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## CHAPTER 2

### The Nature of Biology Knowledge

#### Genetic Drift?

Twelve faculty members in a major university's genetics department were collaborating to produce a televised genetics course. Unexpectedly, they discovered that they were unable to agree on the definition of a gene — the basic unit of their field. How could that be? With so many experts and a rather well-understood entity, how could there be so much dissension about what a gene is?

#### WHAT IS INVOLVED IN “KNOWING BIOLOGY?”

The problem that the geneticists in the opening vignette were facing is not necessarily an unusual situation. Although an outsider might be startled by it, insiders will not be. A biologist's biology knowledge, like all knowledge, consists of various kinds of mental representations — declarative and procedural, logical and emotional, experiential and received, private and public, semantic and structural, basic and applied. The twelve geneticists each had their own specialization, so each knew different parts of the genetics subdomain. Each one viewed genetics through the lens of his own preparation, experience, and specialization. Each had also learned his genetics at different times, under different conditions, and in different ways. Disagreements such as this are generally more common among specialists than among generalists — in part because of the details associated with learning a particular subfield in depth, and in part because of the experts' deep emotional attachment to their own hard-won views of the subject matter.

Not only do specialists view their subject through different lenses, but a study by one of the authors (Abrams & Wandersee, 1995) finds that expert ideas about biology knowledge change over time. Beginning biologists typically believe that biology knowledge is derived solely from observations of the living world, as shown in Figure 2.1.

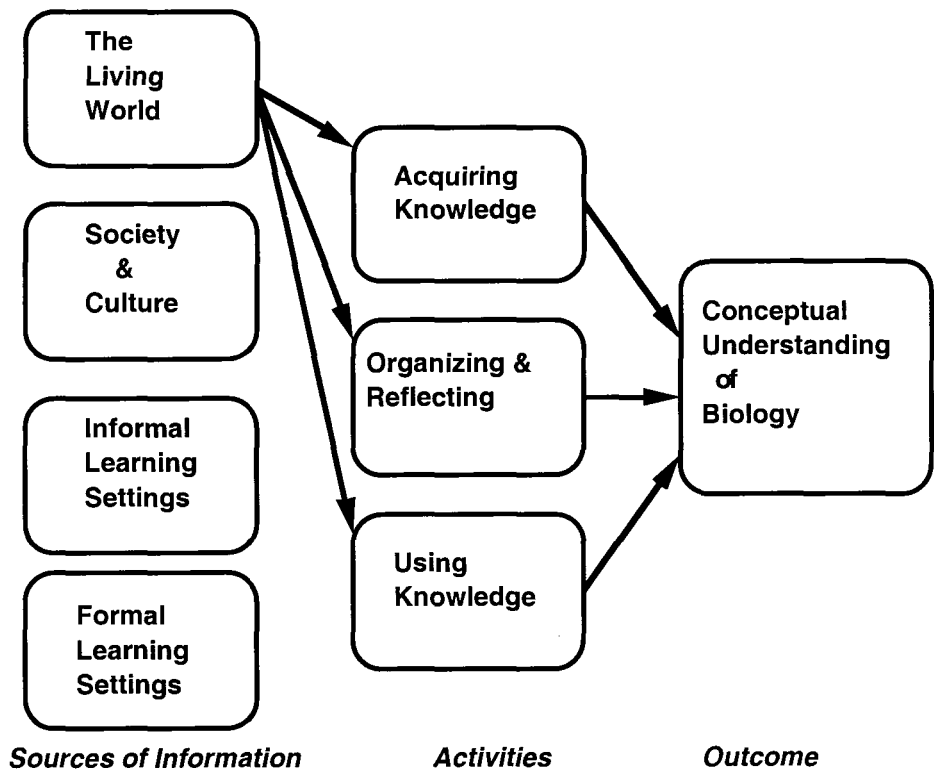


Figure 2.1. Naive view of sources of information influencing biology knowledge. Adapted from Wandersee, 1996.

Gradually, however, practicing biologists come to realize that what we already know affects how we see, acquire, organize, and use new biological knowledge, and even how we perceive and interact with the living world (Figure 2.2).

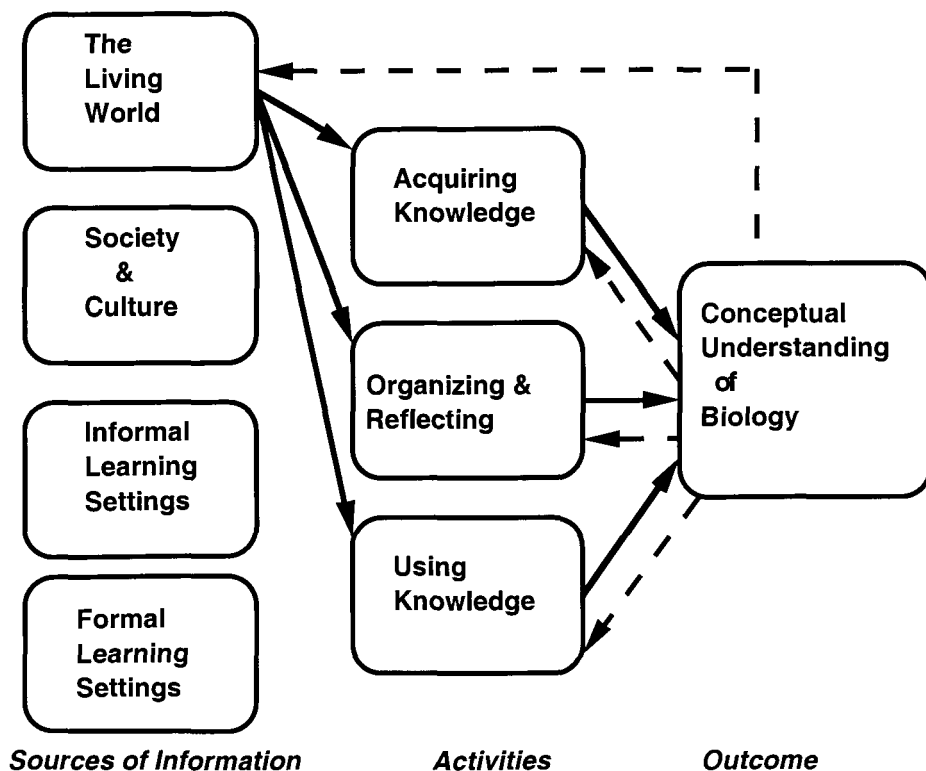


Figure 2.2. Recognition that what we know about biology influences what we see.

But even this is not the whole picture. While the living world is obviously the most pertinent source of biological information, our conceptual understandings of life (and the conceptual understandings of our students) are inevitably influenced by secondary sources such as society, culture, informal learning, and the theoretical constructs we derive from our formal learning (Figure 2.3). Our basic assumptions about what is likely, what is possible, and what is impossible are derived from attitudes and values we develop from these background sources over a lifetime. This is called one's worldview following Joseph I. Lipson (1980, personal communication; see also Cobern, 1996). Worldview may enable individuals to be receptive to certain new ideas or closed to them.

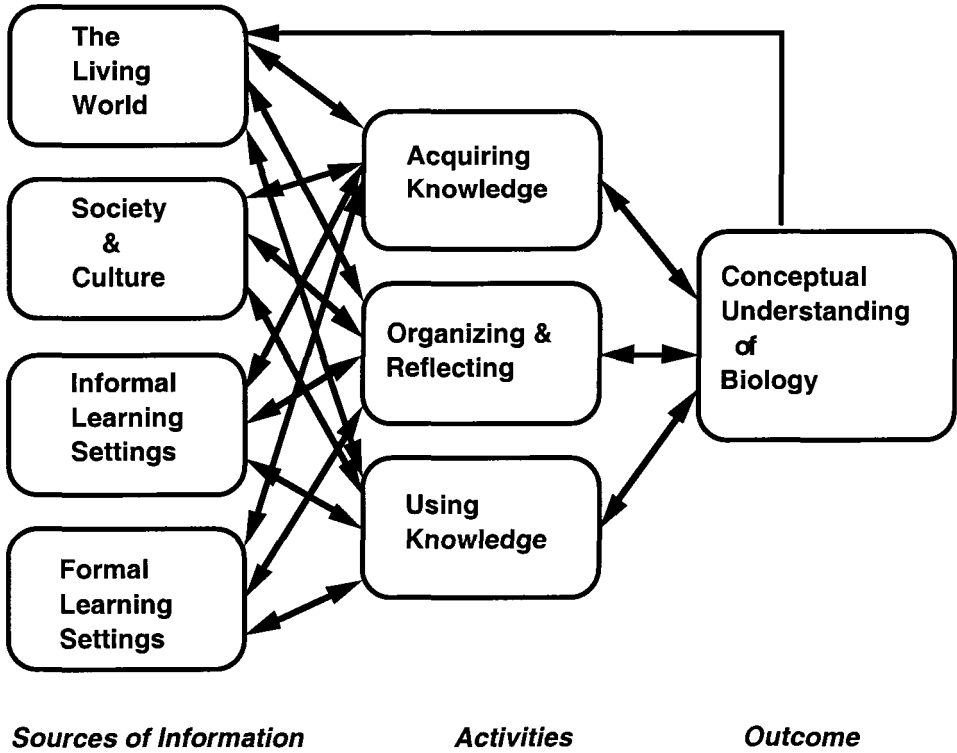


Figure 2.3. A more sophisticated view of learning: Recognition that our cultural assumptions, metaphors for understanding, and overall worldview influence what we see. Modified from Wandersee, 1996.

### THE NATURE OF BIOLOGY

The word “biology” originated in the 19th century. The precursors of this broad field of study were natural history, botany, and medicine, including anatomy and physiology (Mayr, 1982, p. 36). Darwin’s theoretical and evidentiary legacy, coupled with Mendel’s work, unified all of biology and established its explanatory power (Atrans, 1990). Molecular biology and the “modern synthesis” extend the powers of explanation and in some cases allow prediction. Neo-Darwinian evolutionary thought informs our understanding of ultimate causality, while detailed elucidation of DNA gives valuable insights into the proximal causes of cellular control as well as elucidation of phylogenetic relationships both currently and throughout evolutionary time.

Biology is the study of living things. But what are living things? Is all life cellular as claimed by the cell theory? Or are our intimate noncellular parasites, the viruses,

also alive as some argue? And if so, are prions alive? And when does human life begin? At conception? At the onset of neurophysiological activity? At birth? Or is life simply continuous, passed on from cell to cell? Is a person actually dead when her brain stops functioning or when her heart stops beating? Likewise, is the tomato we've just picked up from the grocery store alive? If we slice that tomato, is the slice alive? If we take a seed from that slice, is it alive? And is a cluster of naturally root-grafted White Pine trees really a single super-organism (Kourik, 1997)?

Defining life is not a simple task. Life's boundaries remain much "fuzzier" than we'd like in spite of (or perhaps because of) the many recent advances in our knowledge. Its fuzzy edges are just one of the ways in which the life sciences differ from the physical sciences. The contrasts range from the nature of the objects and events being studied to what counts as an explanation. The form and content of theory and the generalizability of explanations are also significantly different in the life sciences (Rosenberg, 1985, p. 34). Thus, like Ernst Mayr (1982), we respect the physical sciences but do not aspire to become them. Biology is a gradually maturing science, but that does not mean it is simply on its way to becoming more like physics and chemistry. As one example, the levels of organization that characterize life on earth (atom, molecule, cell, tissue, organ, organ system, organism, population, community, ecosystem, biome, and biosphere), each with its own emergent properties, have no close parallels in the physical sciences.

Biologists study objects that have (and vary in) information content and whose history matters, whereas chemists typically study inanimate objects such as atoms and molecules that are essentially interchangeable. Life consists of open systems of a certain minimum complexity. These systems self-regulate, self-repair, maintain a steady state, develop, reproduce, and are seriously constrained by their requirements for survival (Miller, 1973, p. 69). The dynamic, synthesizing, organizing, energy-consuming nature of living things sets them apart from inanimate objects.

John Moore holds that evolution, genetics, and developmental biology are "the core of conceptual biology," because these subdomains focus on "the fundamental characteristic of life — its ability to replicate over time (1993, p. viii)." From the organism's genetic program, to the differentiation that occurs as a single cell becomes a multicellular organism, to the enhancement of the survival of the species that natural selection confers, life has ancestry that cannot be ignored.

Bronowski's Rule (Bronowski, & Mazlish, 1960, p. 218) claims that confidence in any science is proportional to the degree to which it is made mathematical. This rule may be appropriate for the physical sciences, but is not broadly applicable in biology, even though some subfields (e.g., cell physiology, genetics, ecology) make use of mathematics. Another difference is that "The objects with which physical science deals do not have goals, ends, purposes, or functions (except as they serve explicit human purposes)" (Rosenberg, 1985, p. 43). Limb buds in a chick embryo, in contrast, do have developmental goals programmed into their DNA. Under normal circumstances, limb buds consistently and eventually become wings. For these and other reasons, the living and nonliving worlds are profoundly different.

In summary, biology is a unique science, quite different from the physical sciences. Biology knowledge is extensive, highly complex, incomplete, and often ill-

Mapping Biology Knowledge

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