic rules inherited by the individual brain.

As part of gene-culture coevolution, culture is reconstructed each generation collectively in the minds of individuals. When oral tradition is supplemented by writing and art, culture can grow indefinitely large and it can even skip generations. But the fundamental biasing influence of the epigenetic rules, being genetic and ineradicable, stays constant.

Some individuals inherit epigenetic rules enabling them to survive and reproduce better in the surrounding environment and culture than individuals who lack those rules, or at least possess them in weaker valence. By this means, over many generations, the more successful epigenetic rules have spread through the population along with the genes that prescribe the rules. As a consequence the human species has evolved genetically by natural selection in behavior, just as it has in the anatomy and physiology of the brain.

The nature of the genetic leash and the role of culture can now be better understood, as follows. Certain cultural norms also survive and reproduce better than competing norms, causing culture to evolve in a track parallel to and usually much faster than genetic evolution. The quicker the pace of cultural evolution, the looser the connection between genes and culture, although the connection is never completely broken. Culture allows a rapid adjustment to changes in the environment through finely tuned adaptations invented and transmitted without correspondingly precise genetic prescription. In this respect human beings differ fundamentally from all other animal species.

Biologists generally agree that the primary force behind evolution in human beings and all other organisms is natural selection.

A culture is the total way of life of a discrete society-its religion, myths, art, technology, sports, and all the other systematic knowledge transmitted across generation. In 1952 Alfred Kroeber and Clyde Kluckhohn melded 164 prior definitions pertaining to all cultures into one, as follows: "Culture is a product; is historical; includes ideas, patterns, and values; is selective; is learned; is based upon symbols; and is an abstraction from behavior and the products of behavior.

All culture comes from culture.

The great success of the natural sciences has been achieved substantially by the reduction of each physical phenomenon to its constituent elements, followed by the use of the elements to reconstitute the holistic properties of the phenomenon. Advances in the chemistry of macromolecules, for example, led to the exact characterization of genes, and the study of population biology based on genes has refined our understanding of biological species.

What then, if anything, is the basic unit of culture?

Envision concepts as "nodes," or reference points, in semantic memory that ultimately can be associated with neural activity in the brain. Concepts and their symbols are usually labeled by words. Complex information is thus organized and transmitted by language composed of words. Nodes are almost always linked to other nodes, so that to recall one node is to summon others. This linkage, with all the emotional coloring pulled up with it, is the essence of what we refer to as meaning. The linkage of nodes is assembled as a hierarchy to organize information with more and more meaning.

The natural elements of culture can be reasonably supposed to be the hierarchically arranged components of semantic memory, encoded by discrete neural circuits awaiting identification. The notion of a culture unit, the most basic element of all, has been around for over thirty years, and has been dubbed by different authors variously as mnemotype, idea, idene, meme, sociogene, concept, culturgen, and culture type. The one label that has caught on the most, and for which I now vote to be winner, is meme, introduced by Richard Dawkins in his influential work *The Selfish Gene* in 1976,

We recommended that the unit of culture -now called meme- be the same as the node of semantic memory and its correlates in brain activity. The level of the node, whether concept (the simplest recognizable unit), proposition, or schema, determines the complexity of the idea, behavior, or artifact that it helps to sustain in the culture at large.

I realize that with advances in the neurosciences and psychology the notion of node-as-meme, and perhaps even the distinction between episodic and semantic memory, are likely to give way to more sophisticated and complex taxonomies. I realize also that the

assignment of the unit of culture to neuroscience might seem at first an attempt to short-circuit semiotics, the formal study of all forms of communication. That objection would be unjustified. My purpose in this exposition is the opposite, to establish the plausibility of the central program of consilience, in this instance the causal connections between semiotics and biology. If the connections can be established empirically, then future discoveries concerning the nodes of semantic memory will correspondingly sharpen the definition of memes. Such an advance will enrich, not replace, semiotics.

What we know or (to be completely forthright) what we think we know, about the hereditary basis of human nature can be expressed by linking together three determining levels of biological organization. I will present them from the top down, in a sequence that begins with the universals of culture, proceeds to epigenetic rules of social behavior, and ends in a second look at behavioral genetics.

“Prepared learning”. By this concept they meant that animals and humans are innately prepared to learn certain behaviors, while being counterprepared against—that is, predisposed to avoid—others. The many documented examples of prepared learning form a subclass of epigenetic rules. As recognized in biology, epigenetic rules comprise the full range of inherited regularities of development in anatomy, physiology, cognition, and behavior. They are the algorithms of growth and differentiation that create a fully functioning organism.

At the highest levels of mental activity complex secondary epigenetic rules are followed in the process called reification: the telescoping of ideas and complex phenomena into simpler concepts, which are then compared with familiar objects and activities.

Reification is the quick and easy mental algorithm that creates order in a world otherwise overwhelming in flux and detail. One of its manifestations is the dyadic instinct, the proneness to use two-part classifications in treating socially important arrays. Societies everywhere break people into in-group versus out-group, child versus adult, kin versus nonkin, married versus single, and activities into sacred and profane, good and evil.

Genes prescribe epigenetic rules, which are the regularities of sensory perception and mental development that animate and channel the acquisition of culture. Culture helps to determine which of the prescribing genes survive and multiply from one generation to the next. Successful new genes alter the epigenetic rules of populations. The altered epigenetic rules change the direction and effectiveness of the channels of cultural acquisition.

The final step in this series is the most crucial and contentious.

There is nothing contradictory in saying that culture arises from human action while human action arises from culture.

Most people believe they know how they themselves think, how others think too, and even how institutions evolve. But they are wrong. Their understanding is based on folk

psychology, the grasp of human nature by common sense-defined (by Einstein) as everything learned to the age of eighteen-shot through with misconceptions, and only slightly advanced over ideas employed by the Greek philosophers.

In the absence of a common search for consilient explanation, there is not solution. The schism between the two camps will continue to deepen. While biological anthropologists increasingly focus on heredity and reconstructions of human evolution, cultural anthropologists will drift farther away from the natural sciences.

But the SSSM also sees culture as an independent phenomenon irreducible to elements of biology and psychology, thus the product of environment and historical antecedents.

Epigenesis, originally a biological concept, means the development of an organism under the joint influence of heredity and environment. Epigenetic rules, to summarize very briefly my account in the previous two chapters, are innate operations in the sensory system and brain. They are rules of thumb that allow organisms to find rapid solutions to problems encountered in the environment. They predispose individuals to view the world in a particular innate way and automatically to make certain choices as opposed to others.

To this end, scientists look for four qualities in theory generally and mathematical models in particular. The first is parsimony: the fewer the units and processes used to account for the phenomenon, the better.

The second quality is generality: the greater the range of phenomena covered by the model, the more likely it is to be true. In reagent chemistry the periodic table precludes a separate theory for each element and compound. One theory works exactly for all.

Next is consilience. Unites and processes of a discipline that conform with solidly verified knowledge in other disciplines have proven consistently superior in theory and practice to units and processes that do not conform.

That is why, in every scrap of data from every level of biology, from the chemistry of DNA to the dating of fossils, it has been the case that organic evolution by natural selection beats Creationism. God may exist, He may be delighted with what we are up to on this minor planet, but His fine hand is not needed to explain the biosphere. And finally, drawing from all of the above virtues, the definitive quality of good theory is predictiveness. Those theories endure that are precise in the predictions they make across many phenomena and whose predictions are easiest to test by observation and experiment.

THE FULL UNDERSTANDING of utility will come from biology and psychology by reduction to the elements of human behavior followed by bottom-up synthesis, not from the social sciences by top down inference and guesswork based on intuitive knowledge. It is in biology and psychology that icon more predictive models, just as it was in physics and chemistry that researchers found premises that upgraded biology.

So the question of importance in rational choice theory is, how much information is enough? In other words, at what point do people stop reflecting and make up their minds? One simple strategy that provides a cut off point is “satisficing, a Scottish term that combines “satisfying” and “sufficing.” Introduced to psychology in 1957 by Herbert Simon, an economist at Carnegie Mellon University, satisficing means taking the first satisfactory choice encountered out of those perceived and reasonably available in the short term, as opposed to visualizing the optimum choice in advance and searching until it is found.

An alternative to this and other conceptions of traditional rational choice is that people follow rules of thumb, known more technically as “heuristics.” The idea was first advanced by the American psychologists Daniel Kahneman and Amos Tversky in 1974. Rather than calculate costs and benefits, people act upon simple cues and heuristics that work most of the time. By this means the complex tasks of assessing probabilities and predicting outcomes are reduced to a few judgmental operations.

Over thousands of generations the brain evolved to handle simple numbers and proportions but not complex problems requiring abstract quantitative reasoning.

Whatever the mix, rational choice theory, though still the light and the way to many social theorists, is a subject of controversy within psychology. It is too dependent, critics say, on analogies with computer algorithms and abstract optimality solutions. It pays too little attention to the properties of the real brain, which is a stone-age organ evolved over hundreds of millennia and only recently thrust into the alien environment of industrialized society. It is thus inconsistent with the evidence of how people in preliterate cultures reason and have likely reasoned throughout evolutionary time. These qualities have been summarized by C.R. Hallpike in *The Foundations of Primitive Thought*, as follows: intuitive and dogmatic, bound up with specific emotional relationships rather than physical causality, preoccupied with essences and metamorphosis, opaque to logical abstraction or arrays of the hypothetically possible, prone to use language for social interaction rather than as a conceptual tool, limited in quantification mostly to rough images of frequency and rarity, and inclined to view mind as stemming partly from the environment and able to project back out into it, so that words become entities with power unto themselves.

While it is true that science advances by reducing phenomena to their working elements—by dissecting brains into neurons, for example, and neurons into molecules—it does not aim to diminish the integrity of the whole. On the contrary, synthesis of the elements to re-create their original assembly is the other half of scientific procedure. In fact, it is the ultimate goal of science.

Science needs the intuition and metaphorical power of the arts, and the arts need the fresh blood of science.

Yet the great gaps in knowledge are beginning to be filled. That is the strength of cumulative science in a literate world. People learn and forget, they die, and even the

strongest institutions they erect deteriorate, but knowledge continues to expand globally while passing from one generation to the next. Any trained person can retrieve and augment any part of it.

Centuries of Debate on the origin of ethics come down to this: Either ethical precepts, such as justice and human rights, are independent of human experience or else they are human inventions.

Goal of the final theory, the Theory of Everything, T.O.E., a system of interlocking equations that describe all that can be learned of the forces of the physical universe. T.O.E. is a “beautiful” theory, as Steven Weinberg has called it in his important essay *Dreams of a Final Theory*. Beautiful because it will be elegant, expressing the possibility of unending complexity with minimal laws, and symmetric, because it will hold invariant through all space and time. And inevitable, meaning that once stated no part can be changed without invalidating the whole. All surviving subtheories can be fitted into it permanently, in the manner in which Einstein described his own contribution, the general theory of relativity. “The chief attraction of the theory,” Einstein said, “lies in its logical completeness. If a single one of the conclusions drawn from it proves wrong, it must be given up; to modify it without destroying the whole structure seems to be impossible.

To the extent that ethical and religious phenomena do not appear to have evolved in a manner congenial to biology, and especially to the extent that such complex behavior cannot be linked to physical events in the sensory and nervous systems, the empiricist position will have to be abandoned and a transcendentalist explanation accepted.

Science faces in ethics and religion its most interesting and possible humbling challenge, while religion must somehow find the way to incorporate the discoveries of science in order to retain credibility. Religion will possess strength to the extent that it codifies and puts into enduring, poetic form the highest values of humanity consistent with empirical knowledge. That is the only way to provide compelling moral leadership. Blind faith, no matter how passionately expressed, will not suffice. Science for its part will test relentlessly every assumption about the human condition and in time uncovers the bedrock of the moral and religious sentiments.

The central idea of the consilience world view is that all tangible phenomena, from the birth of stars to the workings of social institutions, are based on material processes that are ultimately reducible, however long and tortuous the sequences, to the laws of physics.

The human condition is the most important frontier of the natural sciences. Conversely, the material world exposed by the natural sciences is the most important frontier of the social sciences humanities. The consilience argument can be distilled as follows: The two frontiers are the same.

The world henceforth will be run by synthesizers, people able to put together the right information at the right time, think critically about it, and make important choices wisely.

What are we? Where do we come from? How shall we decide where to go?

The prospect of this “volitional evolution”—a species deciding what to do about its own heredity—will present the most profound intellectual and ethical choices humanity has ever faced.

If these advances in knowledge are even just partly attained, which seems inevitable unless a great deal of genetic and medical research is halted in its tracks, and if they are made generally available, which is problematic, humanity will be positioned godlike to take control of its own ultimate fate. If can, if it chooses, alter not just the anatomy and intelligence of the species but also the emotions and creative drive that compose the very core of human nature.

The global population is precariously large, and will become much more so before peaking some time after 2050. Humanity overall is improving per capita production, health, and longevity. But it is doing so by eating up the planet’s capital, including natural resources and biological diversity millions of years old. Homo sapiens is approaching the limit of its food and water supply. Unlike any species that lived before, it is also changing the world’s atmosphere and climate, lowering and polluting water tables, shrinking forests, and spreading deserts. Most of the stress originates directly or indirectly from a handful of industrialized countries. Their proven formulas for prosperity are being eagerly adopted by the rest of the world. The emulation cannot be sustained, not with the same levels of consumption and waste. Even if the industrialization of developing countries is only partly successful, the environmental aftershock will dwarf the population explosion that preceded it.

To summarize the future of resources and climate, the wall toward which humanity is evidently rushing is a shortage not of minerals and energy, but of food and water. The time of arrival at the wall is being shortened by a physical climate growing less congenial.

Humanity’s best efforts will include every technological fix for an overcrowded planet that genius can devise. Endless stand-by schemes are already on the board. Conversion of nitrogenated petroleum to food is one remote possibility. Algal farms in shallow seas is another. The water crisis might be eased by desalinization of seawater with energy from controlled fusion or fuel cell technology. Perhaps as polar ice shelves break up from global warming, more fresh water can be drawn from icebergs herded to dry coasts. With a surplus of energy and fresh water, the agricultural revegetation of arid wasteland is attainable. Pulp production can be increased in such recovered lands with “wood grass,” fast growing, nitrogen-fixing tree species that can be harvested with giant mowers and then sprout new shoots from the severed stocks. Many such schemes will be tried as demand rises, and a few will succeed. They will be driven by venture capital and government subsidy in the global free market economy. Each advance will reduce the risk of short-term economic calamity.

But be careful! Each advance is also a prosthesis, an artificial device dependent on advanced expertise and intense continuing management. Substituted for part of Earth's natural environment, it adds its own, long-term risk. Human history can be viewed through the lens of ecology as the accumulation of environmental prostheses. As these manmade procedures thicken and interlock, they enlarge the carrying capacity of the planet. Human beings, being typical organisms in reproductive response, expand to fill the added capacity. The spiral continues. The environment, increasingly rigged and strutted to meet the new demands, turns ever more delicate. It requires constant attention from increasingly sophisticated technology.

The common aim must be to expand resources and improve the quality of life for as many people as heedless population growth forces upon Earth, and do it with minimal prosthetic dependence. That, in essence, is the ethic of sustainable development. It is the dream that acquired general currency at the Earth Summit, the historic United Nations Conference on Environment and Development held in June 1992 in Rio de Janeiro.

Much of the technology required to reach that goal can be summarized in two concepts. Decarbonization is the shift from the burning of coal, petroleum, and wood to essentially unlimited, environmentally light energy sources such as fuel cells, nuclear fusion, and solar and wind power. Dematerialization, the second concept, is the reduction in bulk of hardware and the energy it consumes. All the microchips in the world, to take the most encouraging contemporary example, can be fitted into the room that housed the Harvard Mark 1 electromagnetic computer at the dawn of the information revolution.

In national balance sheets economists seldom use full-cost accounting, which includes the loss of natural resources. A country can cut down all its trees, mine out its most profitable minerals, exhaust its fisheries, erode most of its soil, draw down its underground water, and count all the proceeds as income and none of the depletion as cost. It can pollute the environment and promote policies that crowd its populace into urban slums, without charging the result to overhead.

New indicators of progress are needed to monitor the economy, wherein the natural world and human well-being, not just economic production, are awarded full measure.

The search for consilience might seem at first to imprison creativity. The opposite is true. A united system of knowledge is the surest means of identifying the still unexplored domains of reality. It provides a clear map of what is known, and it frames the most productive questions for future inquiry. Historians of science often observe that asking the right question is more important than producing the right answer. The right answer to a trivial question is also trivial, but the right question, even when insoluble in exact form, is guide to major discovery. And so it will ever be in the future excursions of science and imaginative flights of the arts.