From Fertilization to Birth:

Representing Development in High School Biology Textbooks

by

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ABSTRACT

Biology textbooks are everybody's business. In accepting the view that texts are created with specific social goals in mind, I examined 127 twentieth-century high school biology textbooks for representations of animal development. Paragraphs and visual representations were coded and placed in one of four scientific literacy categories: descriptive, investigative, nature of science, and human embryos, technology, and society (HETS). I then interpreted how embryos and fetuses have been socially constructed for students. I also examined the use of Haeckel's embryo drawings to support recapitulation and evolutionary theory. Textbooks revealed that publication of Haeckel's drawings was influenced by evolutionists and anti-evolutionists in the 1930s, 1960s, and the 1990s. Haeckel's embryos continue to persist in textbooks because they "safely" illustrate similarities between embryos and are rarely discussed in enough detail to explain comparative embryology's role in the support of evolution.

Certain events coincided with changes in how embryos were presented: (a) the growth of the American Medical Association (AMA) and an increase in birth rates (1950s); (b) the Biological Sciences Curriculum Study (BSCS) and public acceptance of birth control methods (1960s); (c) Roe vs. Wade (1973); (d) *in vitro* fertilization and Lennart Nilsson's photographs (1970s); (e) prenatal technology and fetocentrism (1980s); and (f) genetic engineering and Science-Technology-Society (STS) curriculum (1980s and 1990s).

By the end of the twentieth century, changing conceptions, research practices, and technologies all combined to transform the nature of biological development. Human embryos went from a highly descriptive, static, and private object to that of sometimes contentious public figure. I contend that an ignored source for helping move embryos into the public realm is schoolbooks. Throughout the 1900s, authors and publishers accomplished this by placing biology textbook embryos and fetuses in several different contexts—biological, technological, experimental, moral, social, and legal.

ACKNOWLEDGMENTS

In looking at high school biology textbooks I could not help but reminisce about my own high school biology experience and my exemplar high school biology teacher, Bill Everts. I only wish I could have discussed this project with him before he passed away. My appreciation goes to the members of my defense committee: Dr. Jane Maienschein, Dr. Karin D. Ellison, and Dr. Jason S. Robert. I also thank the ASU Center for Biology and Society for its support of this study in the form of a Graduate Student Research Enrichment Grant. This grant allowed me to travel to BSCS Headquarters, Colorado Springs, CO, where I was kindly aided by Rhiannon Baxter, Technology Coordinator at the BSCS Archives and Library.

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Biology textbooks are used to convey large amounts of scientific knowledge to people outside of the domain of science, namely students. Given this role, textbooks serve as a type of liaison between the institution of science and the lay public. Within research about the nature of science, there is acceptance that scientists are not entirely value-free and that the enterprise of science and its dissemination are, in part, socially driven (McComas, 1998) The public perception though, and I include students here, falls more in line with the belief that textbook information is the truth, and remains far removed from societal influence.

This project accepted the view that textbooks are created with specific social goals in mind and that embryos are more than just scientific descriptions. Embryos have often been central to such controversial issues as Ernst Haeckel's Biogenetic Law, Jacques Loeb's artificial parthenogenesis studies, *in* vitro fertilization, termination of pregnancies, genetic testing, and stem cell research. My goal was to examine how animal embryos, in particular human embryos, have been portrayed in American high school biology textbooks in the twentieth century and how their portrayal has changed in the context of political, social, and scientific forces. One needs to look no further than eugenics, public health, human reproduction, and radiation and space biology to begin to understand (a) the broad social goals of science education, and (b) how public schools are uniquely equipped to disseminate science.

Embryology, and the embryo itself, are no different from other biology concepts in that they carry a historical record with them, although this message is often subliminal. Coupled with an increasing reverence for embryos and ethical concerns surrounding them, there is an underlying social burden that embryos carry; one that students are not overtly made aware of. From this arises my driving question: what happens to the transfer of content from research context to educational context, especially with a subject such as human embryology that is heavily value-laden?

The use of pre-college textbooks to investigate how the presentation of concepts has changed over time is not a dense research field. Much of it has involved the scouring of specific chapters for misconceptions. These misconceptions have included photosynthesis (Storey, 1989), evolution, (Rees, 2007), and the physiology of action potentials (Odom, 1993). Most textbook misconception research takes a snapshot approach; that is, current texts are examined rather than a historical analysis of how certain concepts have been portrayed over time. Another way that textbooks have been analyzed is to examine them for specific teaching strategies, such as inquiry or case studies. A recent example of this was carried out in 2000 by the American Association for the Advancement of Science (AAAS, 2000). The Association gathered independent teams of biology teachers, science education researchers, and science curriculum experts to evaluate ten biology textbooks for their presentation and accuracy of four topics: cell structure and function, the transformation of matter and energy, the molecular basis for heredity, and evolution. None of the evaluated textbooks was given a high rating.

A chronological study of evolution in secondary school biology textbooks (1900–1977) was written by Gerald Skoog in 1979. In order to establish whether evolution had been neglected or given minor treatment, Skoog used a word count as a relative indicator of emphasis and trends. He addressed particular textbooks and their phraseology with a decade by decade summary, but he did not offer specific hypotheses about why some decades showed fewer or more words devoted to explaining evolution. Skoog offered the generalization that publishers, authors, educators, and politicians had responded to the efforts of antievolutionists and creationists to suppress the teaching of evolution (p. 636).

In response to Skoog's criticism of the *Modern Biology* series, Ronald Ladouceur (2008) reexamined twentieth century biology textbooks, and in particular the work of Ella Thea Smith, to conclude that the notion of no evolution in pre-1960s texts was false. He believed that this conception was held hostage by the Biological Sciences Curriculum Study (BSCS) to defend and promote its own work. Another textbook evaluation of the *Modern Biology* series was done by Steven Selden in 2007. Selden analyzed 73 high school biology textbooks published between 1914 and 1964 for eugenics content. He then compared this data to the eugenics content in ten *Modern Biology* texts published during the same time period. He concluded that the *Modern Biology* series had adjusted its discussion about eugenics over time, while other textbooks had simply dropped eugenics. Selden proclaimed that the high school biology curriculum was indeed what many call "contested terrain."

The purpose of my study was to develop valid and reliable methods to quantitatively and qualitatively analyze representations of animal embryos in American public high school biology textbooks. These books ranged from publication dates of 1907 through 1999. I chose both methods of study in order to generate answers and assumptions to these framing questions:

- What do changes in embryo representations correlate with? Embryology research? Social and political contexts? Advances in science education?
- Is there a correlation between the visibility, or, invisibility, of embryos in textbooks as the ethical issues of artificial parthenogenesis, evolution, abortion, and stem cell research have become highly debated?
- When were human embryos first drawn and discussed in texts? Did the images of embryos change as embryology, genetics, and evolution became more intertwined?

- How have visual representations of embryos been used to represent an image of science? Sex education? Clinical tools?

- When do Haeckel's nineteenth-century embryo drawings appear in texts and do they serve as Haeckel intended? That is, are they used to support the theory of evolution? Has this changed over time? How tangled up are Haeckel's embryos in social influence?

- Were there events that acted as "levers" to help change the perception of the embryo?

To help me focus on what had been written about embryos, I coded paragraphs, diagrams, and photographs about embryos and placed them into one of four categories. These categories were based on the four major themes of scientific literacy set forth by Chiapetta, Fillman, and Sethna, (1991) and are similar to the 1993 science literacy standards published in Project 2061's Benchmarks by the American Association for the Advancement of Science (AAAS, 1993). If the diagram or written text simply aided in describing content, it was placed in the *descriptive* science category. If the text used embryos to stimulate thinking and asked the student to "find out," the paragraph was placed in the *investigative* category. If the text presented embryology as a way of doing science, the paragraph was placed in the *science as a way of thinking* category (commonly referred to as a nature of science category). If a paragraph illustrated the effects of impact of embryology on society it was placed in the *human embryology, technology, and society category* or HETS. This data then helped serve as a basis for answering my framing questions.

Images were also important in this study. Line drawings, graphs, and photographs all have an intellectual inertia, or a permanence that leaves a lasting impression on one's consciousness. With this in mind, attention was given to the cataloging of illustrations to see if certain pictures were commonly used and for what reason. The presence of Haeckel's embryo diagrams was also tallied. In recent years opponents of evolution have used Haeckel's so-called fraudulent drawings to provide "evidence" that evolution must also be fraudulent. What I wanted to document, besides the presence of Haeckel's drawings, was written discussions accompanying the drawings about why Haeckel's embryos were important, or how the captions were to be used by students to foster a better understanding of development or evolution.

Other images that played an important role in the public understanding of embryos included Lennart Nilsson's 1965 *Life* color photographs of embryos and fetal specimens. How long did it take for these images to appear in textbooks and how were they used to help reconceptualize human embryos? Do the works of Haeckel and Nilsson, in fact, illustrate that there are no socially neutral images in science?

BACKGROUND DISCUSSION

This study examines biology textbooks over a period of almost 100 years—1907 to 1999. I entered this research with the assumption that embryo representations are inevitably shaped by not just what scientists do, but also by the social and political context in which we find embryos. As a result of all of these surrounding interests, historians and anthropologists have shown that embryos have always exhibited a high degree of flexibility in terms of how they have been studied and interpreted (Maienschein & Robert, 2010; Morgan, 2009). Have textbook embryos been afforded this same flexibility? In order to help answer this question it was necessary to interpret patterns in the sociohistorical context of embryological research, textbook publishing, science education pedagogy, and evolving societal views of the embryo.

Unlike the ways in which science is often imagined by the public, embryological research does not exist in a vacuum. It too has been shaped by emerging technologies, availability of funding, and political and social views about what is, or what is not, acceptable to study. Jane Maienschein and Jason S. Robert argue that the historical scientific understanding of embryos can be broken into six time periods as shown in Figure 1 (Maienschein & Robert, 2010). Their two earliest categories, the hypothetical and observed research periods, span from the fourth century BCE to the seventeenth century, significantly older than any of the textbooks that I used. Because of this I decided to focus on using Maienschein and Robert's last four embryo research periods to guide my own assumptions about why and when particular developmental concepts were introduced to high school students.

I will describe the four periods, Biological (1827 to 1950s), Inherited (1950s to early 1970s), Visible Human (1978 to 1980s), and Constructed (1980s to 1990s), in terms of time frames and examples of new embryological research that occurred during each research period. My overview is not intended to offer a complete compilation of embryological research, but to cut across the domains of technology, technique, and embryo plasticity—all of which bind the field of embryology together.

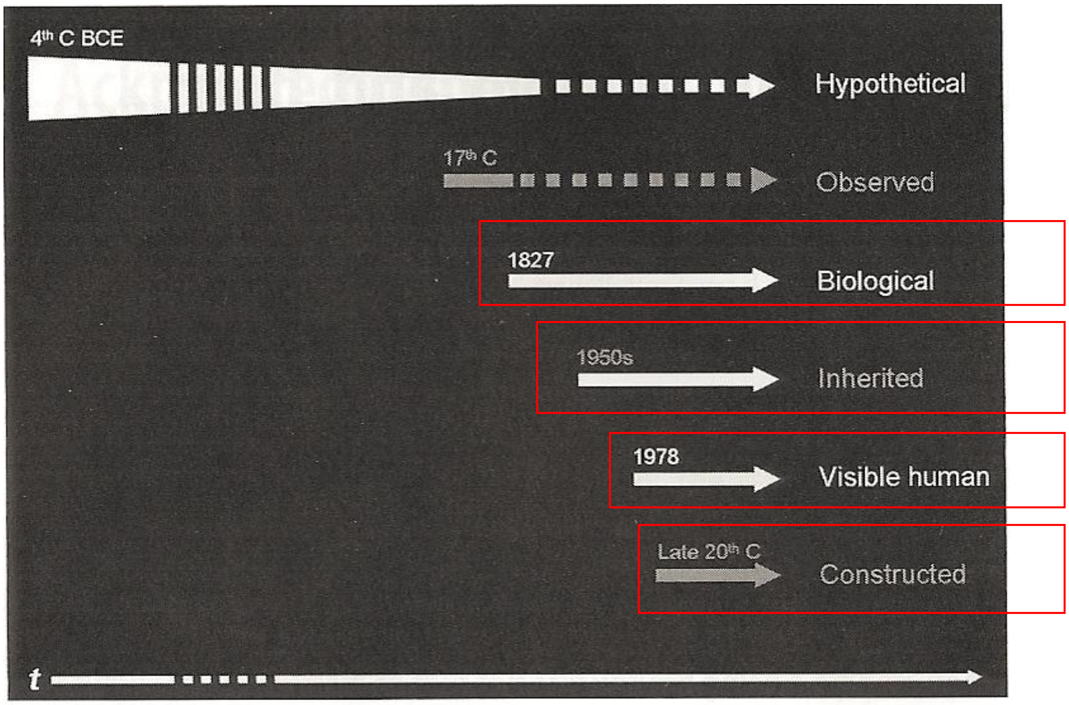


Figure 1. Historical periods in embryology research. The four time periods used for this study are outlined in red. Adapted from "What is an Embryo and How do we Know," by J. Maienschein and J. S. Robert, 2010, In J. Niskar, F. Baylis, I. Karpin, C. McLeod, & R. Mykitiuk (Eds.). *The Healthy Embryo: Social, Biomedical, Legal, and Philosophical Perspectives* p. 2. Cambridge: Cambridge University Press. Adapted with permission.

The Biological Embryo (1827 to 1950s)

The Biological Embryo Research Period is characterized by the joining of the new field of experimental embryology (how does it work?) with the old field of observational embryology (what does it look like?). Karl Ernst von Baer's discovery in 1827 that all mammals develop from fertilized eggs marks the beginning of this research period. By the early 1830s, the scientific approach toward the study of development had been set largely due to von Baer's work, including his description of germ layers that afforded the answer to many problems within the field of morphogenesis (Pickett, Wenzel, & Rissing, 2005). Although Heinz Christian Pander had first developed the concept of multiple embryonic cell (germ) layers, it was von Baer who actually described the layers (he counted the mesoderm twice for a total of four layers, not seeing that the mesoderm splits as the gastrula develops). Von Baer spent years noting how vertebrate embryos resembled each other during the early stages of embryogenesis. These findings eventually led to the beginning of the field of comparative embryology.

Von Baer did not think that the embryos of higher organisms passed through the adult stages of lower organisms in the hierarchy of life, like fellow embryologist Ernst Haeckel did. While Haeckel believed that embryos could, and should, be used to show that all organisms arose from a common ancestor, von Baer disagreed. Instead, von Baer believed in the idea of a primary germ. From this primary germ, four "archetypes" diverged from their shared embryonic form, not necessarily by evolution, with vertebrates serving as one of these archetypes (Hopwood, 2009).

Haeckel is well known for formulating the Biogenetic Law in the latter half of the nineteenth century. At the heart of this law was the mechanism of recapitulation. This was the idea that higher organisms passed through the adult stages of lower organisms in their embryonic development and that new structures or organs were added sequentially and terminally until an organism's final form was achieved. Haeckel used his famous lithographic plates, comparing embryos of different phyla, to illustrate his idea of recapitulation. His drawings were first published in *Natürliche Schöpfungsgeschichte* (*The Natural History of Creation*) in 1868. Haeckel arranged his embryos in a grid-like fashion to show how human evolutionary history was linked with other vertebrates, with the top row of embryos representing the "phylotypic" stage in which all vertebrates possess identical morphologies and structures (see Figure 2).

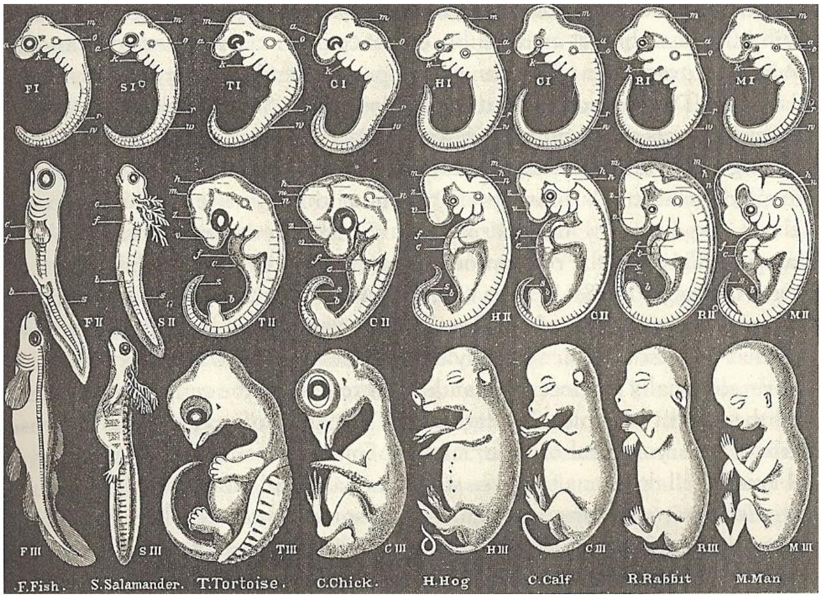


Figure 2. Haeckel’s embryos. All early embryos show evidence of “gill slits” and a tail. From *Natürliche Schöpfungsgeschichte* by E. Haeckel, 1868, Berlin: Reimer.

Haeckel argued that in order for recapitulation to work, three rules had to be followed. First was the law of correspondence. In a human, for instance, the zygote corresponded to the “adult” stage of a protozoan. The human blastula corresponded to a colonial protist, and the gill slit stage corresponded to an adult fish. Second, organisms evolved by the linear addition of new structures. Haeckel believed that all early embryos looked similar because of some type of physical constraint. This constraint was apparently lifted during late development—a time during which an embryo could then modify itself. For example, as Haeckel frequently told his lecture audiences, if humans had not added new structures at the end of their embryonic development, they would still be apes. The last rule concerned the idea of truncation. Haeckel realized that by adding more and more structures at the end of development, gestation periods would be abnormally extended. He proposed that early stages of development were somehow accelerated in higher organisms and that was why certain stages in animals were not the same, or in some cases, could not be observed (Gould, 2002, p. 353).

Recapitulation became a central paradigm in biology, even though by the late 1800s scientists had started to publically proclaim that Haeckel was wrong (Allen, 2007; Gilbert, 2010). Comparative anatomists such as Wilhelm His, Alexander Goette, and Albert von Kölliker proclaimed that recapitulation had too much Lamarckian influence in it and it seemed unlikely that the experiences of past ancestors could be written into inherited material.

Haeckel was also accused of doctoring his images to exaggerate the similarity of vertebrate embryos. He later admitted that he had combined figures of species types to create thought-provoking images (Richards, 2008). He also insisted that he had had to do this, in part, because there were so few human embryos at his disposal to work with. Many distinguished scientists, including Richard Hertwig and August Weismann, while not approving of Haeckel's tendency to exaggerate and perhaps overspeculate, refused to attack him in public, believing that his embryological drawings still held significant validity in the field of evolutionary development.

Model organisms.

Comparative embryologists during the Biological Embryo Research Period did not study human embryos to any great extent because these embryos were so difficult to obtain. Germany's Wilhelm His was one of the most notable embryologists to make the collection of human embryos a priority (Hopwood, 1999). He connected with physicians and coroners much like that of his former student, Franklin P. Mall, former director of the Carnegie Institution of Washington (CIW), to acquire embryos and fetuses for model-making and cross-sectioning (Morgan, 2009). But many embryologists did not have the luxury, or perhaps the need to study human embryos, so they turned to other organisms for their studies.

During the nineteenth century an increasing accumulation of knowledge about the descriptive embryology of fish and birds took place. Teleosts (ray-finned fishes) became model research organisms because of their ability to produce eggs through artificial fertilization, thus guaranteeing a ready supply of transparent eggs, which in turn made microscopic study easy (Wourms, 1997). Technology also came into play, as improved histological, sectioning, and microscopic techniques were all used with fish eggs to provide more accurate descriptions and chronologies. Fish development was one of the first to be photographed and published in an embryological monograph in 1878 (Wourms, 1997). Later micrographs of sectioned trout blastomeres were published in 1898. It might be expected then to see fish embryo pictures in some of the earliest published high school biology textbooks during the early 1900s.

In 1908 embryologist Frank R. Lillie published his classic book on chicken embryology, *Development of the Chick: An Introduction to Embryology.* Along with writing the text, Lillie prepared a large series of serial sections of the chick embryo at various stages to serve as illustrations. With revisions, the text and laboratory manual continue to be used today, serving as one of the best accounts available on bird development (Watterson, 1979).

The study of fish embryology was slowly surpassed not only by chicks, but also by the study of other organisms, such as frogs, sea urchins, as well as other invertebrates. These organisms were favored over fish because they required far less maintenance. Fertilized chicken eggs, for example, could be obtained year-round and amphibians and marine invertebrates could be collected in the wild or purchased from commercial suppliers (Wourms, 1997). Fishes, on the other hand, were not as convenient to collect. Fish hatcheries were not common in the early twentieth century so embryologists had to capture their own wild fish, keep them alive in captivity, and maintain conditions suitable for breeding to occur. To make matters more difficult, there were no governmental research grants available for technicians or facilities for the long-term commitment of time and space to rear fish. There were also some technical disadvantages that fish embryos presented to researchers: fish eggs are fairly small, while amphibian and chicken embryos are large enough to handle by hand for serial sectioning and grafting experiments.

With its use of studying different model organisms, embryology soon found its way into college science courses. From the 1830s, special courses in embryology became mandatory for those majoring in zoology (Hopwood, 2009) and also for those studying for their medical licenses. The demand for these courses resulted in new technologies, including new fixatives and stains, better microscopes, and easier-to-use microtomes to show the internal structure of embryos.

Roux and Driesch.

During the late 1800s embryology turned tack. Evolutionary embryology began to give way to new experiments and investigations designed to get at the question of how cellular differentiation worked. During this time, Wilhelm Roux was instrumental in the development of a new way to look at embryos. Roux, like His, Eduard Pflüger, and Gustav Born was interested in working with living embryos and wanted to see things unfold before his eyes. Many embryologists now wanted to go beyond the “dead” embryo, sliced thin, and fixed to microscope slides. This new physiological approach became known as mechanical embryology or *Entwicklungsmechanik* (Maienschein, 1994).

Roux was keen on answering questions about differentiation, the process that transforms a tiny clump of similar cells in a blastula into an organism with nearly 350 distinct cell types (Moore, 2001). Working with August Weismann, Roux developed the

Roux-Weismann hypothesis. Although relatively short-lived, this hypothesis generally accepted that all cells in an organism had the same set of inherited "determinants" and that the cytoplasm interacted with these to make brain cells brain cells and muscle cells muscle cells, and not something else (Moore, 1987).

Roux is best known for his studies of the early development of frog embryos. He found that when early embryos underwent their first cleavage, the embryo divided into a left and right half. Taking a hot needle, Roux punctured, and essentially destroyed, one cell of the two-cell stage embryo. The cell that was not injured developed into a half embryo—sometimes an anterior end, sometimes a posterior end, sometimes even just the left or right half of a whole embryo. His key finding was that a normal embryo never developed. Roux did not accept the idea of a completely preformed organism in the egg, but he did believe that certain areas in the egg were destined to become specific parts of an organism. To Roux, his results seemed to show that early embryos were a mosaic of independent parts, the functioning of which depended on nuclear division (Maienschein & Robert, 2010)

In 1892, four years after Roux's published work on differentiation, Hans Driesch set out to see if Roux's results with frogs could be replicated with the sea urchin, *Echinus microtuberculatus.* Instead of killing cells with needles, though, Driesch separated the blastomeres. He did this by placing two-celled embryos into a test tube of salt water and violently shaking the tube for at least five minutes. What he found was that the separated blastomeres developed into normal pluteus larvae. He repeated this with 4-cell, 8-cell, and even 16-cell embryos and most often got the same results—entirely new embryos indicating that each cell had the same "instructions" for development and that each cell was totipotent, or capable of forming the entire embryo.

Driesch's results conflicted with Roux's and the former's evidence that half of a two-celled "embryo" could produce a whole embryo meant that epigenesis, rather than preformationism, was responsible for development (Sander, 1992). Epigenesis is the idea that the egg or sperm contains no preformed structures and although Roux did not understand the mechanism of how epigenesis worked, he believed that the process involved some type of regulative development. Somehow the egg divided into identical blastomeres with equal potential with the aid of a guiding internal force. In retrospect, both Roux and Driesch were correct. The idea of preformationism was false and yet the mosaic idea of development had merit. Certain regions in embryos are destined to become specific parts of the adult organism.

Artificial parthenogenesis.

One outcome of *Entwicklungsmechanik* was the rise in the number of marine field stations where various marine invertebrates could be studied (Hall, 2007). In the United States, the Marine Biological Laboratory at Woods Hole, Massachusetts became the site of Jacques Loeb's 1899 work with artificial parthenogenesis of sea urchins (Pauly, 1987). Loeb was driven to see if an egg could begin dividing and eventually develop into a diploid organism without the aid of sperm. Loeb simulated fertilization by exposing eggs to various combinations of acids, bases, and electrolytes. In a few such cases, parthenogenesis occurred and Americans now had a new look at how life could be created. Loeb's physico-chemical work showed that even an unfertilized egg had all the information it needed to turn into a complete organism; all the egg required was a little experimental manipulation. Loeb's work was sensationalized in the popular press, leaving the public to wonder if males would eventually not be required for a woman to give birth.

Embryo collecting.

In 1914 Franklin P. Mall obtained funding from the Carnegie Foundation to establish the Carnegie Institution of Washington (CIW) Department of Embryology at Johns Hopkins University in Baltimore. In 1917 Mall unexpectedly died and George L. Streeter became director. Under Streeter's watch, the number of human embryo specimens at the department grew and helped establish the CIW as the premier institution for the study of human embryology (Maienschein, 2004). Streeter directed embryologists and staff to work on a universal chronology or "stages" of the human embryo throughout development. Putting embryos in exact chronological stages had proven nearly impossible since one rarely knew how old an embryo was when it was delivered to embryologists. Instead of focusing on the age of an embryo, Streeter and his colleagues decided to establish the maturity of the embryos by identifying the presence and morphology of multiple physical structures. This required that normal human embryos and specific organs be studied longitudinally from fertilization to approximately sixty days of development (the final stage represents an approximately eight-week-old embryo, the time by which most organs and tissues are formed).

The Department of Embryology researchers and staff spent decades identifying twenty-three stages of early human embryo development. These "Carnegie stages" became the worldwide standard to which all embryo specimens continue to be compared (O'Rahilly, 1988). Beginning in the 1950s, many of the models, pictures, and black-and-white photos of Carnegie embryos made their way into scientific journals and textbooks.

Fate maps.

The serial sectioning of embryos, as performed by many technicians in Europe and at the CIW, became a popular way to study embryos in the late 1800s and early 1990s (Gilbert, 2007). As sectioning techniques improved, new knowledge about the internal structures of embryos grew by leaps and bounds. But serial sectioning can only tell you so much. Researchers soon became anxious about leaving the staticness of fixed slides to tracing the dynamic movements of embryonic cells during gastrulation.

In the late 1920s German embryologist Walther Vogt began working with amphibian embryos to determine the locations of early gastrula cells. These cells would later develop into germ layers that von Baer and others had located and named (Gaudilliére & Rheinberger, 2004). By using tiny pieces of agar impregnated with different colored dyes, Vogt removed the jelly membrane in various areas of the early gastrula, placed the agar pieces along the outside of the gastrula, and watched the dyes diffuse from the agar and stain embryonic cells. By following the dyed cells as the gastrula aged, Vogt found that the cells destined to form each germ layer remained together as units. He was able to map where each cell went and what it turned into. Essentially, Vogt was able to create a fate map of where cells would eventually migrate to and what their final "fate" would be. The 1930s and 1940s soon became filled with embryologists making fate maps of different species of organisms.

Spemann and organizers.

Hans Spemann was an experimental embryologist best known for his transplantation studies and the organizer concept. To Spemann, studying embryos meant disrupting their normal physiological development. Much of his laboratory work between WWI and WWII consisted of taking tissue from one embryo, implanting it into another, and seeing what happened. Spemann and others were no longer content with just describing what embryos looked like. They wanted answers to questions like how does a simple egg develop into a complex adult? How do the organs of embryos form from parts of the egg that are just like any other part? Why aren't embryos made up of cells, all of the same kind?

The concept of embryological induction, whereby the development of tissues or a structure is affected by closely situated tissues was first clearly demonstrated by Spemann between 1901 and 1903, with the development of frog embryo eyes (Hamburger, 1988). At the heart of Spemann's studies was the role of the three germ layers: the mesoderm, ectoderm, and endoderm. The ectoderm gives rise to skin and nerves and the endoderm produces the lining of the intestinal tract. The mesoderm forms into muscle and blood. When embryonic eyes begin to develop, they start as optic vesicles in the mesoderm and bulge outward on each side of the embryo brain. Upon contact with the overlying ectoderm, the ectoderm invaginates to form an optic cup and, eventually, the eye lens.

Spemann transplanted the eye mesodermal layer to other parts of the frog body to see if he could induce lens development in ectodermal layers far removed from the normal eye area. He found that he could induce lens development practically anywhere on the frog using this method. He then removed the local ectoderm of the eye region and replaced it with ectoderm from other parts of the frog body. Again, lens formation occurred. From this Spemann concluded that head ectoderm possesses a predisposition for lens formation. This work led Spemann to the concept of induction and the "organizer," although he did not use these terms in his report (Hamburger, 1998).

In the 1910s, Spemann established the Spemann School at the University of Freiburg. It was at this laboratory that he and his colleagues carried out numerous heteroplastic transplantation experiments. One of these experiments involved the development of the neural tube. Spemann cut out the ectoderm from embryos and placed individual pieces in separate dishes. The removed pieces of ectoderm did not form a nerve tube, although they did remain alive. Spemann concluded that the start of a nervous system required an attached ectoderm to the embryo (Spemann, 1938). Further, he questioned whether the mesoderm stimulated the development of the ectoderm. To find out, Spemann cut and folded back a piece of ectoderm from the top of an embryo. He then cut out the underlying patch of mesoderm, folded back the flap of ectoderm, and observed that while the ectoderm fused back to the embryo, it did not develop into a neural tube.

To lend further evidence to the importance of the mesoderm in neural tube development, Spemann performed another experiment. He obtained two embryos, both in the early gastrula stage. With one embryo he removed a piece of mesoderm from in front of the dorsal lip of the blastopore. The second embryo had a same-sized piece from the mesodermal area 180 degrees from the dorsal lip. Spemann inserted the piece of mesoderm from the first embryo into the second embryo. The transplanted mesoderm formed a blastopore and moved inside the embryo. Later, neural ridges formed not only near the normal blastopore, but also near a secondary blastopore. Eventually the embryo developed two heads. Spemann concluded that the mesoderm of the dorsal lip region is important (Spemann, 1938). If it is removed, the neural tube does not develop. If it is put in a different place, a spinal cord can develop where one ordinarily would not be found.

A graduate student of Spemann's, Hilda (Proscholdt) Mangold, played a large role in Spemann's organizer concept. As part of her PhD thesis, Mangold removed a piece of the upper lip of the blastopore of a non-pigmented salamander embryo (*Triturus cristatus*) and transplanted it into the blastocoel of a species of salamander (*Triturus taeniatus*). The recipient salamander was different from the donor in that it produced pigmented eggs. Such non-pigmented-to-pigmented transplants made it easy to follow the differentiation of the grafted tissue. Mangold found that the recipient salamander developed into a double embryo with the two salamanders joined at the belly. Upon microscopic examination, Mangold observed that the secondary salamander was made up of a mix of donor and host cells and that the tissues were appropriately arranged to be physiologically sound. From this Mangold concluded that the upper lip transplant had "organized" its new surroundings and had given rise to the development of a working axial system in the second embryo (Hamburger, 1998).

This 1921 experiment resulted in a landmark paper by Spemann and Mangold in which the authors argued that certain parts of embryos, in this case the dorsal lip of the blastopore, could induce the formation of other tissues or structures. This inductive role was coined the "organizer" and the region where the organizer develops was identified as the "organization center." Soon after the publication of Spemann and Mangold's work, embryologists embarked on a long road of trying to find other inducers and perhaps a primary inducer, one that initiates all tissue and organ development. A primary inducer was never found, making the 1930s the decade of "organizer doubt." By the 1940s, many embryologists had abandoned the idea of an organizer (Allen, 1975).

Spemann is also known for his series of constriction experiments which were a new design on an old idea—mainly that of Roux's and Driesch's experiments (Allen, 2007, p. 139). Constriction experiments involved the intricate process of tying fine hairs around embryos and slowly tightening them until the two regions were constricted into a dumbbell shape. Spemann found that when the hairs were tightened around the embryo and made to cross the blastopore (the slit-like invagination of the gastrula through which cells move to form internal organs), two complete embryos resulted. This was not the result when he tied the hairs above or below the blastopore. In these cases, the region containing the blastopore developed into a complete embryo and the region without a blastopore formed a soon-to-die undifferentiated *Baruchstük* (belly mass).

Spemann continued changing variables such as the amount of time the embryo was constricted and the degree of constriction, all of which exhibited the equivalence and totipotency of early vertebrate cells. This was similar to Driesch's studies showing that embryonic cells had the ability to self-regulate to varying degrees. Spemann concluded that an embryo's blastopore region is essential for differentiation. His constriction experiments also showed that the formation of duplicate heads or tails could not be replicated if the manipulation was done at the end of gastrulation. Early gastrulation, it was determined, was when the decisive action for axial differentiation occurs.

Heading into the 1950s, much of genetics and embryology remained separate fields of study. Geneticists were keen on the idea of a genetic approach to development while embryologists tended to ignore new ideas in genetics (Gilbert, 1988, p. 319). A good example of this is Spemann's popular book *Embryonic Development and Induction* (1938) which makes little mention of genetics while discussing the organizer concept.

The Inherited Embryo (1950s)

The Inherited Embryo Research Period is marked by the ways embryology began to be folded into the new field of developmental biology. Within this interdisciplinary field were embryologists, geneticists, biochemists, cell biologists, and molecular biologists who saw the need to unify embryology, genetics, and molecular biology into a single research program. With the discovery of the structure of DNA and its copying mechanism by Watson and Crick in 1953, further support was given to Weismann's theory of the continuity of germ plasm. It was now realized that every cell had a whole set of hereditary material already in it and that there must be a kind of cell division in which the chromosome number was halved (meiosis).

With the discovery of DNA's structure, geneticists quickly found themselves to be better funded than other biologists, and developmental biology soon revolved around genetics and the idea of differential gene expression. Ever since Spemann had created interesting double-headed frogs and "Siamese-twin" salamanders, researchers had continued with transplantation studies. Beginning in the 1950s, they began tinkering again with the notion that an organizer could actually be a gene that promoted induction (Locke, 1996).

Nuclear transplantation.

The work of Robert Briggs and Thomas King (1952) and John Gurdon (1962) in the 1950s showed that cells from a blastula, or even a later embryo, could be placed in an egg that had had its own nucleus removed, and that the egg sometimes began development. In some cases, Briggs and King were able to generate fully developed tadpoles using their nuclear transfer technique (Beetschen & Fischer, 2004). But before all of their success, Briggs and King had spent many years working on the technical intricacies of somatic cell nuclear transplantation, or cloning (Beetschen & Fischer, 2004). First, they had to learn how to enucleate egg cells without destroying them. Second, they had to be able to remove a nucleus from an embryo without harming the nucleus, and third, they had to devise a method for transferring donor nuclei into enucleated eggs without harming the nucleus or the egg. After much trial and error, the two scientists were able to perfect their techniques on the leopard frog (*Rana pipiens*). They achieved the most success when they used nuclei from very young embryos, anywhere from 20 to 30 hours old. Once the frog embryo reached the age of about 85 hours of development (the “tailbud tadpole “stage), the nucleus lost its ability to direct development of a new frog.

Gurdon and his colleagues used a different frog (*Xenopus laevis)* and a slightly different donor nucleus, one that was older, to show that differentiated cell nuclei could still direct development. The researchers took differentiated skin cells from the webbing of the frogs’ feet and placed their nuclei into enucleated *Xenopus* eggs. The eggs survived until gastrulation. At first this was not seen as much of a success but the researchers made serial transplants of the nuclei. That is, they took nuclei from the cleaving egg and put them into a new set of enucleated eggs. Numerous tadpoles were the result. Although the tadpoles died, Gurdon was able to show that a differentiated cell nucleus maintained potency (Gilbert, Tyler, & Zackin, 2005). In this case, the transplanted adult skin cell nuclei produced all the cells of the young tadpoles, even though they did not reach adulthood. Because Gurdon, Briggs, and King were unable to get their "clones" to develop into adults, it left them with the question of whether a differentiated adult nucleus could be fully reprogrammed.

As Maienschein and Robert (2010) point out, it was during this period that embryos became a "complex of genetic inheritance and 'information' to be translated into functioning parts" (p. 7). With this shift of seeing embryos as highly genetically determined, there also came a growing public perception that each person begins his or her unique identity at conception. The publication of Lennart Nilsson's jaw-dropping photographs of human embryos and fetuses in the mid-1960s also helped the public brand individual embryos as highly unique (Morgan, 2009). By the end of the Inherited Embryo Research Period, embryos had moved from the laboratory to human reproduction pamphlets, animations, and coffee table books. Such was the beginning of serious ethical debates that were to take place in the Visible Human Embryo Research Period.

The Visible Human Embryo (1978 to late twentieth century)

Maienschein and Robert (2010) begin this historical era in 1978 with the birth of the world's first test tube baby, Louise Brown. During the late 1940s and 1950s, *in vitro* fertilization (IVF) and nuclear transfer experiments became part of many embryologists' research. At first, their work was aimed at better livestock production but their success quickly made scientists believe that *in vitro* techniques could aid women who were unable to conceive due to blocked fallopian tubes.

***In vitro* fertilization.**

The transplantation work of Robert Edwards, a University of Cambridge physiologist, 2010 Nobel laureate, Patrick Steptoe, a gynecologist, and technician Jean Purdy, successfully removed a mature oocyte by laproscopy from Lesley Brown, fertilized it *in vitro*, and then placed the embryo back into the uterus of Brown. With the 1978 birth of Louise came a growing concern over new reproductive technologies, especially the high financial and emotional costs of failed attempts at *in vitro* fertilization. Later, as scientists refined IVF techniques, they realized that they could freeze blastocysts for future use. When stored and thawed properly, blastocysts obtained from IVF techniques could be implanted and start a new pregnancy. Or, as some pointed out, they could be thawed for future laboratory use.

The Visible Human Embryo Period might also be called “the embryo in the dish” period (Maienschein & Robert, 2010). With advances in IVF, scientists were now making fertilization occur outside of the human body. This technology had been done long before 1978 though. In 1959 rabbits had become the first IVF animal successfully born. This was followed by laboratory mice in 1968. But these were “just” animals and not humans, and so, they did not cause much public outcry. After Louise Brown was born, the idea of further test-tube baby births gave many a feeling of queasiness. Was it ok for this kind of medical intervention to take place? Were test-tube embryos the same as *in utero* embryos? Could *in vitro* techniques lead to designer babies? The human embryo was now visible not only in the laboratory dish, but also in the public eye.

The Constructed Embryo (late twentieth century)

The embryo that had become highly visible starting in 1978 entered The Constructed Embryo Research Period still visible but “one in which scientists can rearrange or even replace cells, recombine genes…and manipulate the internal and external environments to influence development" (Maienschein and Robert, 2010, p. 9). In other words, the embryo was now found in many worlds, including the laboratory, biotechnology firms, fertility clinics, and the mass media. Even Spemann's work became subject of study again. By the 1990s, his organizer concept had returned to the laboratory where new experiments attempted to zero in on the genes that might be responsible for the organizer's activities.

Embryology attained "high profile" status with the advent of cloning and embryonic stem cell research. During the late twentieth century, and continuing into the twenty-first century, researchers had found that not only could they study embryos with far greater detail, but they could actually construct one in the laboratory. This time period has been coined by Ian Wilmut (2001) and others as the "age of biological control" and for good reason. Not only were scientists experimenting with embryos for research purposes, but developmental scientists and physicians were experimenting with embryos in for-profit fertility clinics rather than in university laboratories (Hopwood, 2009).

In the late 1990s, Wilmut and his team of researchers at the Roslin Institute, Scotland announced their successful cloning of a female sheep, named Dolly. Embryonic mice had been cloned before this, but until the Constructed Embryo Research Period, the clones had not lived long and the science of cloning still seemed quite science-fictionish. This all changed on February 27, 1997 when Dolly became the first mammal cloned from an adult cell (a mammary gland cell). This is what made Dolly so different from others which had been cloned using embryonic cells, and the experiment so different from those of Briggs and King and later Gurdon. Since then, the same technique has been used to clone cats, dogs, mice, and beef and dairy cattle, thus proving that almost any kind of adult cell's nucleus can be transferred into an enucleated egg and a new animal can be born.

Stem cells.

Scientists were also concerned with constructing embryos for research and not reproductive purposes. Their laboratories soon became the sites of embryonic gene transfers, gene additions, and gene removal experiments. Embryos were constructed using rabbit eggs and human skin cell nuclei and embryonic stem cell research emerged on the scene in 1998. The history of stem cell research, though, does not begin in the Constructed Embryo Research Period. The concept of stem cells dates back to the mid-1800s and the observation of blood cells. It was realized that there were different types of blood cells that seemed to originate from a single “master” cell, but it wasn’t until the early 1960s that Canadian scientists documented the existence of stem cells in the spleens of laboratory mice (Siminovitch, McCulloch, & Till, 1963). It became clear that a single bone marrow cell could generate copies of itself *and* different kinds of blood cells.

Technology though had to catch up, and it wasn’t until the Constructed Embryo Research Period that stem cell research took embryos by storm: embryos could now be used to harvest stem cells from, and researchers could develop these stem cells into different kinds of tissue. The public questioned this new research. Some saw the need for embryos for stem cell research as a crucial step for trying to cure diseases while others saw it as the destruction of a potential human life. Would it soon be possible to walk down the street and find embryo donor centers and embryo “banks?” As Hannah Landecker, author of *Culturing Life: How Cells Became Technologies* (2007), points out, this time period in research raised the concern that biotechnology was beginning to change what it was to be human.

The Four Historical Periods and Secondary Science

The four embryology research periods that I have described are rich with experiments, investigations, and people. So much so, that it would be impossible to write about embryology in detail without having to reserve copious amounts of shelf space for the multiple volumes that embryology history would take up. With all of this information, what would be considered important for high school biology students to know about development? This is influenced by an author's expertise, what the market looks like for textbook publishers, science education teaching pedagogy, science education reform movements, and public approval. The next sections of this background discussion will look at these influences.

High school biology.

In 1881, Milwaukee became the first place in the United States where a year-long high school biology class was taught (Christy, 1936). At the turn of the century, seven other cities also offered general biology and New York State had developed a state-wide biology curriculum (Hurd, 1961). New York's curriculum guided the writing of several textbook authors including high school biology teacher George W. Hunter (1907) who published one of the first biology textbooks for high school students, *Elements of Biology*.

By the early 1900s, general biology had mainly usurped botany, zoology, and human physiology and combined them into a single course. According to Rosen (1959) there were two main reasons for streamlining three courses into one. First, the high school science curriculum was difficult to navigate through for students and second, a single biology course would place biology on equal footing with the one-year courses of chemistry and physics. In 1909, the High School Teachers Association of New York City released a report emphasizing that the role of secondary biology curricula was to cover topics like conservation, health and nutrition, ecology, and practical applications of biology in everyday life. It was agreed upon that botany should stay as part of biology because plant specimens were easy to obtain and resulted in less "aversion" than handling live animals (DeBoer, 1991, p. 43). In his review of the history of biology teaching, Mayer (1986) refers to this time period as the “bale of hay and pail of frogs” teaching approach (p. 483).

In 1906 the American Society of Zoologists proposed a one year biology course that would emphasize natural history, classification, morphology, physiology, and reproduction. The society also recommended that evolution not be part of the high school biology curriculum. During this time period the AAAS argued for a natural history approach to teaching; the Central Association for Science and Mathematics Teachers strongly advocated for a more academic framework; and others believed that textbooks should move forward with an emphasis on practical biology for good citizenship (Rosen, 1959).

Most textbooks incorporated all three frameworks to some extent, but many elementary science and high school science courses were taught by teachers who had gone through nature study training. In university settings like Cornell, these teachers spent their summers studying local flora and fauna. Upon return to their classrooms, they were prepared to inculcate their students with a love of nature through direct contact with the outside world. These teachers proved resistant to giving up a curriculum that they actually knew about, for something different. The nature study program gained momentum in the 1890s and was soon an accepted course of study in schools throughout the Northeast. By 1907 nature study proved so popular that it was taught in schools throughout the country. Between 1905 and 1915, every state had a nature study outline in its public education system (Armitage, 2009, p.4).

Nature study enthusiasts used instruction in basic natural history, such as plant identification, animal life histories, and school gardens, to promote the skills necessary to succeed in industrial life and to cultivate the spiritual growth that modern life occluded.

Nature study classes “bred animals, raised chickens, learned to identify local birds, watched tadpoles develop into frogs, or eradicated mosquitoes” (Armitage, 2009, p. 3).

Many administrators and college faculty were not enamored with nature study programs. To sit around and build bird boxes seemed a bit effeminate at times and it did not prepare students for the world of industry. As urban immigration increased, Hunter and other textbook writers in New York felt the need to design biology curricula to help adolescents become good and healthy citizens. The decline of nature study became apparent after World War I. Civic biology soon became a popular course for ninth grade students, with the belief that “If well taught, it imparts the information and arouses the interest that every good citizen should have concerning the vital biological problems that daily press on every community for solution” (Gerry, 1920, p. 9). The aims of civic biology were to improve health, reduce hazards in the home and community, reduce natural resource waste, create interest in community and national problems, promote public appreciation of progressive programs, and encourage straight thinking rather than belief in superstitions (Whitman, 1920 p. 20). With textbook titles such as *A Civic Biology* (Hunter, 1914), *Practical Biology* (Smallwood, Reveley, & Bailey, 1916), and *Biology of Home and Community* (Trafton, 1923), early twentieth century biology texts sought to guide students by beefing up discussion on nutrition, the evils of alcohol and tobacco, sewer systems, and eugenics.

During this time, most biology text authors were school teachers in New York City who not only held degrees from elite colleges, but also were in close physical proximity to major book publishers like Macmillan and the American Book Company. Benjamin Gruenberg and George Hunter, whose several texts are part of this study, were fellow biology teachers at DeWitt Clinton High School in Manhattan who helped initiate and maintain New York State’s centralized secondary school system. Hunter’s textbooks were widely used throughout the United States, ranging from the 1907 edition of *Elements of Biology*, revised in 1914 to *A Civic Biology*; *Problems in Biology* (1939), and ending with a posthumous publication in 1949 titled *Biology in our Lives.* Hunter's *A Civic Biology* would serve as the book of interest for the 1925 Scopes trial in which John Scopes was tried for teaching evolution in a public school science class.

Hunter's first book consisted simply of chapters on botany, zoology, and physiology. It had little organization or flow between the units. His *Essentials of Biology* continued with the basic "three-science" plan, but he now offered an explanation of what a course in biology should provide to the student. The content was part of a plan to help students "recognize first-year biology as a science founded upon certain underlying and basic principles" and that the "principles underlie not only biology but organized society as well" (Hunter, 1911 p. v). As nature study continued its retreat from textbooks, Hunter's next book, *A Civic Biology* (1914), was written for a more urban audience. This text offered a more specific purpose for the study of biology: "…the study of biology should be part of every boy and girl, because society itself is founded upon the principles which biology teaches . . . those that are best fitted for life outstrip the others" (p. 18). *Civic Biology* exemplified what was considered important for students to know. Plants and animals were either economically valuable or they posed economic threats to the country. The topic of eugenics was prominently placed in chapters following Charles Darwin and natural selection, usually in a chapter titled "Improvement of Man."

Gruenberg's *Elementary Biology* was published in 1919 and *Biology and Human Life* in 1925. Other New York teachers contributed their own texts, including the husband-and-wife team of Maurice Bigelow and Anna Bigelow (*Introduction to Biology,* 1913) and Syracuse's trio of William Smallwood, Ida Reveley, and Guy Bailey with their long running text series, beginning with *Practical Biology* in 1916. Overall, New York educators produced twelve of the eighteen biology texts published between 1900 and 1925 (Pauly, 1991).

Sex education.

Most biology textbooks in the Progressive Era were devoted to social hygiene and human anatomy, but human reproduction was left out. While texts all had obligatory coverage of plant reproduction (the sexual nature of the fern!) and the embryology of the frog, the association of human embryology with that of sex and evolution tended to keep discussion about human development out of schools (Hopwood, 2009). Authors Hunter, James Peabody, and Maurice Bigelow combined forces in 1911 by organizing a joint meeting of the American Society for Sanitary and Moral Prophylaxis and the New York State Association of Biology Teachers. They called for the incorporation of sex education in the biology curriculum to help students plan for children and to understand certain principles of heredity. While educators such as Hunter argued that the scientific study of sex was fundamental to biology, the subject proved difficult to incorporate into the curriculum.

In 1913 the Committee on Natural Sciences of the National Education Association stated that one of the objectives of biology courses should be to include principles of human reproduction. Textbooks did not include drawing of human reproductive systems for fear that the books “might fall into the wrong hands” (Pauly, 1991, p 683). Some texts did delve into mammalian embryology, probably with the hope that the study of mammals would throw light on the reproduction of humans without the author having to break the moral code of conduct at the time.

Even those educators who fought for the inclusion of human reproduction were divided: should sex education focus on healthy reproduction or should it set its sights on making students aware of venereal disease and the then “pathological” nature of masturbation? There was worry that by presenting sex from a scientific standpoint, student curiosity would lead to experimentation, a worry that continues today. Issues with sex education have never really gone away. In the 1990s, many school boards reversed decades of accepted teaching practice and forbid the teaching of sex education. Textbook publishers took note and did little to publish anything that would antagonize the public.

From 1910 through the 1920s, the emphasis of secondary biology curricula was placed on improving human welfare—the human body was something to be kept healthy and fixed. Students learned everything from the avoidance of communicable diseases to how to make tourniquets. The specialized courses of zoology, botany, and physiology had all but disappeared from the American high school and replaced with a school-year-long general biology course (Rosen, 1959). By 1923, 83.8 percent of American high schools offered a biology course, compared to only 26.5 percent in 1908 (Finley, 1926). This growing market drove publishers to search for new textbook authors and to revise the biology texts that were already in print.

In 1938 the Progressive Education Association published *Science in General Education*. In it, science curricula was to target the needs of individuals in everyday lives in order for each person to reach his or her maximum potential, both as individual citizens and as part of a democratic society (Progressive Education Association, 1938). The biology texts were similar to all science texts at the time, “created to provide the masses of new students streaming into the high schools with an appreciation of the value of science in modern society and the skills to apply scientific thinking in their daily lives” (Rudolph, 2005, p. 354).

Many scientists and educators, however, were not happy with this “science for living” approach and believed that the focus should be on the “science of life.” The orientation for high school biology slowly changed in the 1930s from practical to academic, and is reflected in text titles such as *Essentials of Biology* (Meier & Meier, 1931), *Our World of Living Things* (Heiss, Obourn, & Manzer, 1936), and *New Biology* (Smallwood, Reveley, & Bailey, 1937).

As biology education became more academic, it occupied a transitional place in the curriculum between the emerging general science courses on the one hand and physics and chemistry on the other. During the 1940s, biology was taught almost exclusively as a tenth-grade subject, following general science or earth science, and preceding chemistry and physics. It had the responsibility of dealing with a variety of important practical issues that touched the lives of students, such as human anatomy and physiology, health and hygiene, and sex education. These areas of study intensified in the 1950s as births skyrocketed following the end of WWII. The emphasis was now on healthy pregnancies and babies. But all of this attention to pregnancy and birth would soon give way to an emphasis on inquiry learning and updating outdated biology curricula in the 1960s. In particular, the new field of developmental biology (molecular biology and genetics along with the descriptive morphology of embryology) was emerging in the laboratory; how soon would it be before it emerged in biology classrooms?

1960s.

Prior to the 1960s most textbooks followed the same content-laden format, with woefully out of date discussions about scientific advances (Kahle, 2007, p. 916). Major chapters included invertebrates, vertebrates, botany, and the human body. Organisms such as frogs, birds, and mammals were presented in sequence to their anatomy, physiology, growth, reproduction, and development (Lazarowitz, 2007). Other subjects such as microbiology, genetics, ecology, and evolution were placed in texts at the discretion of authors and publishers. Texts that included evolution usually placed it at the end of the book where it could be easily ignored or teachers could simply state that they did not have time to get to it (Webb, 1994). All in all, students spent a lot of time identifying parts of flowers and ordering insects into proper families. At this time, textbooks were mainly the work of high school biology teachers rather than college professors. Education reformers drew upon this fact to help with their argument that biology texts were outdated. After WWII, they claimed, there had been a growing fascination with space science, radiation technology, and the defense industry, but these topics were missing in education.

Science education reform may have become visible in the 1960s, but the momentum for change was present already in the 1940s, well before the launch of Russia's Sputnik satellite on October 5, 1957. Scientists, especially physicists, were vocal about the lack of current scientific advances to be found in science textbooks. In 1955 the American Institute of Biological Sciences (AIBS) formed a committee to examine biology curricula at the secondary and collegiate levels. This, along with the success of Sputnik accelerated the publication of newly designed textbooks. Government officials quickly pointed to the "soft" education being offered to adolescents as the problem: while American kids were learning how to cooperate with one another or how to bake an apple pie, Soviet students were learning calculus and nuclear physics! Congress responded to a rising national dissatisfaction with science and math education by passing the National Defense Education Act on September 2, 1958. The main purpose of the Act was to revise science and mathematics curricula by channeling money through the National Science Foundation (NSF).

BSCS.

The Biological Sciences Curriculum Study (BSCS) was established by AIBS in 1958 with help from the NSF by way of a $143,000 grant. Under the direction of geneticist Bentley Glass and zoologist Arnold B. Grobman, the BSCS program, centered at the

University of Colorado, set out to improve secondary biology teaching on all levels—new textbooks, ancillary classroom materials, and summer teacher institutes held on university campuses. The BSCS was awarded over $7,000,000 over the course of the 1960s (Nelkin, 1977).

Prior to the 1963 publications of BSCS texts, approximately 75% of high schools were using either *Modern Biology* written by Truman J. Moon, Paul B. Mann, and James H. Otto or *Exploring Biology* written by Thea Ella Smith (Engleman, 2001). The BSCS Steering Committee wanted to publish inquiry-based materials that would distance itself from the texts written by Moon and Smith. The BSCS textbook writers quickly realized that there would be no consensus about what should go into a single biology textbook. There were basically three camps in the committee: those who felt that a biology text should be organized around cellular and developmental biology; those who wanted molecular biology to be the running theme; and still others who saw the growing interest in ecology as the base for a textbook. Instead of trying to make everyone's interests fit into one textbook, writing teams of scientists, high school biology teachers, and editors were assembled to write, from scratch, three introductory high school biology texts, labeled by color, based on cell biology, molecular biology, or ecology. Another reason for three separate editions was to stem criticism that BSCS was attempting to establish a single, national curriculum for biology (Webb, 1994, p, 131).

Scientist-writers who were in charge of developing the BSCS texts had on their hands vast new changes that had occurred in biology during the 1950s and early 1960s. The field of embryology, for instance, had become part of the larger field of developmental biology. In order to try to organize textbooks in some fashion, it was decided to use seven levels of organization: molecular, cellular, tissue and organs, organisms, societal, communal, and biome. The executive committee singled out two themes for fullest development—the nature of inquiry and the historical development of biological ideas—believing that this would help biology be recognized as a great scientific discipline, much like that of physics and chemistry (BSCS, 1959).

The *Biological Science: An Inquiry into Life—The Yellow Version* focused on development and cellular biology. Its curriculum was considered the most content oriented of any of the BSCS versions (Lazarowitz, 2007) which may explain why it was the one adopted by most schools and teachers in the United States—it did not appear too radical. The *Biological Science: Molecules to Man—The Blue Version*, approached biology from a molecular biology and biochemistry standpoint. It was never a best seller, no doubt owing to the difficulty of the college-level content and the newness of the content for teachers to have to teach. The *High School Biology—The Green Version* emphasized ecological aspects the most, and was adopted primarily in rural high schools throughout the United States (Engleman, 2001).

During field testing, BSCS ran into several problems. In Dade County, Florida, officials refused to allow textbooks into classrooms because the books contained diagrams of human reproductive systems. In Texas and New Mexico, state boards of education objected to the chapters on evolution. BSCS though would not budge—it did not drop, nor did it soften its language, when it came to evolution.

After testing draft texts and other teaching materials from 1961 through 1962, the BSCS textbooks were ready for commercial release. Publishers were invited to examine the materials and to place bids on the texts of their choice. In a novel idea, the BSCS retained the copyright to all of its materials. This meant that publishers could not change, delete, or add content to influence sales. The BSCS signed contracts with Rand McNally to publish *High School Biology* (green version); with Harcourt, Brace, Jovanovich with *An Inquiry into Life* (yellow version); and with Houghton Mifflin for *Molecules to Man* (blue version). During this time the grant to fund BSCS was transferred from AIBS to the University of Colorado. In the early 1970s, BSCS became a private nonprofit 501C3 corporation.

Within a few years of their appearance in 1963, the BSCS books were used in more than 50 per cent of American high schools (Mayer, 1986). Other publishers quickly took note and their texts came to resemble those of BSCS in content, organization, and even color. William Mayer, former director of BSCS, argued that some publishers weighed in against BSCS because of its threat to the status quo. The companies planted the idea that BSCS was too big and that it would eventually become a national curriculum, all in itself. By 1973, sales of BSCS Green made up 33% of the national sales; BSCS Yellow made up 14%; and BSCS Blue made up only 1%. About 49% of the sales at this time was for *Modern Biology* (Lowery & Leonard, 1978).

The time span from about 1960 through 1975 was a period of innovation in science education. There was federal funding available that had never been seen before, with money available to help develop new or updated science curricula and to purchase new equipment. Molecular biology and ecology were firmly established as core content areas, influenced no doubt by early BSCS materials. But federal money and support would not last forever. In 1975 the U. S. Congress withdrew all further funding for NSF-sponsored science curriculum development. The reason for this was not because education had finally reached its goals of sound inquiry-based teaching, but due to a growing concern about the inclusion of sex, reproduction, and evolution in the biology curriculum (Yager, 1982).

Early in 1975, John B. Conlan, a Republican congressman from Arizona, began a series of attacks on the NSF for funding evolution and sex-education-based textbooks. The attacks against the NSF were also supported by a number of publishers who felt that federal support of curriculum development activities constituted unfair competition (Mayer, 1975, p. 438). Around the same time, creation science emerged and its supporters demanded that their religious viewpoints be allowed to compete with scientific ideas in biology classrooms.

Perhaps in response to these attacks, John D. Rockefeller III helped establish the Project on Human Sexual Development in 1975. One of the goals of the project was to add to the presence of human reproduction in biology texts. In 1979 and 1980 almost one dozen states introduced legislation to mandate the inclusion of creationism in the biology classroom (Bybee & Kahle, 1982). There was also a growing opposition to animal dissections, reproductive biology, and genetic engineering—all things that were seen as essential components of a progressive biology classroom (Mayer, 1989, p. 402).

STS.

In the 1970s, biology education goals shifted towards addressing environmental problems and the role of science and technology in society (Hurd, Bybee, Kahle, & Yager, 1980). One of the first persons to formally propose teaching about the importance of the relationship between science and society was James Gallagher in 1971. Gallagher argued that science education in the 1960s was too limiting because it only focused on conceptual schemes (DeBoer, 1991, p. 178). By the 1980s, the science education literature was filled with discussions about how to teach biology using a Science, Technology, and Society (STS) curriculum.

The shift to teaching students the social interactions of science was in response to an enormous post-WWII change in students' attitudes toward science and technology. Because of what was considered a misuse of technology during WWII (the atomic bombing of Japan) and continuing through the Vietnam War (Lazarowitz, 2007), social problems seemed to dwarf achievements in science and technology, and those achievements that did occur were often seen as not helping to improve the lives of people living in poverty. Students began expressing disinterest in science and teachers found trying to teach pure biology content to students was proving a tough sell. In reaction to this, curriculum changes were made to include aspects of technology. This curriculum became known as STS and its aim was to direct the goals of biology teaching to contemporary issues in science and society.

Many educators and university science education programs began modeling and organizing a science curriculum based around biosocial issues, including genetic screening and *in vitro* fertilization. The birth of the first "test tube" baby in 1978 placed embryos in an unsettled ethical, legal, and social debate that students became aware of through their textbooks and biology classes. But would this kind of biology teaching and student learning continue on to the end of the twentieth century?

1990s.

In the 1990s, biology and technology became closely tied with the continued growth of STS curricula. An explosion of computer-based learning (CBL) and software infiltrated classrooms as evidenced by examining articles and advertisements in the *American Biology Teacher* during this time. Reaction to STS was mixed. Some science educators such as Robert Dromhout and Ron Good claimed that the aim of science education should be a coherent study of fundamental science. They believed that trying to include socially relevant topics would prove ineffective on two counts: socially relevant topics would distract teachers from educating their students about the structure and methods of science, and more radically, that social activists would essentially pervert science education (Bybee, 1987).

In the late 1980s and early 1990s, several curriculum frameworks were published; most noticeably *Project 2001* by AAAS, the *National Science Education Standards*

(NSES) Project and *Scope, Sequence, and Coordination* (SSC) by the National Science Teachers Association (NSTA). The goal of *Project 2061* was to improve scientific literacy. This would be achieved in the science classroom by focusing on the natural world, recognizing diversity and unity, understanding concepts and principles of science, being aware of the interdependent nature of science, mathematics, and technology, learning how to think scientifically, and using scientific knowledge for social purposes. *Project 2061* was explicit about the need for all students, not just those destined to become scientists, to attain a certain amount of fluency about science. With this was the need to expand STS to include some understanding of the nature and history of science and technology. The NSES and SSC projects had similar goals as *Project 2061*, including a focus on STS issues and the history and nature of science, and calling for science classes for all Americans.

All three projects were well received by science educators but they came at a time when state standardized testing, along with a reform movement that centered on returning back to the basics, came to the forefront of public education. Many states did use objectives from all three projects to serve as their own standards, but implementation at the end of the 1990s was considered suspect. Thus there was a retreat from STS issues and a push towards understanding basic science without the social and political context to place it in. How would this influence reproduction and development in textbooks published during the 1990s?

Textbook Publishing at the end of the Twentieth Century

For students of all ages, nothing compares to an informative and thought-provoking textbook. Textbooks have been a vital component of biology classrooms since the discipline became formally taught in the United States in the early 1900s; so vital that high school biology can be characterized by one word—textbooks (Budiansky, 2001;

Yager, 1982). Who decides what is essential for students to learn in biology? Scientists? Parents? Students? Publishers? Textbook authors? School Boards? State or Federal Agencies? If you answered all of the above you are right, but some players have more influence than others. Authors no longer have as much control since the content of textbooks and texts are edited for grade-level readability by editors who may or may not have a solid science background. The political pressure placed on textbook publishers is immense. California, Texas, and Florida are huge markets for textbook publishers and these three states are primarily responsible for driving textbook content. Of course, texts are reviewed by professional and scholarly reviewers, but their work can be negated when texts go up against the public and special interest groups in these three states.

Every state has its own method of textbook adoption. Many states use some form of textbook adoption in which school districts get to pick from a state-selected list (Tobin & Ybarra, 2008). Books do not get placed on the list until passing through committees to see that state standards have been met and public comment has occurred. If a publisher's book does not make the state-selected list, the publisher cannot make any profit and has lost money in the development of its text for that state. Other states allow books to be chosen on a county or district level. It has become so increasingly expensive for publishers to get their books into classrooms that they have to try and keep everyone happy—to offend various user groups is self-defeating. Compared to methods used years ago, it is now rare to find a teacher who is allowed to order the science text that he or she really wants to use.

In the spirit of competitiveness, one might think that certain texts would rise to the top. But in Harriet Tyson-Bernstein's (1988) book, *A Conspiracy of Good Intentions*, she argues that what is in the best interest of the student is often not what is in the best interests of publishers. With California and Texas driving the adoption of texts, small groups within these two states have managed to dictate what goes in, and what is left out, before state approval occurs. This leads to an industry that must produce books that are “provocative but not so different as to be controversial” (Nelkin, 1977, p. 22). Because the publishing industry’s prime interest is sales and not education, an almost impossible task has been created: textbooks must stand out in some way, yet be standardized sufficiently to attract the largest possible market.

Another aspect of textbook publishing is volume. Biology textbooks have always had a lot of content in them. This shouldn’t be a huge surprise since the field itself has a lot of content. But in trying to stuff more and more content into bigger and bigger biology textbooks, publishers commit a pervasive sin called “mentioning.” This is a term used by researcher Dolores Durkin (1992) at the University of Illinois that refers to textbook prose that rapidly goes from fact to fact, and topic to topic, without giving the student any context that helps make sense of the concept and why it is important. For example, a text might discuss what stem cells look like without any information about why they are important in the field of embryology and medicine. While the goals of my study do not include a complete pedagogical analysis of biology textbooks, the fact that there are so many outside forces acting upon the publication of textbooks will undoubtedly factor in on how embryonic development is presented to students.

RESEARCH METHODS

The Textbooks

In this study I analyzed 127 commercially developed high school biology textbooks (see Appendix A) to determine how animal reproduction and development have been treated over the course of the twentieth century. The decision was made to not review textbooks published after 1999 to provide intellectual distance from the texts. That is, by not using textbooks from the 2000s and focusing only on earlier texts, it allowed enough time for the unique social and political events of previous decades to become more apparent to me. All texts reviewed were written for public high school (grades 9-12) biology classes. Any text solely dedicated to embryology, home schooling, or textbooks published for parochial classrooms was not used, and I make no claim that the textbooks reviewed represent every textbook published for use in the high school classroom.

One thing became apparent concerning textbooks published in the 1990s. Although advertised for high school biology use, some of the texts were actually introductory biology texts written for college students. The reason for this was the development and emphasis of honors and AP biology classes that began in the late 1980s; more rigorous courses demanded more rigorous texts. Since these college texts all had much more human development and human reproduction content compared to regular high school biology books, including AP high school texts would falsely indicate that the 1990s was a rebirth of human embryology. For this reason, any text that served both high school and college students was not used.

I decided early in the project to eliminate plant embryos and focus only on animal embryos. Some texts were laden with embryos of flowers and corn but gave little mention to animal embryos. This would end up skewing the results and since human embryos are the main focus of the research, removing plant embryos from the study seemed prudent.

Embryo Content Analysis

My initial strategy of finding information on embryos and development consisted of searching each book's index for the terms “embryo,” “embryology,” and “evolution” (for Haeckel's diagrams). It quickly became clear that this method would prove to be too limiting. For example, evolution was often discussed in a text but not referenced in its index. In addition, the term “embryo” was all too often indexed only for those paragraphs found in chapters about reproduction. In the same book, chapters on frogs, fish, and mammals sometimes had information on embryos relevant to these certain species, but this information was not indexed. Thus, using the index by itself would lead to underreporting of development content. Rather than solely rely on an index, I quickly, but carefully, scanned each text for passages and pictures about development in all of its chapters.

With so many texts to review, it was necessary to use a coding system to help provide some type of quantification of results. Being able to place paragraphs and visual representations in a classification scheme would make patterns easier for me to see and help with interpreting the results. In order to determine what authors and publishers deemed important for students to know, four categories for content analysis were established: descriptive, investigative, nature of science, and technology and society. These categories were based on the four major themes of scientific literacy set forth by Chiapetta, Sethna, and Fillman (1993). They also correlated with literary recommendations established in *Benchmarks for Science Literacy* published by the AAAS (1993) and the *National Science Education Standards* published by the National Research Council (1996).

Whenever paragraph coding is done there is always the problem of what to do with figures and photographs. I decided to code photographs using the caption that accompanied each figure. On the rare occasion that a figure had no caption, it was placed in the descriptive category. Body text, figures and captions, and figures without captions were analyzed and placed in one of the four following categories:

Descriptive. The intent of this category is to present what is known about development by way of terminology, facts, and concepts. For example, what features of an organism appear when? What is the life history of an organism? Descriptive paragraphs reflect the transmission of scientific knowledge about embryos and fetuses to be learned by the reader. For example, in the 1968 BSCS *An Inquiry into Life* biology text, this paragraph was coded as descriptive:

> The ectoderm is originally a sheet of cells on the outside of the embryo. In the course of development some of these cells curl up to form a tube. Later the tube differentiates into a brain and a spinal cord. (p 507)

Investigative. If a paragraph is used to stimulate thinking and doing by asking the student to “find out,” it is placed in the investigative category. Material in this category requires the student to answer a question through the use of charts and tables, make calculations, reason out answers, or engage the student in a thought experiment or activity. This type of instruction can include paper-and-pencil as well as hands-on activities. An example of a paragraph that was coded as investigative was an activity described in the 1968 BSCS *An Ecological Approach* text about chick embryology. After viewing chick embryos over the course of several weeks, the students were asked,

> What characteristics of a chicken egg are adaptations that enable it to develop on land? If the egg developed within the hen instead of outside, what structures would be less important? What explanations can you give for the early development of heart, blood, and blood vessels? How do your observations support the statement that chordates show segmentation? (p. 612)

Science as a way of thinking (nature of science). If a paragraph presents embryology as a human endeavor that changes over time, it is placed in the science as a way of thinking category, or perhaps better known as the nature of science category. Material presented in this manner describes how a scientist experiments, the historical development of scientific ideas, the use of assumptions, how embryology proceeds by inductive and deductive reasoning, and cause-and-effect relationships. For example, the following paragraph used in this study expanded upon the process of scientific investigations:

> Recently a substance has been found that may be this "messenger." The substance was found by an American embryologist, M. Niu, who took a piece of mesoderm from the dorsal lip area and let it stand in a salt solution for a few hours. Then he removed the piece of mesoderm and put it in a piece of ectoderm. In the culture dish, the ectoderm formed nervous tissue. Niu did a control experiment in which he put a piece of ectoderm into plain salt solution that had not been exposed to mesoderm. The control piece of ectoderm did not form a nervous system. (BSCS *Inquiry into Life*, 1968 p. 512)

Interaction of human embryology, technology, and society (HETS). If a paragraph illustrates the impact of human embryology on society or vice versa, it is placed in the human embryology, technology, and society, or HETS category. This aspect of embryology pertains to the application of science and how technology may pose ethical questions for humans. In this category the text describes the usefulness and ethical concerns of research and technology or discusses social issues related to embryology. For example, in Kimball's 1994 *Biology*, the ethical complexity of freezing embryos is raised:

> *In vitro* fertilization is an elaborate and expensive procedure, and more attempts at implantation fail than succeed. So a prospective mother may want to try again and again until she succeeds. Fortunately, it is not necessary for her to undergo the egg-harvesting process each time. If a sufficiently large number of eggs were harvested, fertilized, and grown into morulas the first time, the surplus can be frozen indefinitely for use at a later time. But what if the prospective parents separate or one or both die? Here again, advances in biological technology threaten to outstrip our ability to cope with the new and complex ethical and legal issues that they create. (p. 408)

Interrater Reliability

Since a single investigator may be biased while categorizing text information, and to ensure the validity of deciding which category to place each paragraph in, an intercoder agreement coefficient was calculated using Cohen's Kappa (Cohen, 1960). This interrater reliability test was conducted with two high school biology educators and me. The kappa statistic was chosen as an appropriate statistic since we worked independently and the units of analysis, in this case categories, were independent of each other. The kappa statistic has a range of -1.00 to +1.00 with 0 representing chance agreement among raters. It is generally agreed that a kappa value greater than 0.75 indicates excellent agreement among coders and that kappa's between 0.40 and 0.75 indicate moderate to substantial agreement (Rubinstein & Brown, 1984).

Each rater was given twelve paragraphs from assorted texts that had been analyzed by me and the paragraphs were placed in what I believed were the most appropriate categories. Working independently, and with a key explaining the requirements of each category, each rater placed each paragraph in one of four categories that he or she deemed most appropriate.

The kappa values for descriptive paragraphs was 1.0; for investigative paragraphs, .77; for science as a way of thinking, .77; and for HETS, 1.0. The kappa values between the three raters showed excellent agreement and gave me confidence that my coding procedures were valid for this study.

Additional Quantitative Data

Besides coding paragraphs, I was also interested in collecting information about other textbook representations of development. These extracts would serve as the data for rendering possible narratives about the plasticity of textbook embryos. This information included:

- Examining the types of organisms used to teach about development. Organisms such as fish and salamanders were tallied as well as the types of illustrations used to help visualize development for the student.

- Identifying the time periods when certain "firsts" occurred. For example, when the first human embryo drawing was published; when the first pictures of childbirth were published; and when the first pictures of human fetal surgery were seen.

- Examining texts for notable photographs such as photos taken by the Carnegie Institution and microphotographs taken by Lennart Nilsson. I was interested in using this information to show how pictures helped reconceptualize human embryos.

- Examining texts for the occurrence and persistence of certain types of embryological research (e.g., transplantation) and embryologists. Such quantification of certain people and their discoveries would help with my interpretation of the persistence of embryology in textbooks.

Haeckel's Embryos

The comparative anatomy of embryos has long been used to illustrate Haeckel's Biogenetic Law and recapitulation. One of my goals was to examine and catalog the use of Haeckel's embryos and then to describe how the diagrams were used by authors to support or refute the idea of recapitulation: that is, the idea that organisms like humans, show evidence of their evolutionary ancestors in their embryonic development. I was also interested to see if the organisms originally used by Haeckel in his diagrams had changed over time, including the presence of human embryos to support evolution.

RESULTS AND DISCUSSION

Against the background of historical periods of interpretations of embryos, I looked at high school textbooks published throughout the twentieth century. This section reports the findings from that analysis. The first section examines quantitative data collected by looking at how much and what sort of embryology content appeared in all of these primary sources. In particular I focused on the amount of attention given to the concept of development, the breakdown of the total number of paragraphs into scientific literacy categories, the types of organisms used to discuss development, and the embryologists that were written about. Discussion of these findings takes up the first section. The second section provides an interpretation of the textbook data based on a decade by decade discussion of the patterns that emerged. Third, following the empirical description and the discovered patterns, I provide an examination of the visual representations that were selected by publishers. Presumably these were selected to help students understand development, though in some cases, it seems likely that the social and political context may have influenced the selections. Along these lines, I will discuss Haeckel's embryo diagrams which appear repeatedly and in many forms and whose use seems to reflect background conditions that warrant interpretation.

Section One: Content Analysis Findings

One of my first questions was how much "space" was allotted for discussion about male and female reproductive systems and development from fertilization to birth. Table 1 shows the average number of paragraphs and the range of paragraphs for each decade of text review. The first two decades of the 1900s were combined since there was only one text that I was able to review for the 1900 to 1910 time period.

It is fair to say that other than a slight increase in paragraphs between the second and the third decade, the first half of the twentieth century was stagnant in terms of authors

Table 1

Average Number and Range of Development Paragraphs

Text Data	1900-1919	1920-1929	1930 1939	1940-1949	1950-1959	1960-1969	1970-1979	1980-1989	1990-1999
Texts reviewed	9	12	13	14	16	18	19	12	14
Paragraphs/text	8.7	21	18	22	21	60	65	57	54.4
Paragraph range	0-13	3-54	0-34	9-46	0-37	9-145	21-113	15-97	11-102

writing about embryos. The fact that there were texts in the 1910s, 1930s, and 1950s that made no mention at all about development at all leads me to conclude that some authors did not see development as something that high school students needed to know, or they themselves were not comfortable writing about it.

The increase in paragraphs during the 1960s can be attributed to changes in science education pedagogy and a public majority that finally consented to more openness about teaching human reproduction in high schools. An increase in the length of textbooks may have been a factor but the average increase in pages of a 1960s text compared to a 1950s text was only 90 pages. This impact would have been slight. The drop in the number of development paragraphs that occurred in the 1980s and 1990s was caused, in part, by a decrease in the number of texts discussing how comparative anatomy of embryos supported the theory of evolution, and a decrease in the amount of discussion given to amphibian and avian reproduction. It is important to note that while some texts in the 1960s and onward gave much more attention to development, there were still texts that only had nine or ten paragraphs written about this concept. A more detailed analysis follows this section of the results.

Scientific literacy categories.

Once the total number of paragraphs and visual representations were counted, the question remained about how to categorize the paragraphs in a way that would help me determine how such factors as science education pedagogy, the types of research conducted with embryos, and social and political issues surrounding embryos influenced how development would be presented to high school students.

I coded all development paragraphs and diagrams into one of four scientific literacy categories: (a) descriptively; (b) as part of an investigation or experiment; (c) as a way of knowing about science (NOS); or (d) the interfacing of human embryos with society and technology (HETS). The scientific literacy data for each decade is shown in Figure 3.

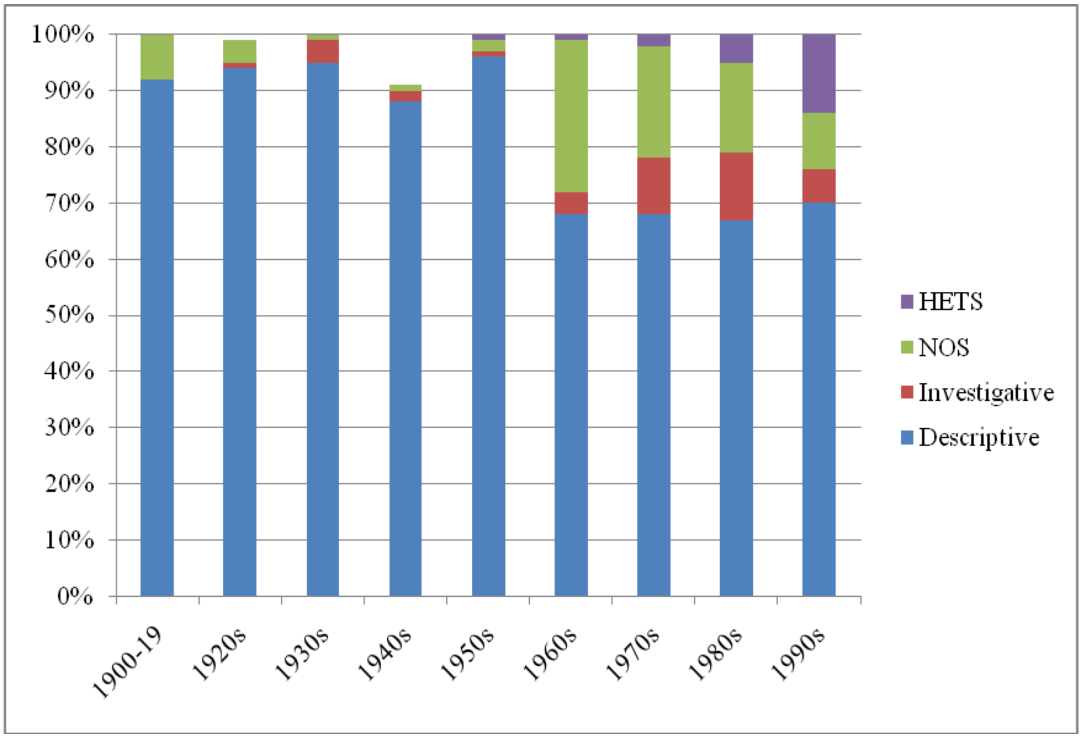


Figure 3. Coding paragraphs into scientific literacy categories.

It was no surprise that for every decade, descriptive paragraphs dominated the discussion. Content facts and figures have always been at the heart of science education and textbooks have always been repositories for content. I found that early twentieth century texts presented biology and embryos with a high degree of staticness—as if there was nothing more to discover. This way of looking at development began to change in the 1960s when the descriptiveness of embryos began to be replaced by other ways to study them. Beginning in the 1960s it became common to include the nature of science in biology. The number of NOS paragraphs that I counted did decrease after the 1960s but this was countered by more attention given to experimentation and social discussion about embryos. Part of this was due to the influence of the science, technology, and society (STS) curricula, but another reason could be the "mainstreaming" of the embryo. Embryos and fetuses had steadily become part of public discussion because of their involvement with stem cell research, *in vitro* fertilization, genetic screening, and abortion. The public began to show a willingness to allow these issues to be discussed in a high school biology classroom beginning in the 1980s.

Development and representative organisms.

What we know about human development started from the investigation of many different kinds of organisms. These organisms have ranged from sea urchins, chicks, and frogs, to the eventual study of human embryos themselves. I wanted to know what types of organisms textbook authors decided to use to introduce embryos to students (see Table 2).

What I found was that at the turn of the century, embryos were shown only in association with certain organisms, e.g., invertebrates like sea urchins and "lesser" vertebrates like frogs and chicks. Occasionally a mammalian embryo would be seen but it most definitely would not be a human embryo. At the time, society seems not to have deemed it prudent for high school students to study such things.

Table 2

Embryos Represented in Textbooks by Decade

Organism	1900-1919	1920-1929	1930-1939	1940-1949	1950-1959	1960-1969	1970-1979	1980-1989	1990-1999
Sea Urchin		x	x			x			x
Star Fish				x		x	x	x	x
Salamander	x		x	x	x	x	x	x	x
Frog	x	x	x	x	x	x	x	x	x
Toad		x							
Clam	x								
Oyster		x	x						
Crayfish	x								
Amphioxus	x		x	x	x	x	x		x
Chick	x	x	x	x	x	x	x	x	x
Fish	x	x	x	x	x	x	x	x	x
Rabbit	x	x	x		x	x			
Opossum			x	x	x	x	x	x	x
Mouse				x	x	x		x	
Pig					x	x		x	x
Horse							x		x
Monkey						x			x
Human		x		x	x	x	x	x	x

Certain organisms such as the toad, clam, and crayfish were nothing more than "one hit wonders," marked by a single appearance in a single textbook. Frogs, chicks, and fish were always found in textbooks, probably owing to the way that texts have laid out chapters phylogenetically and the fact that these organisms possess a type of institutional inertia in the world of textbook publishing. Authors see no reason to remove frogs or fish from textbook embryology since they have been a standard of embryology for so long. Frogs have also been used in different ways—from early descriptions of how frog eggs develop to transplantation and cloning experiments done in the 1930s through the 1990s—the use of frogs in textbooks says a lot about the versatile nature of frog embryos in descriptive and experimental embryology.

The use of different mammalian embryos was evident beginning in the 1950s. This is most likely due to the fact that mammalian reproduction started to get more attention and mammals served as an acceptable segue in the 1940s and 1950s to begin discussion about human reproduction.

Major embryologists.

One of my four scientific literacy categories was embryology and the nature of science. As interested as I was in how texts described scientific experiments and ideas, and how embryology was investigated, I was also curious about who the major players were. That is, what scientists got repeated from decade to decade? The data are shown in Table 3. What this table tells you is the year when a name was seen in a textbook. It does not tell you, however, the total number of times the embryologist was seen in textbooks published in that same year. Few embryologists were written about before the first editions of BSCS textbooks were released in 1963. Jacques Loeb and Ernst von Baer are two of the few embryologists who are seen in multiple decades before the 1960s. Loeb's last appearance, by name, occurred in 1965. Von Baer on the other hand continued through the 1980s. What is interesting here, and will be further discussed in Section Four, is that von Baer was sometimes wrongly credited for being the originator of Haeckel's Biogenetic Law. This caused von Baer's appearances to go up while Haeckel was rarely seen.

Many experimental embryologists were written about in the 1960s, just when the biology curriculum was infused with BSCS texts. These texts placed emphasis on the nature of science so it was no surprise that experiments were now part of every student's reading assignment. This trend continued through the 1980s but what is surprising is that

Table 3

Embryologists in High School Biology Textbooks, 1907–1999

Embryologist	Year(s) in which embryologist occurred in texts
Agassiz	1963, 1968, 1973, 1985
Aristotle	1944, 1958, 1968 1969, 1973, 1974, 1980, 1985
Boveri	1963
Briggs & King	1963, 1973, 1978
Driesch	1963, 1966, 1968, 1971, 1973, 1974, 1977, 1980, 1985
Duran-Reynolds	1971, 1977
Edwards	1973
Gudernatsch	1919
Gurdon	1978, 1983, 1990
Haeckel	1969, 1973, 1999
Harrison	1937
Hartsoecker	1963, 1968
Harvey	1963, 1968
Hertig & Rock	1954
Holtfreter	1963, 1968
Jacob & Monod	1978, 1980
Just	1971, 1977
Kollar & Fisher	1994
Loeb	1922, 1938, 1944, 1949, 1954, 1965
Mangold, H.	1983, 1990
Mintz, B.	1974
Niu, M.	1963, 1968
Pincus	1949, 1954
Rose, Meryl S.	1963
Roux	1946, 1963, 1965, 1968, 1971, 1974, 1977, 1980, 1985, 1990
Schotte	1963, 1978
Spemann	1937, 1963, 1965, 1968, 1973, 1974, 1977, 1978, 1980, 1983, 1985, 1990, 1994
Stockard	1944
Von Baer	1922, 1944, 1958, 1961, 1963, 1965, 1966, 1971, 1973, 1974, 1977, 1985
Weismann	1978
Wolff	1963, 1966, 1968, 1971, 1974

so few names are mentioned during the 1990s. Even though NOS was still important, and there were many new findings that had been accomplished in embryology, matching people with their research almost disappeared. This could have been part of an educational publishing trend to discuss experiments but to eliminate factual material like dates, places, and names. In turn, this may be the reason for the surprising lack of times that I saw Robert Briggs and Thomas King mentioned in texts. Even though cloning was discussed, it seemed that students in the 1990s may have been led to assume that embryology was now being done by machines and not people.

Like clams and crayfish, some embryologists appeared once and then disappeared. Embryologist Charles Stockard fits in this category. His “freak” one-eyed minnows are mentioned in 1944 but his work was never referenced again. There were many embryologists like Stockard who participated in experimental embryology, changing the chemical and physical environments of embryos, or moving pieces of tissue layers from one area to another or from one species to another. But all of their work seems to have paled in comparison to that of Hans Spemann. In fact, no other embryologist was mentioned more in this study than Spemann. And the use of the word “mention” is an understatement.

In most textbooks, Spemann’s work was more thoroughly explained than any other work, of any other scientist, in the whole textbook. All too often textbooks are criticized for glossing over difficult to understand material but the way in which Spemann’s experiments are presented seems to counter this: authors took great pains to show students that there was an underlying complexity to learning about complex topics. One thing to note is that Spemann’s work was primarily done in the 1920s and 1930s (he was awarded the Nobel Prize in Physiology or Medicine in 1935), and yet, his work did not become firmly placed in biology textbooks until 1963. This may simply be due to a lack of attention to the nature of science at the time or possibly, it may have been an uneasiness in the 1940s and 1950s to discuss a German embryologist, doing transplantation experiments, after public awareness of Nazi experiments with human subjects became known.

One reason for the popularity of Spemann's work is that it is just plain interesting. His line diagrams and photographs of two-headed salamanders or salamanders with eyes growing out of their bellies are captivating to a young audience. His work also represented the transition of embryology from being purely descriptive to that of being experimental and was important in helping bridge the gap between genetics and embryology. This allowed Spemann's work to be incorporated into chapters on development and genetics. Spemann was also a good fit for authors who wanted to discuss more than Aristotle or Haeckel—scientists who probably seemed too old for students to relate to.

In a 1988 book review by Jan A. Witkowski, of Cold Spring Harbor Laboratory, Witkowski comments that "it is strange that Spemann has not received more attention, for he is the only embryologist to have been awarded a Nobel Prize" (p. 365). I assume that Witkowski is speaking about the lack of books and journal articles published about Spemann because if Witkowski examined high school biology textbooks, he would certainly have to amend his statement. Spemann is everywhere in high school biology. Spemann's organizer concept has remained prevalent and relevant in high school biology since the early 1960s—a concept that embryologists in the 1990s began zeroing in on with new experiments to identify genes that might underlie the organizer's activities (Marx, 1991).

Section Two: Discussion of Data by Decades

According to noted qualitative researchers Robert Bogdan and Sari Biklen (1992), any attempt to quantify has a history. All of the paragraphs that I counted and coded were located at a particular historical moment, meaning that the paragraphs by themselves did not stand alone. What I will now discuss is how my “numbers” concerning embryos and development relate to the social and historical contexts that generated them. Because I had cast a wide empirical net, I decided to group the textbooks by decade. This is common practice for science education researchers when they are involved with textbook and curriculum study research.

1900–1919.

Science education historian John Rudolph (2008) describes how general science courses in the early 1900s tapped into the enthusiasm about how things work. As a result, science curricula was designed to examine appliances, industrial gadgets, and great experiments. My examination of the biology texts during the time shows a distinctly different approach to teaching. Outside of the world of textbooks, during the Biological Embryo Research Period (1827–1950s), a considerable amount of descriptive biology had already been done before the first biology textbook in my study was published in 1907. There had already been experiments by Roux, Driesch, and Loeb, and there would soon be the beginning of transplantation experiments. However, a student would realize little of this by reading any of the nine biology textbooks that I analyzed for this time period.

These textbooks all stressed botany, zoology, and human physiology. The physiology sections were divided into chapters on circulation, respiration, digestion, and nervous systems, but there were no chapters on human reproduction. Any discussion of embryos was most likely be found in the zoology chapters that were laid out phylogenetically, this is, starting with protozoans and finishing with mammals. The amount of text devoted to embryos ranged from zero paragraphs (Hodge & Dawson, 1918) to thirty-two paragraphs (Bigelow & Bigelow, 1911). Nearly all of these paragraphs were devoted to facts about development (92%) and of that, the life history of the frog and chicken were most frequently encountered, although crayfish, salamander, and rabbit embryos were also seen. Chick embryos were discussed in chapters about birds and included diagrams and descriptions of how a chick egg matures.

Frog embryology appeared prominently in almost all of the texts, either in a chapter solely about frogs or a chapter about amphibians. The life cycle and cell division of a fertilized egg, drawn from the one-cell to thirty-two-cell stage, was commonly discussed and visually represented. This was information that had been extensively studied and known about long before the introduction of biology textbooks into the secondary education curriculum. There could be another reason, however, why frog eggs and tadpoles were so prominent. Frog eggs were easy to obtain and could be studied in the classroom; some texts even suggested to student to “go out and collect your own.” Perhaps this is a reflection of the nature study’s influence in science classrooms during the early twentieth century.

There were no human embryo drawings seen in texts during this time period, but there were a few drawings of mammalian embryos, most often a rabbit (Bigelow & Bigelow, 1911; Hunter, 1914). Evolution was not stressed which led to an absence of Haeckel’s embryos. The first occurrence of Haeckel’s drawing is in Bigelow and Bigelow’s 1911 *Applied Biology* and the same grid of embryos does not appear again until Gruenberg’s *Elementary Biology* in 1919. Both textbooks include human embryos labeled as “man” in their Haeckel diagrams.

There were only two texts that offered something other than descriptive embryology. James Peabody and Arthur Hunt’s *Elementary Biology* (1912) described an investigation to be performed as “optional homework.” In their chapter on birds, students were asked to secure the egg of a hen or another domestic bird, and to carefully study its internal structure. A diagram of a cross-section of a hen’s egg was included (see Figure 4).

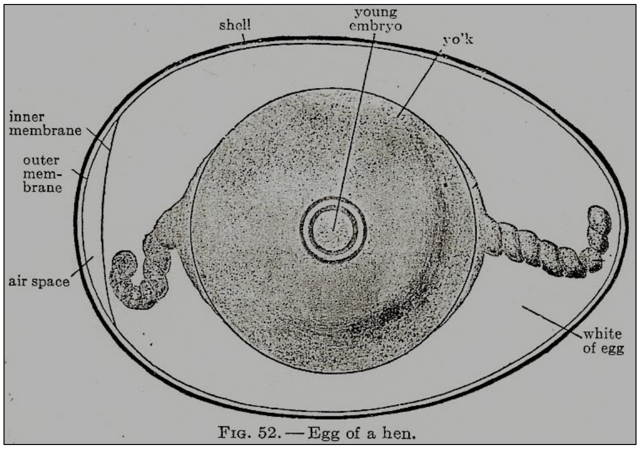


Fig. 52. — Egg of a hen.

Figure 4. Cross-section of chick egg with embryo. From *Elementary Biology. Animal and Human* (p. 69). By J. E. Peabody and A. E. Hunt, 1912, New York: MacMillan.

The same diagram was seen in other, future textbooks and was sometimes credited to Frank Lillie at the University of Chicago. In this case, however, no credit was given. Lillie’s classic book on chicken embryology was published in 1908 so Lillie could very well have given textbooks his permission to publish this chick egg drawing during this time period. It was also common during the early 1900s for pictures and diagrams to be bootlegged without consent (Ladouceur, 2008).

The only areas where embryology was presented as a way of doing science (NOS category) was seen in Gruenberg’s *Elementary Biology: An Introduction to the Science of Life* (1919) in a chapter titled “Conditions for Development.” Here, Frederick Gudernatsch’s physiological experiments with tadpoles were briefly discussed. Students were told that when tadpoles were fed ground-up thymus glands obtained from calves, the tadpoles grew to a large size, but remained tadpoles. The author’s intent was to show how changes in the external environment influenced the development of animals, just as they influenced the development of plants. This was an early example of recent embryology research making its way from the laboratory to the public realm: Gudernatsch's actual experiments with tadpoles were discussed in a 1914 issue of the *American Journal of Anatomy*.

In the same chapter where Gudernatsch's experiments were discussed, Gruenberg identified how the manipulation of laboratory environments could cause drastic changes in development:

> By changes in the chemical condition of the medium, experimenters have made the eyes of certain fish develop into animals having a single eye in the middle of the head; and other "freak" forms have been produced as a result of changing the external conditions of development (p. 289).

Here, Gruenberg is most likely referring to the work of Charles R. Stockard (1909). By altering the concentration of magnesium in an aquarium that contained fish eggs, Stockard was able to produce cyclopean fish, meaning that the two lateral eyes had merged and fused in the middle of the fish' head. The inclusion of the relative "newness" of Gudernatsch and Stockard's research may reflect Gruenberg's attempts to engage students with some of the latest findings in experimental embryology research.

1920–1929.

Despite an increase in the number of biology textbooks published in the 1920s, evolution was still not treated as a concept that students should be aware of. For this decade, I found only three out of twelve textbooks that used Haeckel's diagram. Of the three, only one included a human embryo (Woodruff, 1922).

The amount of descriptive embryology in these texts remained similar to the textbooks written in the previous decade. Approximately 94% of the paragraphs were devoted to scientific terminology and life cycles. Unlike the earlier texts though, all of the textbooks in the 1920s actually included something about embryology, even if it was only a few paragraphs. Frogs and chicks remained the embryos of choice, although the embryos of sea urchins (Kinsey, 1926) and oysters were also seen (Smallwood, Reveley, & Bailey, 1920). The oyster seems an odd choice but its inclusion may have been influenced by William Keith Brooks' noted work on oysters that was published in a second edition in 1905, *The Oyster. A Popular Summary of a Scientific Study.* Brooks was well known for his embryological studies of the embryo and his efforts to bring back commercial oystering to the Chesapeake Bay area.

The first drawing of a human embryo was seen in Lorande Woodruff's 1922 edition of *Foundations of Biology* (see Figure 5). Appearing in the chapter "Reproduction in Animals," the drawing shows a young embryo in a uterus with the placenta, blood vessels, amnion, and umbilical cord labeled. In the same text appears the first drawing of a human egg cell and a human sperm, credited to Swedish anatomist Gustaf Retzius.

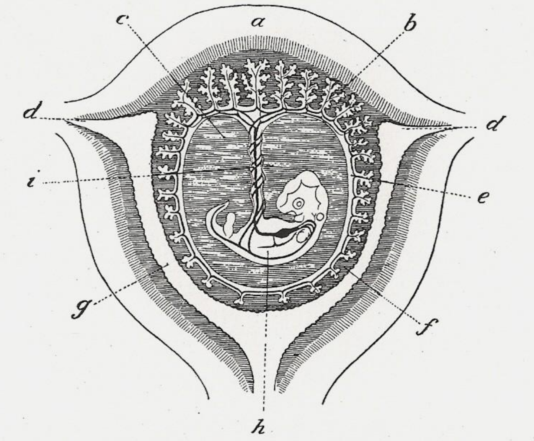


FIG. 113. — Diagrammatic section of the human uterus with developing embryo. The embryo (*h*) is suspended in a fluid-filled cavity (*c*) surrounded by the foetal membranes (*e*) and by tissue (*f*) from the uterus itself. The sole path of communication between embryo and mother is by blood in vessels passing up through the umbilical cord (*i*), spreading out into capillaries in the placenta (*b*) and there coming into close relations with the maternal blood supply. The openings of the oviducts (*d*) into the uterus become closed during the development of the embryo. *a*, dorsal wall of uterus; *b*, placenta; *c*, fluid-filled cavity of amnion; *d*, openings of oviducts (Fallopian tubes); *e*, foetal membranes; *f*, uterine tissue; *g*, uterine cavity; *h*, embryo; *i*, umbilical cord.

Figure 5. First illustration of a human embryo appearing in a textbook. From *Foundations of Biology* (p. 205). By L. L. Woodruff, 1922, New York: MacMillan.

This was not the only time Retzius's picture appeared in biology texts. It was used by many publishers although it wasn't always credited to Retzius. I noted that in this picture the sperm and egg were separated and not touching, a common occurrence until the 1960s when fertilization photographs finally showed sperm making contact with an egg.

As author of *Foundations of Biology*, Woodruff was a protozoologist and a biology historian who taught at Yale University. He also taught the embryology course at the Marine Biological Laboratory at Woods Hole from 1910 to 1914 (Hutchinson, 1980) and served as president of the American Society of Zoologists in 1942 (Benson & Quinn, 1990). His background in science and history may be what led Woodruff to push the boundaries of high school biology textbook writing. This was the only textbook published in the 1920s that acknowledged the shift that embryology had taken during the Biological Research Period. Woodruff told students that descriptive embryology was changing:

> Embryology is something more than the description of the kaleidoscope series of stages which seem to melt one into the other as development progresses. It attempts, especially at the present time, to look below and beyond structure to the processes involved, and to determine how the sequence of events is brought about. This is but a repetition of the stages of progress in all science; a passage from *descriptive* to the *experimental* (p. 252).

Woodruff touched upon preformationism, epigenesis, and artificial parthenogenesis to show how embryology was turning into an experimental field. Although he did not refer to Jacques Loeb by name, Woodruff acknowledged that “recent developments” with invertebrates which normally required fertilization could be induced to start development parthenogenetically by subjecting eggs to certain chemicals, temperatures, and physical force. Even though Loeb’s embryological work was highly sensationalized in newspapers in 1900, his science was most often ignored by high school biology textbook writers and publishers. Woodruff’s inclusion of Loeb’s work here is a rarity.

1930–1939.

The 1930s saw several new texts enter the market, including the first edition of *Exploring Biology* (1938) by Ella T. Smith and *Our World of Living Things* (1936) by Heiss and Obourn. Other texts appeared as revised editions such as the long running favorite, *Modern Biology* by Moon and Mann (1938) and *Biology, The Story of Living Things* by Hunter, Walter, and Hunter (1937). Almost all of the paragraphs that I coded from the thirteen textbooks in this time frame fell into the descriptive category. The remaining paragraphs fell into the investigative category. Textbook authors tried to show how progressive the field of biology was becoming by using titles such as *Dynamic Biology* (Baker & Mills, 1933) and *New Introduction to Biology* (Kinsey, 1933), but embryology was still presented no differently than it had been presented in the past. In this decade there was only one text with a human embryo (Hunter et al., 1937), probably due to continued public concern about the teaching of human reproduction in high schools.

All of the texts featured pages of explanation about how a frog egg turns into a polliwog and how a chick turns into a hen. One thing did change, however, and this was with chick embryos. The old hand drawn diagrams were replaced with actual photographs—some of the first embryo photographs seen in high school texts. The photographs were copyrighted by Charles F. Herm who worked at the American Museum of Natural History (AMNH). Herm was the inventor of the motion picture camera and he took time-lapse photos of the inside of chick eggs during their twenty one days of development. His pictures of chick embryos appeared in biology texts as a series of artistically-rendered pictures that found their way into many different publishers' hands.

Several texts had at least one paragraph that I coded as investigative. This category is characterized by asking the student to "find out" something rather than to just read and memorize. In the case of *Biology for Today* (Curtis, Caldwell, & Sherman, 1934) and *Our Environment* (Wood & Carpenter, 1938), students were asked to look at a diagram of Haeckel's embryos and answer questions about similarities. In *Everyday Problems in Biology* (Pieper, Beauchamp, & Frank, 1936) students were instructed to open and observe a chick egg each day, for approximately twenty-one days, and to answer questions about the chick based on their observations. Hunter's *Problems in Biology* (1939) challenged students not only to observe frog eggs on a daily basis, but to go out and collect them.

After first reading about experimental embryology in Woodruff's 1922 text, it was not until 1938 that more NOS paragraphs appeared. In *Biology and Human Welfare* by Peabody and Hunt (1938), the authors discussed the advantages of sexual reproduction but made an interesting note of Jacques Loeb's parthenogenesis studies and how chemico-physical manipulations of eggs had led to eggs developing in a manner similar to normal fertilization by sperm (p. 220).

Representative organisms.

While frogs and chick embryos still dominated the conversation, texts in the 1930s did expand on the number of different organisms used. For the first time, a salamander embryo was seen, along with opossum and amphioxus embryos. At first glance, the opossum and amphioxus seem a bit odd to be included, but the opossum's embryology and reproduction habits had been investigated throughout the 1920s by Carl G. Hartman, a renowned authority on mammalian reproduction (Vollman, 1959). There are several unique things about an opossum: it is a marsupial that carries its young in a pouch and females have a bifurcated vagina and two uteri. Thus the opossum, while at first glance a strange organism to examine, may have been chosen because of its "uniqueness" and the fact that new developmental research had just been published about this North American mammal.

Amphioxus was in the limelight in the 1930s serving as a research organism to see if certain chordates (organisms with backbones) were the closest invertebrate relatives of the vertebrates (Gee, 2007). Part of this research involved Edwin Goodrich‘s work with the evolution of head segmentation in amphioxus. With this, I would have thought that amphioxus would be found in evolution chapters, but Hunter used amphioxus to describe early cleavage in isolecithal eggs (an egg with its yolk distributed throughout the egg). The odd placement of amphioxus was helped by the fact that with many texts of the 1930s, evolution was either not discussed or it tended to be brief, noncontroversial, and characterized by restraint (Skoog, 1979, p. 628). For Hunter, who did not even use a Haeckel embryo diagram, it may have been too much to discuss how amphioxus fit into evolution.

New research.

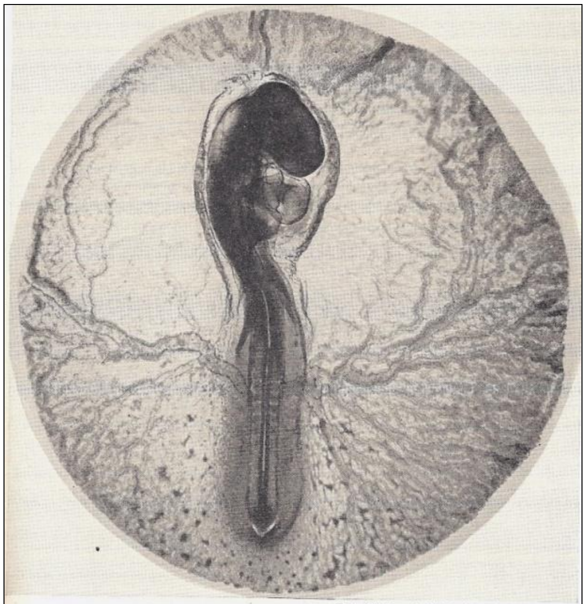
Perhaps as a clue to what was to come, Hunter discussed “potencies” of eggs. He declared that some organisms have totipotent eggs while other non-totipotent species have eggs with a determinate cleavage pattern. In the first instance that I could find, Hunter also mentioned identical twins in the context of embryo totipotency. He stated that “cleavage in man is apparently of the totipotent type, and is the logical explanation of the production of *identical* twins (p. 432).

Smith’s 1938 *Exploring Biology* was the first text to provide diagrams about how vertebrate neural tubes were formed, and she and Hunter, were the first writers to describe chromosomes and genes as having importance to the field of embryology. In addition, Smith’s 1938 text has an investigation with the influence of hormones on growth. A controlled experiment (the first time an embryology experiment using controls had been discussed in my texts) with two aquaria and tadpoles was required. In one aquarium were tadpoles that were fed flour; the other aquarium had tadpoles that were fed flour mixed with a crushed thyroxin tablet. Students compared the growth of the tadpoles for two weeks. In 1919, Hunter had discussed this type of experiment stemming from Gudernatsch's physiological experiments in his biology text; Smith, however, took it a step further and modified it so she could use it as an experiment for students. It is the first such high school experiment dealing with embryology that I could find.

1940–1949.

The fourteen textbooks that I reviewed for this period showed an increase in three things: photographs of embryos rather than drawings, prenatal care, and an emphasis on evolution. Even with the increased discussion about evolution, though, human evolution was often not mentioned (Skoog, 1979). This most likely explains the increase in the number of Haeckel embryo diagrams seen (eight out of fourteen textbooks) but at the same time, only one textbook (Benedict, 1941) had a human embryo in these diagrams**.**

Textbooks still addressed development descriptively but there was an increase in the number of paragraphs that I coded as science as a way of thinking or NOS (10%). Some of the textbooks were characterized by stable content. That is, the treatment of embryology remained the same in the 1940, 1946, and 1949 editions of one textbook (Curtis et al., 1940, 1946; Curtis & Urban, 1949) and for Smith's 1942 and 1949 editions of *Exploring Biology*. However, 1940s texts also mark the first time in which discussion about meiosis, chromosomes, and genes are added to units on embryology and reproduction. Frogs and chicks continued to dominate descriptive paragraphs but for the first time, there was more discussion about chicks than frogs. Texts continued to use Herm's photographs of chicks in eggs but another soon-to-be widely seen photo appeared. A series of early chick embryo photos credited to the Biological Supply House in Chicago became popular in many of these texts. Some texts only used one photo, most often the 48-hour chick embryo picture as shown in Figure 6, while others used a series of chick photos showing growth from 23 hours to 96 hours.



Copyright General Biological Supply House, Chicago

A FORTY-EIGHT-HOUR CHICK EMBRYO. Can you locate the heart, eye, ear, and external blood system?

Figure 6. A commonly seen chick embryo photo from the 1940s. From *Science of Living Things* (p. 487). By C. G. Weymouth, 1941, New York: Holt.

The opossum was discussed in three textbooks and the starfish embryo made its first appearance with a series of photos illustrating eight stages of its development. The starfish photographs were copyrighted by the General Biological Supply Company and reflects upon a time when a series of biological supply companies opened for business in the 1940s. Not only was this in response to growing research needs in biology, but also to the growth of the number of biology classes offered throughout the country after the end of WWII (Rudolph, 2005).

Prenatal influence.

A new trend was noted in the textbook *Biology for Better Living* (1946) by Ernest Bayles and R. Will Burnett. Prior to this text, vertebrate embryos had always been discussed from an amphibian and bird point of view. Bayles and Burnett, however, gave ample discussion of mammalian embryos, and in particular, the human embryo that needed to be protected while in the womb. The text addresses the belief of prenatal influence, stating that,

> There is no way that the embryo can be deformed or 'marked' by anything the mother thinks or does (except actual bodily injury to the embryo, of course). Probably you have heard stories of mothers marking their babies by being frightened. If there is no nervous connection between mother and embryo, how could the mother's thoughts affect the embryo? You may now see it does no good whatsoever for an expectant mother to attempt to influence the attitudes and abilities of her baby. (p. 659)

This is the first textbook that offers even a hint that human females can become pregnant, and discusses why pregnant mothers should ignore what people said about prenatal influence, also known as maternal impressions. This was a widely accepted late-nineteenth century belief that pregnant women could adversely affect their unborn children by exerting themselves too much, allowing themselves to become hysterical, or letting themselves get scared in certain situations. To counter prenatal influence, pregnant women had been advised to avoid exercise, sexual relations, and even saying no to riding in cars (Morgan, 2009).

Many embryologists, including Franklin P. Mall at the CIW Embryology Department scoffed at the idea of prenatal influence, stating that research had shown that the placenta created an impermeable barrier between mother and child. This is seen with Bayles and Burnett's comment regarding the absence of a nervous connection between mother and embryo. By the mid-twentieth century, the belief in prenatal influence was finally fading (Morgan, 2009, p. 55), evidenced by Bayles' and Burnett's use of scientific arguments to advance a new view.

As births in the U. S. skyrocketed during the 1950s (Preston, 1986), medical science now turned more attention to healthy pregnancies. In textbooks of this decade, students were no longer just shown mouse and opossum embryos—human embryo development was also part of the discussion. Much attention was given to the length of the human gestation period and do's and don'ts for pregnant women. For example, in *Biology for You* (Vance, Miller, & Teeters, 1946) pregnant women were advised to exercise to keep in the best of health, yet not to over exercise. With the rise of hospitals and the "hospitalization of medicine" that was peaking during the late 1940s (Hopwood, 2009), the authors recommended to students that "the mother needs the attention of a competent physician and should follow his directions" (Vance et al., 1946, p. 515). This was accompanied by the first textbook picture of a newborn human with a caption stating that both mother and child needed care for a while after the baby was born.

Other texts also began addressing the topic of parental care for the first time. For example, in *Dynamic Biology* (Baker & Mills, 1948), the authors stated that a student's understanding of embryology would not be complete without noting several important factors that distinguished human embryos from all others. One factor was "protection of the female during the period of gestation; a second is parental care of the offspring after birth; and a third is the keeping of records called vital statistics" (p. 580).

Baker and Mills dismissed the idea of prenatal influence but they did point out that embryos could become deformed if the mother was in a serious accident, or if she caught a communicable disease that spread to the newborn through the mother's bloodstream. The second factor of importance, parental care of offspring, was discussed in terms of puppies followed by the comment, "a newborn babe of the human species is one of the most helpless of all new forms of life" (p. 581).

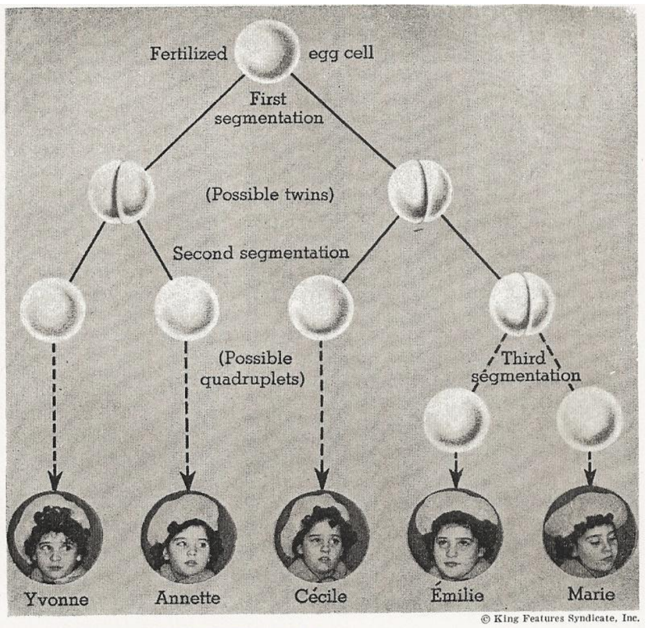
The inclusion of keeping vital statistics in a chapter on reproduction is odd, but is perhaps related to the increase in record keeping that occurred during and after WWII. Here, students were made aware that a birth certificate was necessary for all kinds of things—employment, travel abroad, military service, and court appearances. Not only was the embryo to be protected, but it now needed to be kept track of.

I also found evidence of a growing need for prenatal care in other texts, especially the need for mothers to protect their unborn from communicable disease. In *Biology and Daily Life* (Curtis & Urban, 1949) syphilis was described as a disease that could be transmitted to the baby before birth, and because of this, there were state laws requiring tests for venereal disease before a marriage license could be issued. In *Exploring Biology* (Smith, 1949), the author discussed how gonorrhea could affect babies at birth.

Twins.

Perhaps because some textbook authors had become so bold to write about human childbirth, the mentioning of twins during the 1940s would be expected to follow suit. This was seen in several texts (Smith, 1949; Vance et al., 1946; Weymouth, 1941). Gruenberg (1944) uses a picture of the Dionne quintuplets to show how five girls, born in 1934, arose from one fertilized egg (see Figure 7). Other than this picture of an egg going off in five different directions, there were no drawings of twins *in utero* during the 1940s. The closest that I could find to a twin picture was that of a milk cow with two twin offspring in Smith's discussion about twins (1949). While the texts during this time period were beginning to talk about human embryos and fetuses, they apparently were not ready to put them on display. Another point was that discussion about twins never mentioned conjoined twins: textbook pregnancies during this time focused on normal development, only.

Why twins would appear during this time can be explained by several factors. First, there was much twin research done in Canada and the United States that benefitted from early development of clinical and experimental genetics in the 1920s (Gedda, 1961). Second, recent twin studies had shown how the certain characteristics of twins were



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FIVE GIRLS FROM ONE FERTILIZED EGG

Each cell resulting from the first two or three cell divisions of a developing embryo would seem capable of becoming a complete individual. The most reasonable interpretation of the resemblances and differences among the "Quints" is that after the second cell division, three of the four cells developed into Yvonne and Annette and Cécile, while the fourth cell divided again, developing Émilie and Marie

Figure 7. The Dionne quintuplets. From *Biology and Man* (p. 361). By B. C. Gruenberg & N. E. Bingham, 1944, New York: Ginn.

controlled by genes. This became part of the popular nature versus nurture debate (Ladd, 1982). There was also the beginning of research looking at the physiology of twin pregnancy. This information did not immediately make its way into secondary textbooks however, because human reproduction was not discussed until the 1940s. Thus, there was a growing body of scientific research about twins that was available to textbook writers who were now in the position to write about the subject.

Another reason for including twins in textbooks was because twins are interesting from a social perspective. The United States was one of the first countries to promote twin research by establishing social organizations for twins in 1931 (Gedda, 1961, p. 30). Pictures of teenage twins, wearing the same clothes, and appearing happy made for noncontroversial subject matter in textbooks. Although most of the texts that discussed twins did so in chapters about development and reproduction, the 1947 edition of *Modern Biology* presented twin studies in a discussion about the role of heredity in human performance. It did not take much to read between the lines—the authors were still stuck in a mainline interpretation of eugenics. In this text, the IQ tests of twins proved that intelligence was determined by genes, although the authors evinced some caution about totally dismissing one's environment as a contributing factor, too.

1940s investigations and NOS.

As I worked through the texts, my tally column for investigative paragraphs remained conspicuously absent of tic marks. I was not surprised since texts in the early twentieth century were high on content and low on questions or experiments. There was one exception though and that was found in the 1938 and 1949 *Exploring Biology* texts by Smith. In 1938 she had students explore the effect of thyroxin on tadpole growth. In her 1949 text, Smith continued with her emphasis on experimentation, becoming one of the few authors to incorporate this type of investigation into a text during this time. Smith dropped her thyroxin and tadpole experiment and replaced it first, with what embryologists had always done—having students go out and catch some frogs. Once the frogs were brought back to the classroom, the female frogs were put in an aquarium (nothing is mentioned about what happened to the male frogs) and students waited to see if the female frogs laid eggs without a male frog around. Apparently the female frogs complied and students then took a few of the unfertilized eggs and placed them in containers with varying amounts of salt in them. The goal was to see if different concentrations of salt induced the unfertilized eggs to begin development—an experiment that is reminiscent of Jacques Loeb's artificial parthenogenesis work.

While Smith's goal was to have students experiment with embryos, Gruenberg's and Bingham's *Biology of Man* (1944) showed students that embryologists in labs did experiments, too. This text accounts for most of the NOS paragraphs that I counted in the 1940s. Gruenberg was the first to really dig deep in time as he mentioned Aristotle and his periodic examination of hen eggs. Jacques Loeb was mentioned, but not for his parthenogenesis work. Gruenberg discussed Loeb's experiments with changing the temperature of an organism's environment to modify the rate of development. Chemical influences on differentiation were explored by examining Charles Stockard's work with "freak" minnows. Students were shown the drawing in Figure 8 and told that by systematically changing the relative amounts of magnesium and calcium in sea water, experimenters had been able to make various types of freak minnows hatch out of the same batch of eggs. In some cases, a high magnesium concentration resulted in two eyes that moved together and fused in the middle.

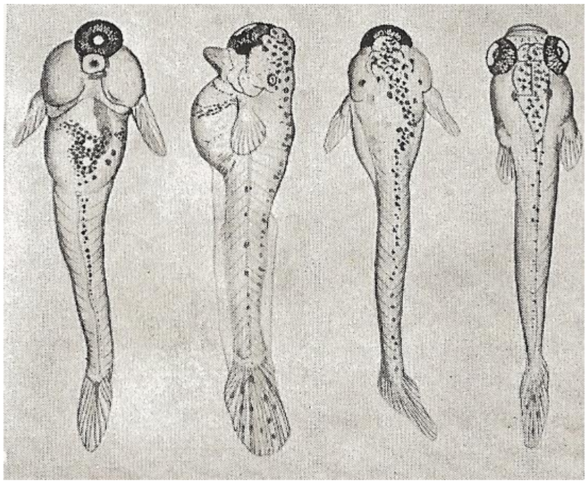


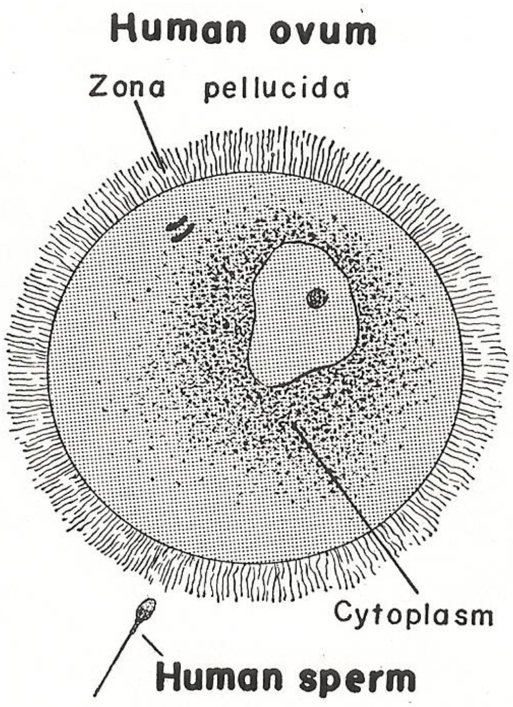
Figure 8. Stockard's freakish fish experiment. From *Biology and Man* (p. 360). By B. C. Gruenberg & N. E. Bingham, 1944, Boston: Ginn.

Gruenberg also wrote about transplantation studies in the form of growing organs out of place, such as transplanting an eye-bud on the side of a chick embryo. Students were introduced to terminology like dorsal lips, optics cups, and lens formation. Hans Spemann's work was explored in detail, for the first time in any textbook, paving the way for more discussion about thousands of experiments that have been carried out on embryos of many species. For the most part though, if a student wasn't reading Gruenberg during the 1940s, they most probably would have been memorizing the parts of a frog embryo.

1950–1959.

I analyzed sixteen textbooks for this period and found the stability that had characterized development in some textbooks during the 1940s, also carried through to the 1950s. The 1951 and 1956 editions of *Modern Biology* by Moon et al. continued to avoid any discussion of human development and stuck with the reproduction of the hen. *Everyday Biology* (Curtis, Caldwell, & Sherman, 1953) had the same material on embryology as was used in its three earlier editions (Curtis et al., 1940, 1946, 1949). But all was not totally the same. There were some texts that had updated content on reproduction and embryos, such as Smith's *Exploring Biology* (1954). In it, the author used new photos in a section about human development, one of which was a Carnegie photograph of a sixty-hour human embryo with a short description of how Arthur T. Hertig and John Rock had first reported about the embryo. This is the first photo of a human embryo that I saw. The picture is repeated in Smith's 1959 edition, along with photos of a human ovum, credited to Gregory O. Pincus of oral contraceptive fame, and a human sperm credited to urologist Seymour F. Wilhelm.

Laboratory research and improvements in microscopes and micrography during the 1950s probably increased the number of photographs that publishers could now choose from. Smith's use of separate photos for human eggs and sperm appeared to be the norm for this decade. Other textbooks use pictures of egg and sperm, but they too, never showed a sperm touching and fertilizing an egg. In *Biology for You* (Vance & Miller, 1958) an egg and sperm *almost* meet but not quite (see Figure 9).



Comparative sizes of a human egg and sperm.

Figure 9. Pre-1960s textbooks kept sperm and egg apart. From *Biology for You* (p. 465). In B. B. Vance & D. F. Miller, 1958, Chicago: Lippincott.

Whether the texts seemed to present the same material over and over, or presented new information about development, the material presented remained descriptive and was packed full of new terminology. The texts that I coded resulted in the highest amount of descriptive paragraphs out of any decade (96%). One of the arguments made for a revamping of textbooks in the 1960s was that textbooks offered little in terms of updated science and what was presented was merely recall information. Based on my coding of paragraphs, this appears to be true.

According to Skoog, evolution in texts during this time period was present but limited. The term “evolution” was often disguised by using expressions such as racial development, progressive development, and simply, change (Skoog, 1979, p. 631). My findings show that the number of texts using Haeckel’s diagrams increased from 57 percent in the 1940s to 69 percent for this decade. But even with this increase, only two texts used human embryos in their Haeckel grids (Heiss & Lape, 1958; Kroeber, Wolff, & Weaver, 1957).

Human pregnancy.

During the 1950s, new technologies emerged and so did society's views on women and childbirth. By 1940, 55 percent of America's births took place within hospitals; by 1950, hospital births had increased to 88 percent of the total; and by 1960, most children of suburban and urban mothers were born in hospitals (Leavitt, 1986, p. 171). As human pregnancy became more "hospitalized," it became commonplace for doctors to use obstetric technologies, including x-rays and blood tests. This increased the visibility of the fetus (Hopwood, 2009) and led to the view that obstetricians now had two patients on their hands, the pregnant mother and the fetus. It is here, in the 1950s where the fetus is first seen as a "patient." This view would increase dramatically when I examined texts published in the 1980s.

According to historian Elaine Tyler May (2008), the 1950s saw an emphasis on the creation of safe homes with large numbers of children. Achieving both of these things signaled a return to normalcy after World War II and satisfied a reaffirmation of American values in the face of the Cold War with the Soviet Union (Rudolph, 2002, p. 11). To help American teenagers understand this, biology textbooks showed young girls and boys what their upcoming roles were to be when it came to having babies. This type of curriculum, driven by a life-adjustment curricular ideology, was similar to that of the progressive education movement in the early 1900s: academic subject matter was marginalized in favor of designing a curriculum to meet the immediate social, personal, and vocational needs of the student (Rudolph, 2002, p. 4).

In *Man and his Biological World* (Jean, Harrah, & Herman, 1952) a full chapter is given to human pregnancy and protection of the unborn child. Prenatal influence continued to be discussed as a non-valid belief and more do's and don'ts were offered for pregnant women. Running, leaping, and riding a horse were definitely to be avoided, and for the first time, so were drugs and alcohol. Students were warned that mothers needed to avoid becoming "a victim of some active, pernicious disease such as syphilis or gonorrhea" (p. 157). In 1950's textbooks, pregnant women were advised to avoid contact with sick children, especially in the first trimester of pregnancy. For the first time, measles was identified as a virus with the capability of disrupting normal embryonic development (the measles, or rubella virus, was first linked to congenital defects in 1941). The texts did not tell students what was in store for rubella-exposed newborns, and with abortion illegal at this time, the assumption was that mothers of affected babies would courageously carry on.

As new medical technologies emerged, so did the influence of the American Medical Association (AMA) and its effort to increase prenatal care for pregnant women. This is evident in several texts that advised pregnant mothers to consult their physicians regularly, according to a schedule recommended by the AMA (Jean et al., p. 158). And of course, pregnancies were to be spaced out and occur only when the "cooperation of a sympathetic and cooperative husband could be achieved" (p. 159). This same type of information was available to pregnant mothers in 1940s women's journals: hospital-based births meant progress and women needed to follow their doctors' orders, regardless if they understood why or not (Leavitt, 1986).

In *Exploring Biology* (Smith, 1959), students were told that medical care during pregnancy was of vital importance. This text was the first to discuss the problems that occurred with Rh negative mothers carrying Rh positive fetuses. Unlike previous decades, we now see how things can go wrong with the unborn, and in this case it is because the fetus is immunologically different from the mother. The research that exposed Rh incompatibility with mothers and babies was published in 1941 by Philip Levine and his colleagues, but it took nearly twenty years for this information to make its way into textbook science. I don't believe it was because the science was not seen as important but the fact that the portal, that is, human pregnancy, wasn't accepted as something that should be discussed in textbooks until the 1950s.

Shortly after publication of the 1959 edition of *Exploring Biology*, William Liley pioneered fetal transfusion technology with fetuses with Rh incompatibility disease. This would become one of the first instances of a fetus as primary patient. The mother, who also had to undergo surgery, was more or less treated as a support technology (Casper, 1997). No textbooks that I reviewed discussed fetal transfusion technology, but in the 1990s, fetal surgeries were described exactly as feminist ethnographer M. J. Casper had described fetal transfusions–fetus as patient and mother as incubator.

In the 1950s, with an emphasis on baby production, the human embryo took on a different tone. It is in Smith's textbook and others as well that that human childbirth is labeled as "remarkable." This is a key point and demonstrates what social historian Donna Haraway (1991) claims as our inability to look at the human embryo or fetus objectively without seeing it through the lens of our own culturally-defined and prefabricated frame of reference. With all other organisms, textbook births were presented scientifically and with little fanfare. In *Exploring Biology* (Smith, 1959), human reproduction is extolled with the question, "Is there anything on Earth more amazing, more unbelievable, or more helpless than a new born baby?" (p. 506). Such statements treated motherhood and human development as an awesome and seamless trajectory from conception to birth (Morgan, 2009, p. 134).

The trend in the 1950s was that the embryo was now something to be protected, evidenced by authors' advice to pregnant women that they should consult clinics or private physicians on how to provide the best possible environment for their developing baby. More evidence of the institutionalism of pregnancy is seen in *Biology* (Kroeber et al., 1957) with a picture of a nurse and nine new born babies in a maternity ward. A few texts also mention protecting neonates from the harmful effects of radiation on prenatal development. By the mid-1950s it was generally known that radiation exposure could cause abnormalities and death to embryos (Russell & Russell, 1954). Neonatal deaths from x-ray exposure were found to be common in mice and in pregnant women who survived the atomic bombings of Hiroshima and Nagasaki, especially if their radiation exposure occurred during organogenesis (weeks 3 to 6 in human embryogenesis). Because of this research, obstetricians became much more cautious in the 1950s about using diagnostic x-ray exams for pregnant women, especially in the first trimester (Casarett, 1968). This research made the leap to high school textbooks most notably in the form of prenatal health advice rather than in chapters on radiation biology.

1950s investigations and NOS.

In examining the texts for investigative, nature of science, or societal issues, I nearly came up empty-handed. Only three texts gave even a passing paragraph to experimentation. In Smith's 1954 *Exploring Biology*, the author declares that Loeb's artificial parthenogenesis work convinced Loeb that "fertilization makes an egg start to grow, at least partly because it stimulates rapid chemical changes in the fertilized egg "(p. 399). Gregory Pincus was discussed as providing evidence that chemistry plays an important role in fertilization, even though the author described his work as subjecting rabbit eggs to cold temperatures, a physical rather than chemical process. In Smith's 1959 edition there was no mention of Loeb or Pincus; in fact, there were no discussions about the nature of science and development at all in her later textbook.

1960–1969.

There was an unprecedented emphasis on evolution in textbooks during this period. Skoog attributes this to the recognition of evolution as a major biological theme by the BSCS. Not only were three different BSCS texts released in 1963, but the same texts were revised and released again in 1968. With six BSCS textbooks showcased in the 1960s, it certainly looked like evolution had finally arrived, especially when other textbook publishers revised their own textbooks to fall more in line with the BSCS model. This accounts for the increase in Haeckel's diagrams, with seventeen out of eighteen books that I examined using Haeckel's embryo grid and more significantly, fourteen of these textbooks showed human embryos.

Evolution wasn't the only concept, though, that saw increased playing time. More was written about development during the 1960s than any decade of textbooks that I reviewed. It wasn't just more content either—the amount of descriptive paragraphs dropped to 68 percent while the number of paragraphs devoted to the nature of science rose to 27 percent. Since the 1960's texts came on the heels of the Inherited Embryo Research Period (1950s to early 1970s), one of the things that I was now looking for was discussion about developmental biology, nuclear transplantation, and the role of genes in differentiation. And I found it, but not everywhere.

During this decade, the fields of embryology and genetics began to be wedded into the field of developmental biology. According to Scott Gilbert (2008), this merging consisted of two different avenues of synthesis: the merging of genetics and embryology and the integration of post-embryonic processes and non-traditional organisms. Development no longer was just about embryos but now covered every aspect of regular change that characterized a particular species of animals (and plants). With this new research platform, developmental biologists were also investigating wound repair, regeneration, menstrual cycles, aging, and death.

Compared to previous decades where embryos were often placed in chapters titled "Amphibians" or "Life Cycles," the texts in this decade saw embryos placed in newly named titles that often included the word "development." These chapters included materials about cell differentiation, experimentation, and the role of genes in embryo development. For example, Kimball (1965) placed embryos in a chapter titled "Sexual Reproduction in Animals" and in a chapter titled "Development: Cleavage, Morphogenesis, and Differentiation." The 1968 edition of the BSCS Yellow version had embryos discussed in "The Development of Animals" and in "Analysis of Development." In the 1963 edition of *Modern Biology* (Moon et al., 1963), embryos were discussed in individual chapters with the titles of "Amphibians," "Birds," and "The Mammals." Two years later, in the 1965 version of *Modern Biology* (Otto & Towle, 1965) embryos had been placed in one major chapter titled "Reproduction and Development."

Developmental biology and NOS.

Three textbooks stood out in presenting new information about developmental biology: *Biology* (Kimball, 1965) and the 1963 and 1968 of the BSCS Yellow and Blue texts. With an emphasis on genetics, the 1963 Yellow version discussed post-embryonic development for the first time. The 1968 Yellow version discussed post-embryonic development in "Analysis of Development" in the form of cell replacement, regeneration, aging, cancer, and genes. Such embryology and genetics information had not been seen by students before, but one should not be too quick to claim that the 1960s was the birth of developmental biology in high school biology textbooks. Much progress had indeed been made to update texts with more current laboratory research, but the actual weaving together of genetics, embryology, and molecular biology into a single coherent chapter titled “Developmental Biology” did not occur during the 1960s. Discussion of genetics, embryology, and reproduction was still constrained by giving each of these topics their own chapters. This limited any attempts to bring the three areas together and was reminiscent of embryology in the early twentieth century rather than the 1960s.

Even with this criticism, the 1963 BSCS Yellow and Blue versions were remarkable in many ways—one being the manner in which embryology was presented. Given the paucity of NOS in the decades prior to this, it was like a NOS explosion had gone off in these two texts. The first edition of *Molecules to Man* (Blue version) and *An Inquiry into Life* (Yellow version) contained fifty-seven and forty-eight paragraphs, respectively, dedicated to NOS and development. The 1963 BSCS *High School Biology* (Green version) only had one paragraph.

An examination of the “Development” chapter in the Blue revealed key names, terms, and investigations. Aristotle, preformationism, and epigenesis were given more attention than ever before. Hartsoecker’s homunculus drawing and Casper Wolff’s early chick illustration were reproduced and discussed. This was followed by Harvey’s deer embryo studies and von Baer’s observation of rabbit and dog development. Here, the authors stressed how difficult it was to find microscopic fertilized eggs but embryologists soon turned from mammals to invertebrates like starfish and sea urchins.

The use of dyes and charcoal to trace where various parts of embryos moved to and what they developed into was introduced, but how these investigations helped with the making of fate maps was not mentioned. This served as the entry point to the world of experimental embryology and the work of Roux and Driesch. At a full three pages, the experiments of the two embryologists were used to explain how complex development is, and that preformationism was an incorrect developmental mechanism.

Experimentation with embryos continued with the “clever experiments” of Spemann. Although Spemann was briefly mentioned in Gruenberg’s 1944 text, it was here, in both the 1963 and 1968 editions of the Blue version, that Spemann’s work was first discussed in great detail and placed within a historical context. The experiments described ranged from salamander transplantation, resulting in “Siamese” salamander embryos, to embryonic induction and eye development. Joannes Holtfreter’s work with the induction of a tissue entirely outside of an embryo followed the work of Spemann. The manner in which Spemann’s, Holtfreter’s, Driesch’s, and Roux’s experiments were described showed embryology to be dramatic and dynamic.

The 1963 Blue version also was a text of “firsts.” It was the first text to describe the function of the placenta in depth; the first to show life-sized models of child birth; and along with the 1963 Green version, was the first to show a photograph of a human sperm making contact with a human egg. This photo, shown in Figure 10, was used in several other texts after 1963 and is credited to Landrum B. Shettles (1960) who published his picture in *Ovum Humanum*.

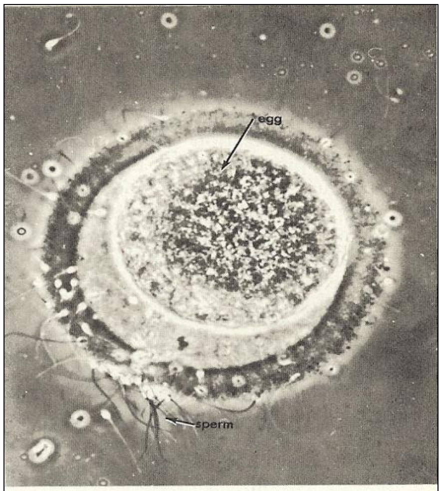


Figure 13–15 *The fertilization of a human egg.* (*L. B. Shettles*)

Figure 10. A common human fertilization photograph. From *Biological Science: Molecules to Man* (p. 315). In BSCS, 1968, Boston: Houghton Mifflin.

The 1963 Yellow version was similar in many ways to the Blue version. Roux and Driesch and Spemann were all discussed and there was more emphasis on how the study of model organisms such as sea urchins, frogs, salamanders, and monkeys had allowed embryologists to understand human embryology. The work of M. Nui was introduced and the authors interpreted Niu's results as evidence that induction occurs by the transfer of a nucleic acid from the mesoderm to the ectoderm. Nui's work was done in the mid-1950s and represents a part of the transition period from the Biological Embryo to the Inherited Embryo research periods.

The other text that I found novel in its approach to embryology was John Kimball's *Biology* (1965). At the time, Kimball was a secondary school science teacher at Phillip's Academy in Andover, Massachusetts (he would later return to Harvard and obtain a PhD in biology before revising his texts that appeared in the 1970s). Kimball discussed Loeb and in particular, his parthenogenesis experiment of pricking an egg with a needle dipped in frog blood to initiate development. Not only did Kimball describe the experiment but he also discussed why such a seemingly strange experiment even took place.

The work of experimental embryologists continued in *Biology* within the context of what controls development. Roux and Driesch's work was discussed, as was Spemann's. Kimball explained Spemann's techniques of using fine baby hair to constrict newt eggs and transplantation studies which "ultimately resulted in a two-headed monster" (p. 513), and Kimball credited Spemann for discovering the guiding forces of embryonic development.

Biochemical techniques used by embryologists were discussed for the first time in *Biology* in relation to heart myosin concentration becoming more localized as an embryo ages. Kimball discussed several embryologists who I had not encountered in any previous textbooks, including noted experimental embryologist S. Meryl Rose's mid-1950s work.

His experiments supported the idea that embryonic development was accomplished by the production of inhibitor substances. Rose grew frog embryos and transplanted pieces of adult frog tissue into the embryos. He found that when embryos had tiny pieces of adult frog heart in them, the embryos did not develop a normal heart. The same thing happened when a piece of adult frog brain was transplanted into a frog embryo—the embryo's brain did not develop normally. It appeared at the time that adult organs produced substances that inhibited differentiation, rather than promoted it.

Robert Briggs and Thomas King's work with nuclear transplantation was first seen in Kimball's text. Described as an experiment that built on Spemann's work, the two researchers successfully transplanted a nucleus from one frog to a frog egg that had no nucleus, resulting in different patterns of development. The inclusion of this early 1950's work indicates that textbooks were beginning to move development in two directions: first, more discussion about experimental embryology and how embryologist work (NOS) and second, the incorporation of more recent experimental findings or a move from how embryos were viewed in the Biological Embryo Research Period to the Inherited Embryo Research Period; the latter consisting more of embryo manipulation and how chromosomes and genes were involved with differentiation.

The BSCS effect.

What BSCS did, many others followed. The "BSCS effect" was evidenced by texts that copied BSCS's format and began adding more investigative and NOS material to the overall picture of development. Because so many texts were now adding information about embryological research, the paragraphs that I coded as NOS increased from 2 percent in the 1950s to a phenomenal 27 percent in the 1960s. No other textbook decade would have as much nature of science information in it.

A leading contributor to the increase in NOS and an example of the BSCS effect was Stanley Weinberg's *Biology: An Inquiry into the Nature of Life* (1966). He discussed epigenesis and preformationism, Roux and Driesch, and what appeared to be everyone's favorite embryologist, Hans Spemann. Spemann's work was popular in 1960s texts, and with more than a simple regurgitation of some of his transplantation studies. Spemann was now used to represent science as a series of dilemmas which led to the understanding that there was an underlying complexity to learning about complex topics. The many pages devoted to Spemann's work might have reflected the authors' deep understanding of Spemann's experiments, but it might also have been the result of the authors' recognition that with science education, there was an increasing need to provide much more detail about why experiments were done, and how they were done, for student understanding to occur.

Not all texts followed what BSCS writers did, including *Elements of Biology* (Dodge, 1964) which still read the same as previous editions. While *Modern Biology* (Moon et el., 1960, 1963; Otto, & Towle, 1969) got off to a slow "developmental biology" start in the early 1960s (it focused on bird embryology), its 1969 edition had a complete chapter on human reproduction and development. The 1969 edition no longer had long-time author Truman Moon listed as primary author. This factor, along with a growing acceptance by the public that human reproduction was something that high school students should know about, probably led to this change.

A surprising observation was the complete lack of NOS-related material in Smith's last textbook edition of *Exploring Biology* (1966). In previous editions, Smith had been on the forefront of presenting new findings such as hemolytic disease of the newborn and Gregory Pincus' work with rabbit eggs, but her last textbook, which for the first time was coauthored, appeared to have closed up shop to the use of investigation and NOS-related materials that she had used in previous editions.

1960s and investigations.

Prior to this decade, my tally of investigative work, or even of paragraphs that merely asked students questions about something related to development, was almost nil. If I had eliminated the 1963 and 1968 BSCS editions, I would have kept my tally at 1 percent. But the Green and Blue BSCS versions, all by themselves, increased the number of investigative paragraphs to 4 percent. The Blue version offered a detailed laboratory investigation about the action of hormones on frog reproduction. Rather than throw a mixture of flour and thyroxin into a tank of tadpoles like Smith had suggested in her previous editions of *Exploring Biology*, a pituitary preparation (purchased from the ever-expanding number of biological supply houses) was given hypodermically to female frogs to initiate egg-laying. From here, students "milked" the frogs after 24 and 48 hours. The ambitious experiment continued with students adjusting two variables: temperature and length of daylight

To obtain frog sperm, the males had to be double-pithed (brain and spinal cord destroyed), the testes crushed, and Holtfreter's solution added and stirred. Through an elaborate process the eggs and sperm were mixed and stored for 24 hours. Fertilized eggs were then ready for study. The text offered further suggestions to help students design their own experiments with the eggs: what effect would chemicals such as alcohol or caffeine have on the developing embryo and how would aeration of the water affect development. Such inquiry experiments, which made students devise certain aspects of their study (e.g., controlling for variables), were typical of the push by science educators in the 1960s to help students see science as a process rather than as a bunch of facts and terminology. The Green version contained a similar inquiry-based experiment but rather than use frogs, it had students investigate fertilized chick eggs and devise an experiment showing how temperature affected development.

The theme of motherhood and pregnancy management that had dominated the texts of the previous decade literally disappeared in the 1960s, although syphilis and measles were still discussed, marking more trouble for embryos. There continued to be chapters on human reproduction, but the information now focused on the timetable of embryonic development, fetal circulation, the role of hormones role in pregnancy and childbirth, menstruation, and male and female reproductive systems. There were even photographs of human embryos and fetuses but students probably did not realize that the fetuses in these pictures, used to represent "life,' were in reality, quite dead.

Up until this point in time, there was no discussion about developmental biology and society in textbooks. Outside of the classroom there was growing concern about the sexual revolution sweeping the United States and in 1960 the FDA had approved sale of birth control pills. Meanwhile, in the laboratory there were nuclear transplantation studies and *in vitro* research was being carried out. Were there any texts that described the usefulness or dangers of this research or discussed social issues related to embryology? The answer is, very few. While the field of science education was moving towards inquiry-based curricula, there appeared to be little incorporation of STS into textbooks.

The 1968 BSCS Blue version discussed the problems with thalidomide and the danger of relying solely on research that is done with laboratory animals. The 1968 Yellow version discussed the advantages of using amphibian embryos over those of humans, including the fact that "human embryos require special conditions for growth that have not been duplicated in the laboratory. But, when scientists do come up with the right growing conditions, society will then have its first test-tube baby" (p. 494). Other than these two entries, there were no other texts that addressed ethical concerns with new technology and developmental research in the 1960s.

1970–1979.

There were many forces affecting biology education in the 1970s. The “back to basics” movement began, whereby it was deemed essential to teach more about basic facts and discuss less about controversial subjects. There was also a lack of interest in using interdisciplinary approaches to teaching science. (Yager, 1982) Outside of the classroom, the U.S. Supreme Court ruled in 1973 that abortion was legal and there was a 1975 moratorium on federally supported research on *in vitro* fertilization (Culliton, 1978). All of these events influenced how authors would now write about embryos and fetuses.

The gains seen in incorporating evolution into science textbooks in the 1960s dropped off a bit in the 1970s. In the textbooks for this time period there were fourteen out of nineteen texts that used Haeckel diagrams and nearly all of them (thirteen) used human embryos in their illustrations. Skoog states that there was a rise in objections made against evolution in textbooks during the 1970s (1979, p. 634) but the texts I reviewed showed that authors continued to use Haeckel diagrams as embryological evidence for the support of evolution.

Several of the texts were established, meaning that they had previous editions published in the 1960s and now offered more than one edition in the 1970s. Among these were BSCS’ Green versions (1973, 1978), *Biology: An Inquiry into the Nature of Life* (Weinberg, 1971, 1974, 1977), *Biology: Living Systems* (Oram, 1973, 1976), *Biology* (Kimball, 1974, 1978), and *Modern Biology* (Otto & Towle, 1973, 1977).

The amount of descriptive content did not change from the previous decade, but I was curious whether the type of content had varied. In particular, were new areas such as developmental genetics continuing to make headway into the discussion about how embryos grew and differentiated? During the early 1900s, research and consensus showed that the chromosomes in each cell of an organism were the same as the chromosomes that were first established in the fertilized egg of the organism (genomic equivalence). This led to the question, if every cell has the same genes, why don't they all produce the same proteins? The answer became apparent in the 1960s with the discovery of differential gene expression. Researchers found that while all cells have the same genes, not all genes are expressed, and this led to the discovery of the role of different RNA molecules in gene expression. Since this work had been done in the 1960s, and I had not seen much discussion of the role of genes in development in the 1960's texts, I was interested to see if developmental biology had finally arrived on the high school textbook scene. Of the nineteen texts, there were no chapters titled "Developmental Biology" although many chapters had the word "development" in them. The texts that had addressed genes and development in the 1960s continued to do so in the 1970s, and there were a few new texts that also began bringing the discussion of embryos and genetics closer together.

Even those texts that kept embryos firmly placed in chapters on animal development, included information that had not been seen by students prior to this decade, such as the relationship of the pituitary gland to the uterine cycle, hormone control of male and female reproductive systems, hormones and child birth, and spermatogenesis and oogenesis. With all of this new information, the texts of the 1970s portrayed development as making rapid and giant strides forward.

1970s texts and photographs.

In 1965, *Life* magazine published several of Lennart Nilsson's color photographs of human embryos and fetuses. The public was captured by the detailed images of human life that they had never seen before, and this helped lead the embryo from the laboratory to the living room in the form of coffee table books. The journey of Nilsson's photos did not stop there; beginning with Stanley Weinberg's 1971 *Biology: An Inquiry into the Nature of Life*, they became highly publicized in high school biology textbooks. Although there had been pictures of human embryos in textbooks prior to this, they were usually small snapshots of black and white Carnegie photos. Nilsson's pictures were published in color and they were often the only color photographs in the whole textbook.

Several texts used Nilsson's photographs beside Weinberg's three texts published in 1971, 1974, and 1977. These included *Modern Biology* (Otto & Towle, 1977), *BSCS Green Version* (1973, 1978) and *Biology* (Smallwood & Green, 1977). While I discuss Nilsson's photographs in more detail in the third section of my findings and discussion, it is important to note that the use of these photographs marks the beginning of the transition from the Inherited Embryo Research Period to the Visible Human Embryo Research Period. The public was finding it not only acceptable to view such "icons of life" but to acknowledge that they had a place in both public and scientific spheres (Morgan, 2009). On an individual basis, a parent's first visual contact with his or her child now occurred while the fetus was hidden in the womb, rather than at birth.

HETS and the 1970s.

Up until the 1970s, my coding of paragraphs in the Human Embryo, Technology, and Society (HETS) category was nearly non-existent. A cursory glance at the percentage of HETS paragraphs in the 1970s reveals a paltry 2 percent. However, this value represented a small shift that rapidly expanded into the 1980s and 1990s. Most 1970s textbooks talked about experiments but only one text, Kimball's *Biology* (1974, 1978) brought up ethical questions about reproductive engineering. Kimball wrote, "The rapid advances that have been made in the understanding of human reproductive physiology raise the prospect of manipulating the process in ways not hitherto possible (1974, p. 447). In *Biology,* students were introduced to several technological advances: the ability to freeze and store human sperm for future use; the possibility of using surrogate mothers to incubate embryos; *in vitro* sex determination; amniocentesis and genetic screening; and tetraparental offspring.

Several of these examples had only been done in laboratory animals at the time that this text was published, including tetraparental research reported by Beatrice Mintz. In what I would consider a classic example of “embryos in a dish” research, and part of the Visible Human Embryo Research Period, Mintz’s work involved taking early embryos at the eight-cell stage from a mother mouse and placing them in a culture dish. By carefully pushing two embryos together, they often fused into a single embryo. The resulting embryo with two fathers and two mothers was then put back into a mouse and allowed to develop normally. In a case of foreshadowing, Kimball declared that all of these manipulations raised ethical and legal questions that needed to be dealt with before the need to do so became critical. Like the embryos in the laboratory dish, the textbook embryo had now become a future-directed enterprise that would have societal consequences.

In another first, Kimball included discussion about blocking contraception—even as the embryo has become more and more visible in society, it appeared that not everyone actually wanted one. Several contraceptive aids to prevent pregnancy were introduced, including the intrauterine device (IUD), birth control pill, and tubal ligation. Even though the decision to make abortion legal in the U.S. had been handed down in the *Roe vs. Wade* Supreme Court decision in 1973, there was no mention of termination of pregnancies in any of the 1970s textbooks.

In Kimball's 1978 edition of *Biology,* he offered the same reproductive engineering concerns and examples as he did with previous editions, but with one addition: the ability of humans to reproduce asexually. What Kimball described was John B. Gurdon's mid-1950s transplantation studies with *Xenopus* frogs. The author used this transplantation study to raise the possibility of creating human clones of genetically identical humans. This discussion was accompanied by a well-known photograph where twenty genetically frogs were stitched together to show Gurdon's work (see Figure 11).

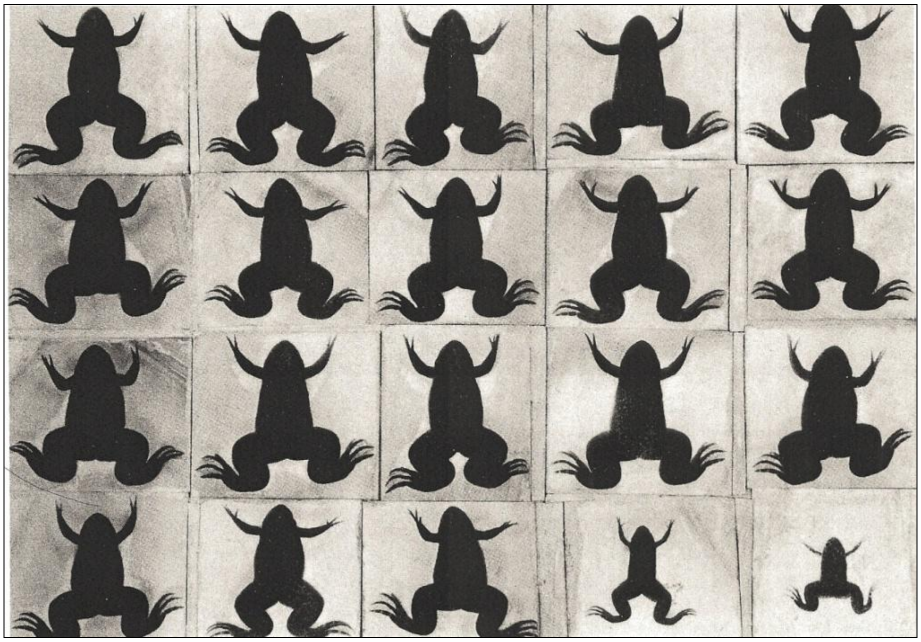


Figure 11. Twenty genetically identical South African clawed frogs. Part of John Gurdon's work in *Journal of Heredity*, 1962. From *Biology* (p. 386). In J. Kimball, 1978, Reading, MA: Addison-Wesley.

Kimball was also one of the first to associate the word teratogen with embryo development. A few previous textbooks had warned students about the dangers of measles and alcohol during pregnancy but the timing of when to avoid these agents was not discussed. In Kimball's editions he pointed out that embryos had "critical periods" where they were sensitive to viruses and chemicals which caused serious malformations. Thalidomide, which had led to babies born with shortened arms and legs (phocomelia) to mothers who had taken the drug during their pregnancies in the late 1950s and early 1960s, was discussed. Although Kimball used language that was far from the paternalistic tone used in the 1950s, this was another example of showing how embryos needed protection and monitoring.

While the textbooks of the 1960s get credit for updating the biology curriculum, I contend that the textbooks published in the 1970s did as much, if not more, updating. Not only was there an appearance of STS-type questions, but relatively recent information about male and female reproductive systems added more presence of human reproduction in biology texts, and discussion about gene splicing, recombinant DNA, and genetic engineering gave embryos a futuristic glow. There was also a certain amount of "beauty" added to embryos with the use of Nilsson's oversized photographs, exaggerating the amount of space that embryos occupied not only in their mothers, but in textbook importance as well.

1980–1989.

The 1980s marked the beginning of the Constructed Embryo Research Period. Textbooks published during this time did so against the backdrop of tremendous change in the world of the embryo. The research embryo was now spending time having its DNA rearranged, recombined, or replaced, while ethical questions were raised by a public who still saw embryos in the form of Lennart Nilsson's color photographs. These questions centered on what some groups considered embryo exploitation: cloning, *in vitro* fertilization, and abortion.

I examined twelve textbooks to see if new developmental research and technologies were written about and if ethical concerns about the technologies were raised. One of the reasons that the number of textbooks available to me dropped from nineteen in the 1970s to twelve in this decade, was that texts by Weinberg and Kimball were no longer published. *Modern Biology* only had two editions put out in the 1980s, as did BSCS Blue and Yellow versions. The rest of the texts were by new authors.

It quickly became apparent that a change had taken place in textbook design. As advanced placement and honors biology classes were put in place for “high achieving” students, textbooks that had originally been used as first semester college undergraduate texts were bought by school districts to replace high school versions of biology. The students in regular biology classes were now given texts with large font sizes, sidebars of extraneous information, and lots of pictures (although the number of Nilsson photographs diminished during this decade). These texts were visually overwhelming to me and for the most part, offered students much in terms of facts and figures, but little in the areas of NOS or investigative work. Texts such as *Experiences in Biology* (Bauer, Magnoli, Alvarez, & Chang-Van Horn, 1981, 1985), *Biology* (Slesnick, Balzer, McCormack, Newton, & Rasmussen, 1980), and *Biology, The Science of Life* (Hanson, Lockard, & Jensch, 1980) offered little discussion about human developmental biology, deciding to simply stick with explanations of frog and chick development. Students who used these textbooks graduated with an idea of embryology that was virtually unchanged from that of fifty years earlier.

The BSCS Blue and Yellow fourth editions (1980) both saw a continued decline of the incorporation of NOS into developmental research. There were, however, in terms of descriptive information, attempts to update the texts. The Blue version continued with its preformation and epigenesis discussion, but unlike previous editions where epigenesis was the agreed upon mechanism of development, the development of a fertilized egg now had a “great deal of epigenesis and some preformationism in it” (p. 250). The work of Roux, Driesch, and Spemann was greatly reduced compared to BSCS texts published earlier. There was more discussion about how genes were responsible for cell differentiation and the role of hormones on male and female reproductive systems, including the coordination of milk production with the birth process.

A 1987 text by Wallace and Simmons devoted its discussion of NOS to prenatal development studies. X-rays, rubella, and thalidomide were identified as harmful agents to normal development. Results from experiments with mice embryos and radiation exposure were presented in graph form (graphs were still a rarity in biology textbooks at this time). Unlike the 1950s where embryos were shown developing into babies who needed the protection of their parents, these embryos were used to show how pregnancy can go wrong. Perhaps to an already anxious public this only added to the idea that human embryos needed a great deal of watching over.

1980s and investigations.

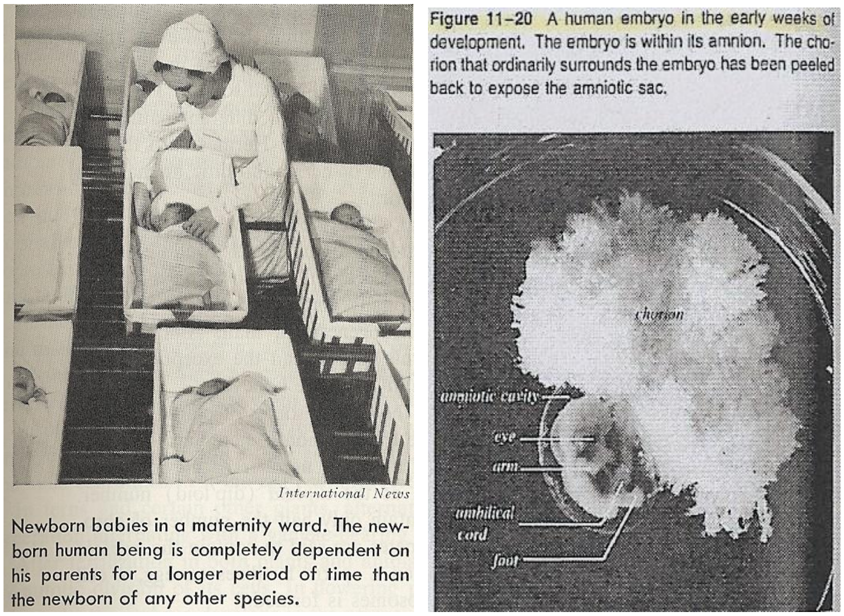
Textbooks during this period contained the most investigative paragraphs of any decade. The investigations remained similar to those of the 1970s mainly because BSCS texts continued with their chicken and amphibian embryo investigations. The 1985 BSCS Blue version added more inquiry to its frog embryo lab by posing questions to the students to further investigate. These questions revolved around devising experiments to determine how temperature differences, chemicals such as alcohol or caffeine, the amount of oxygen in water, and hormones like thyroxin, affected embryonic growth.

Two non-BSCS texts had students observe the growth of chick embryos by removing the shell from the wide end of an egg and then reincubating the eggs after drawing what they saw for several days (Bauer, et al., 1981, 1985; Slesnick et al., 1980) The BSCS Green versions prior to 1987 had always included investigations with chick eggs and frog embryos but with its 1987 edition, the reins were pulled back on this kind of experimentation. Students were, instead, presented a dry lab with pictures of chick embryos in different stages of development. The students did not use actual hens' eggs but were told to observe the diagrams and put them "in order."

1980s and HETS.

As might be expected, the number of paragraphs that were devoted to human embryos, technology and society increased from previous decades. Human embryo pictures were also present in Haeckel diagrams. While the number of Haeckel diagrams dropped to 67 percent in the 1980s (about where they were in the 1950s), all eight books with these diagrams in the 1980s used human embryos in them. Both of these events, an increase in HETS discussion made possible by a push for STS curricula, and Haeckel's human embryos, help explain why for the first time, there were more pictures and descriptions of human embryos than pictures and descriptions of frog and chicken embryos combined.

My observation about human embryos supports science education researcher Paul Dehart Hurd's (1982) comment that the 1980s would become the decade for studying the ethics of human research in high school biology classrooms. But not every book followed this lead; only four out of twelve books showed HETS material and the rest, including *Modern Biology* (Otto & Towle, 1985), remained firmly entrenched in the descriptive world of the embryo, only. The comparison of HETS in the 1950s to the 1980s can plainly be seen in a 1958 textbook and the 1980 BSCS Blue version text. In the 1950s, babies were shown alive in incubators (a technology that evolved over time); and in the 1980s, dead embryos and fetuses were shown in Petri dishes (see Figure 12).



Newborn babies in a maternity ward. The newborn human being is completely dependent on his parents for a longer period of time than the newborn of any other species.

Figure 11–20 A human embryo in the early weeks of development. The embryo is within its amnion. The chorion that ordinarily surrounds the embryo has been peeled back to expose the amniotic sac.

Figure 12. A comparison of 1950s (left) and 1980s (right) development. From *Biology* (p. 277). By C. J. Lauby, J. C. Silvan, & G. M.A. Mork, 1958, New York, American Book (left).From *BSCS A Molecular Approach* (p. 238). By BSCS, 1980, Lexington, MA: Heath (right).

Also in the 1980 Blue version was a description of how mammals could have embryos with multiple parents. Two examples were given: (a) the use of a cell culture medium to fertilize a human egg and when ready, placing the egg is into a surrogate mother; and (b) “fusing” mouse embryos together to make one embryo with two mothers and two fathers. In the 1985 Blue version, there was the same discussion of mammals with multiple parents, but no mention was made of human embryos and surrogate mothers. The later edition also added new discussion about technologies for embryo safety: amniocentesis for identifying genetic characteristics of the fetus or to look for biochemical abnormalities (see Figure 13); ultrasound to determine fetal sex and age; and chorionic villi biopsies (now known as chorionic villi sampling) for chromosome and biochemistry testing. Ultrasound pictures were commonplace in the 1970s texts, perhaps due to the fact that around 1970, psychologists had proposed that ultrasound could help mothers bond with their yet-to-be born children (Petchesky, 1987).

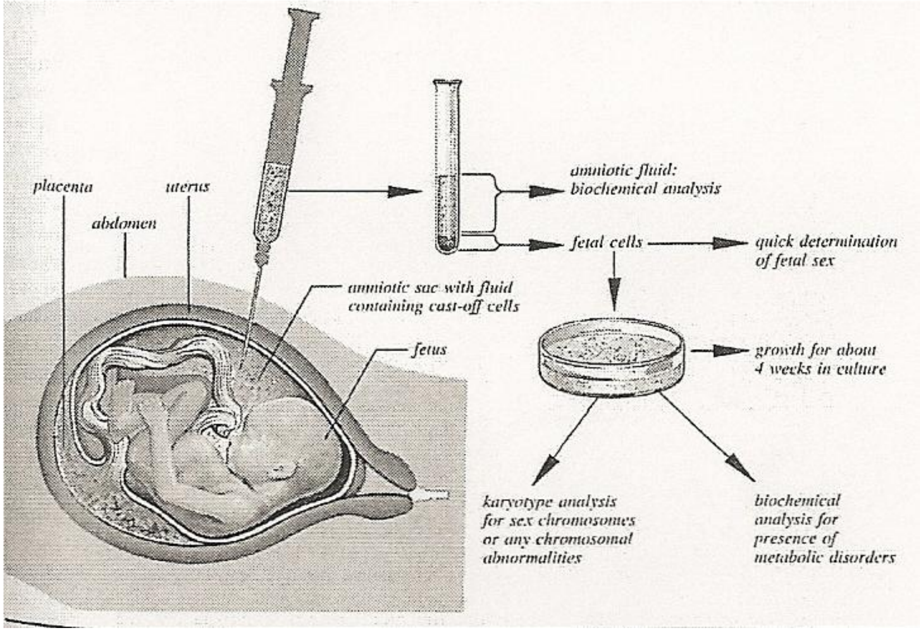


Figure 13. Entering the 1980's world of the fetus via amniocentesis. From *BSCS A Molecular Approach* (p. 315). By BSCS, 1985, Lexington, MA: Heath.

Abortion.

Two texts discussed abortion: the 1987 BSCS Green version and *Biology for Living* (Wallace & Simmons, 1987). In the BSCS text, students were told that nature aborted many fetuses before birth but that there was also voluntary termination. Voluntary termination was not always done just because a fetus had a major chromosomal or genetic abnormality, but that unmarried women and even married women, "may want to terminate a pregnancy because they are not able to support and properly raise a child" (p. 215). Ethical issues associated with abortion were addressed with the acknowledgement that some groups felt strongly that human fetuses should not be aborted under any circumstance. Other groups felt that individual women should be able to choose whether they wanted to terminate or continue a pregnancy. Added to the discussion was whether an unborn fetus had the same legal rights as someone *after* birth.

In *Biology for Living*, Wallace and Simmons discussed abortion in a chapter titled "Personal Biology." Unlike the BSCS Green version, this text discussed abortion only in the context of genetic diseases and prenatal accidents: "it is for fear of abnormal births that physicians often recommend abortions when the embryo has been exposed to a known damaging agent" (p. 48). The authors also discussed spontaneous abortions and interjected that "despite terminology that has become commonplace in recent years, there are few, if any pro-abortionists in this world. There are really only 'anti-abortionists' and 'anti-anti-abortionists'" (p. 49). The authors stated that abortion laws in the United States had been liberalized but they identified abortion as having only one purpose: to remove damaged embryos from their mothers. There was no acknowledgement of the fact that abortions might be performed on healthy fetuses for any number of reasons.

One thing that Wallace, who had served on the BSCS board for several years, and Simmons did with their text was to present students with a series of scenarios to clarify their thoughts on matters of abortion. The first scenario gave the students background on fetal physiology. The human embryo does not need a brain *in utero* since oxygen and nutrients are delivered by the mother's circulation system. If the embryo and fetus can be kept alive this way, should it be aborted? The second statement concerned the fertilized egg: the fertilized egg (diploid) is given moral value, whereas before fertilization, both eggs and sperm are considered worthless and discarded. Students were left to ponder this discrepancy. The last scenario addressed the fertilized egg as a person. Did the loss of a fetus, for any reason, warrant an official investigation to assess blame? Or what of embryo transplants where "stand by" embryos were destroyed? With these questions, the 1980s marked the time when the ever-adapting embryo began showing up in a lot of places: the laboratory, the pregnant mother, the ultrasound video camera, and now the courtroom.

Another examination of ethics and multiple births in *Biology of Living* was presented in a side-bar (see Appendix B). A series of headlines, doctors' comments, and parent reactions showed the interplay between assisted reproductive technologies and the ethics of transferring more than one fertilized egg to a women's body. The concern about implanting several embryos, all at once, into a mother was an issue even in the 1980s.

Although not all texts during this decade addressed concerns with embryological research and technology, enough of them did to make me take notice of how embryos were starting to be perceived. The most obvious change dealt with embryos and pregnancy. In the late 1940s and 1950s texts, pregnancy was shown to be rather foolproof, if the expectant mother avoided lifting heavy things, saw her doctor, and had a compassionate husband. Pregnancy in the 1980s was different. A developing embryo was now known not to be fully protected by the uterus and placenta and this led to a heightened sense of urgency that the embryo be monitored, checked, and tested before being allowed to grow up. Pregnant mothers no longer had the luxury of sitting all day in a chair with their feet up; in addition to avoiding anything that could harm the embryo, they now had to make appointments for genetic screening, amniocentesis and CVS to detect abnormalities, ultrasounds to detect for more abnormalities, blood work for hormonal tests, and numerous checkup visits with their obstetricians.

1990–1999.

Textbooks in this decade followed the same pattern as the 1980s: there were fewer textbooks and more new authors. With the exception of Kimball (1994), all texts had multiple authors, some with as many as six writers. The days of one author having control over all content had all but disappeared. Wayne A. Moyer (1982), past executive director of the National Association of Biology Teachers, stated that the content and emphasis of high school biology had changed through the years in response to diverse social forces. Evolution and Haeckel's embryos were once again attacked with renewed vigor from the creationist camp. This most likely explains why there was a drop in the appearance of Haeckel's embryo diagrams in the 1990s. What is more significant though is that several publishers, while using Haeckel's diagrams, decided to offend no one by giving human embryos in the diagrams the boot.

While Moyer wrote more from the perspective of teaching evolution in schools, the teaching of embryology in this decade also showed continued signs of societal influence. A large percentage of textbooks (79%) addressed some type of HETS issue—a first for several texts. In addition, the content in many texts had been updated. It was now hard to find a book that did not write about genes and their influence on embryonic development. It had taken about thirty years for textbooks to address gene expression, regulator genes, and cell-cell interactions with embryo development; a relatively long response time for developmental biology to finally arrive at the public high school classroom.

Genes on the scene.

The 1990 BSCS Blue version, the sixth edition of *A Molecular Approach* had a new chapter in it titled "The New Genetics." It was an attempt to address new research and new interest in genetic disorders. A pedigree chart showing the inheritance of hemophilia and a description of mutations and "good" genes allowed me to see how genetic engineering could be interpreted as a tool for a new eugenics program. Ethical questions dealing with genetic engineering, however, were not brought up in this textbook. There was much description given of genetic engineering and models of differentiation, including evidence for the genetic equivalence model (all cells contained the same genes) and the differential gene model (different cells contain different genes).

John Kimball's *Biology* (1994) returned to the classroom after a sixteen year absence. In a chapter titled "Development and Its Regulation," Kimball was the first author to mention homeobox genes, discovered in 1983 but not really accepted as a developmental mechanism by the scientific community until the 1990s. These genes are found in almost all organisms and are involved in the regulation of patterns of development. For years, textbooks had used Haeckel diagrams to show the similarities of early embryos of different vertebrate species. Now, as shown in Figure 14, the gene sequences of invertebrate and vertebrate species were similar in ways that had never been imagined. I found it discouraging that something so new and important to developmental biologists had taken so long to make its way to the public in the form of secondary biology textbooks.

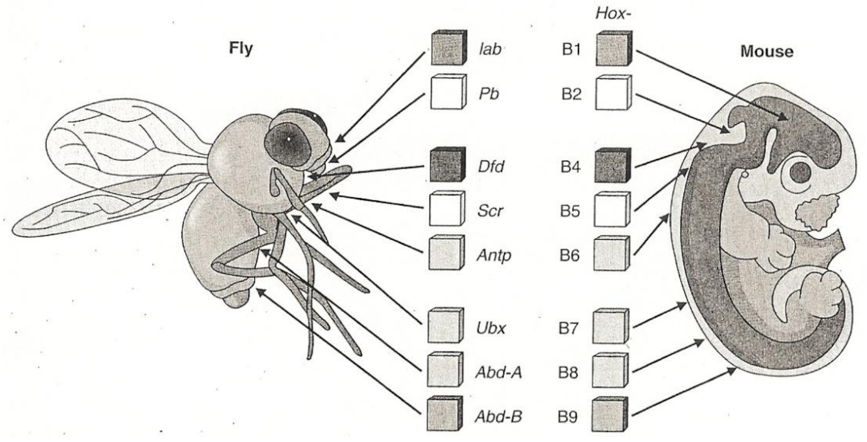


Figure 14. Organization of homeobox genes in *Drosophila* and the mouse. From *Biology* (p. 235). In J. Kimball, 1994, Dubuque, IA: Wm C. Brown.

1990s and HETS.

Attention given to technology and reproduction continued to increase during this decade; from 6 percent in the 1980s to 15 percent in the 1990s. While HETS paragraphs were only found in two textbooks in the decade prior, nearly all of the textbooks, eleven out of fourteen, discussed rapidly growing technologies in developmental biology. Even the 1991 edition of *Modern Biology* lived up to its title by presenting information about IVF. The victory was short-lived, as the 1999 edition of *Modern Biology* reverted back to its highly descriptive formula and had no HETS paragraphs in it. Table 4 shows the different technologies discussed in the 1990's texts.

While the successful 1978 IVF-assisted birth of Louise Brown in England, and the first successful American IVF baby, born in 1981 (Sullivan, 1981) had made headlines, no texts published in the 1980s discussed *in vitro* fertilization. By 1987, at least 5000 IVF babies had been born worldwide, 1000 of them in the U.S. (United States, 1987). As the American public became more comfortable with the thought of a new human being conceived in a glass dish, this allowed several authors in the 1990s to discuss IVF in their texts.

Table 4

1990s Textbooks and HETS Topics

Text	Genetic Counseling	Prenatal Diagnosis	Gene Therapy	Fetal Surgery	Birth Control	Cloning	IVF	Abortion
BSCS Blue 1990	X	X	X					X
Schraer 1990				X		X		
McLaren 1991	X	X		X				
Goodman 1991							X	
BSCS Green 1992		X						
Towle 1991							X	
Kimball 1994		X			X	X	X	X
BSCS Human 1997		X				X		
BSCS Green 1998		X			X			X
Leonard 1998		X			X			
Strauss 1998		X						

Prenatal diagnosis techniques such as amniocentesis, ultrasound, and chorionic villus sampling were the most common technologies discussed. More detail was given about what was done with the amniotic fluid and chorionic villi compared to the 1980s. For example, fetal cells were no longer simply "obtained and tested." They were now used to make karyotypes and evaluated for high levels of alphafetoprotein, an indicator of spina bifida disorder. The 1990 BSCS Blue version also suggested that the evaluation for functioning genes by way of testing for proteins might lead to a correction of the disorder through human gene therapy. With prenatal diagnosis technologies now become mainstreamed, the embryo and fetus became more "visible" to students while at the same time, distancing the fetus from the mother.

Some texts presented HETS material quite descriptively, with no mention of bioethical issues. For example, fetal surgery was discussed in two texts (McLaren, Rotundo, & Gurley-Dilger, 1991; Schraer & Stoltze, 1990) but the procedure is presented more from a "heroic medicine" standpoint than as a possible issue. Both texts declared that fetal surgery presented a significant advance in medical science, but only McLaren et al. wrote that that any treatment of the fetus could be risky for both the mother and the fetus. A photograph accompanying this text showed a fairly large fetus either being pulled out of a sliced-open uterus or being shoved back into it (see Figure 15). The bloody surgical gloves and hemostasis clamps are testament to the extent that surgeons and society would go to make an unhealthy fetus healthy again. The use of this popular image helped portray fetuses as viable objects that needed to be saved from "death," and imparted values on embryos and fetuses that were much different from the "neutral" embryo of decades past. In effect, what students were told was that "all embryos will live!" In reality though, the majority of embryos and fetuses that they saw in textbooks were quite dead.

Other HETS topics were presented both descriptively and in an issue-oriented format. For example, McLaren et al. presented a case study in their “Issues in Bioethics” section. Here, a fictitious married couple is expecting a baby. An ultrasound reveals a fetus with an underdeveloped brain and the parents are told that if the baby is not born stillborn, it will probably not live longer than one week. The couple decided to donate the organs of their baby when they find out that the child, if born alive, could be kept living with the aid of a respirator. Students are asked why someone would disagree with the couple’s decision to keep their baby alive long enough to donate the organs. Throughout the essay the authors avoided mentioning the option of abortion, certainly wanting to avoid further controversy with an already controversial subject.

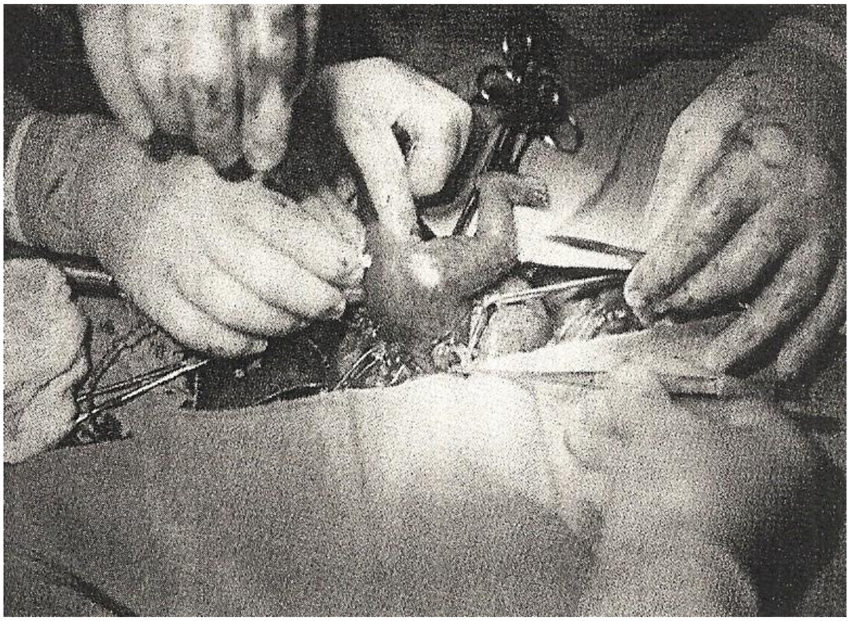


Figure 15. Fetal surgery. From *Biology* (p. 193). By J. E. McLaren, L. Rotundo, & L. Gurley-Dilger, 1991, Lexington, MA: Heath.

Other controversies brought up by Kimball (1994) included discussions about birth control techniques, cloning, and IVF. In the case of *in vitro* procedures, Kimball was the only author to note how expensive and relatively unsuccessful IVF had turned out to be.

He also raised the ethical concerns of egg storage. What if the prospective parents separated or one or both died? What would happen to the frozen embryos? Like his 1970s texts, Kimball again told students that advances in biological technology threatened to outstrip our ability to cope with the new and complex ethical and legal issues that they created (p. 408).

The BSCS Green version (1998) discussed the science of genetic screening and genetic engineering and raised questions about the social impact of screening for genetic diseases. Carried to the extreme, the authors stated, some people could be forbidden to marry, to have children, or to do certain kinds of work.

Legal issues and embryos were addressed in *Biology Today* (Goodman, Graham, Emmel, & Shechter, 1991) in a section titled "Issues in Biology." The authors presented an ethical question about IVF and the ownership of embryos. An actual case was briefly described where a couple asked that their embryos produced by IVF be transferred to a facility in another state. The clinic refused, claiming that the couple's ownership of their embryos ended once the embryos left the facility (the couple eventually won the court battle).

1990s and abortion.

Several texts mentioned abortion, including the 1990 BSCS Blue version. Unlike previous editions where the term "abortion" was avoided, the Blue Version presented abortion as an option given to parents by a genetic counselor. The 1998 BSCS Green version included abortion in its discussion about birth control. Whereas students using other texts were led to believe that abortion was only done as a last resort because the mother was carrying an unhealthy fetus, this text stated that "many abortions are undertaken because contraception failed" (p. 135) and that the issue of planned abortions was complex and emotionally charged.

Kimball's 1994 *Biology* also acknowledged that while abortion was not universally accepted, it was the most common birth control method in the world. Kimball then examined RU 486 (Mifepristone) and early pregnancy prevention. His description included how RU 486 blocks the action of progesterone, leading to a breakdown of the endometrium which is then expelled, along with any embryos in the uterus. At the time of publication, RU 486 had been declared "safe and effective" by the FDA but it was not approved for distribution in the U. S. until September, 2000. In some respects, the 1990s continued with the perception that it was a difficult time for all embryos.

The inclusion of court cases, birth control, and future embryo scenarios indicated several things: (a) these STS topics were encouraged by science educators; (b) the public still saw the interface between science and society as an acceptable target to help students understand science; and (c) as the twenty-first century approached, embryos had become part of an unsettled ethical, legal, and social debate. More than any other decade, high school biology students in the 1990s were seeing that biological advances had societal consequences. It was interesting that there was a shift in emphasis with HETS discussions in the 1990s when at the same time, a back-to-basics school movement, with an emphasis on more descriptive content, was taking place.

Decades Analysis Summary.

After looking at representative biology textbooks from many different time periods, it became obvious to me that textbooks have changed embryological content in many ways. In the early 1900s embryos occupied a very small segment of most textbooks and were not well integrated into other areas. During the 1940s through 1950s, the embryo showed signs of "plasticity" by remaining in chapters about frogs and birds, but also taking on more of a presence in human reproduction chapters. Starting in the 1960s, the embryo was still used for life cycles and human reproduction, but was now given the he added responsibility of being an important research organism, especially in trying to discover how genes and the environment were involved with differentiation.

All of these ways to view embryos continued into the 1970s, but during this decade embryos were put on an additional paths, including prenatal diagnostic testing, the legal right of women to have fetuses aborted, and picture-perfect portraits of embryos and fetuses displayed as Lennart Nilsson photographs in textbooks. The role of embryos diverted even more during the 1990s with textbook descriptions of genetic engineering possibilities to make unhealthy embryos and fetuses healthy again.

Section Three: Visual Representations

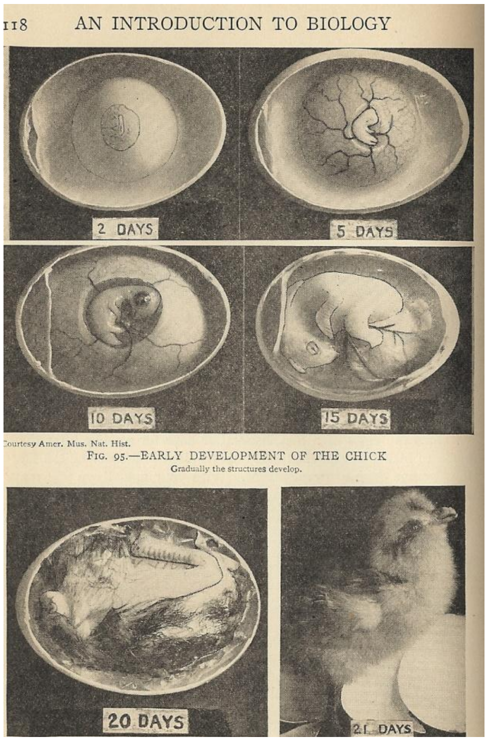
Whereas scientific journals often use copious amounts of equations, graphs, and tables to summarize data, high school textbooks predominantly use photographs or line drawings (Pozzer & Roth, 2003). Even when biology textbooks appeared in the early twentieth century, illustrations and photographs were present. For example, Hunter's 1911 *New Essentials of Biology* presented nearly one illustration per two pages of text. A study of high school biology texts by Roth, Bowser, and McGinn (1999) showed one illustration per page for texts published in the 1990s. In knowing that embryos and fetuses are often displayed within a given social context, I examined the books for pictoral representations of development. These included graphs, line drawings, and photographs, which I placed under the umbrella of visual representations. I treated Haeckel's embryo drawings separately and discuss them in the next section.

The visual representations could be broken down into three broad categories: descriptive, human, and research. There was a certain amount of overlap among the three categories and within each of them I was able to further divide illustrations into subcategories. The data obtained from categorizing the photographs and drawings was used to help interpret "why and when." That is, why were certain embryo photographs and pictures placed in certain chapters and when did they become acceptable for public viewing? For example, images that played an important role in the understanding of human development include Nilsson's 1965 color photos that appeared in *Life* magazine. To me it was important to follow the transition of Nilsson's work from magazines to textbooks and to discover which textbooks used his photos, if they were printed in color, how were they captioned, and if they persisted in subsequent text editions

Descriptive visual representations.

During the early twentieth century publishers had the freedom to appropriate and reprint images. Scientific illustrations, in particular, fell into the "nebulous artistic zone" reflected mainly by the Haeckel images seen with this study (Ladouceur, 2008). The earliest illustrations of embryos were mainly those of chicks or frogs, with no credit given to their illustrator. These diagrams were descriptive in nature, with the intent of showing students embryonic structures or life cycles. Some of the first photographs of embryos that I found were taken by Charles F. Herm, a "cinema" biologist who worked at the American Museum of Natural History (AMNH). Herm invented the motion picture camera in 1919 and soon became an advocate for instructional biology films. He criticized textbook dependence on drawings, declaring that no drawing could take the place of a real object ("Biological Picture," 1919). Shortly after 1919, Herm's motion pictures of chick development appeared in biology texts as a series of artistically rendered pictures (see Figure 16). In order to procure these pictures he had cut a small window in the shell and focused his camera on the developing chick. The camera was controlled by a clock that automatically photographed the growing embryo every few seconds. These represented some of the first photos ever taken of a live embryo as it progressed from conception to hatching (Herm, 1924).

Textbook publishers used Herm’s pictures in numerous biology texts ranging in publication date from 1926 through 1958. Some of the textbooks showed six pictures while others only used three of the pictures. The pictures were sometimes rendered by someone who outlined the chick embryo and drew over veins with a dark pen or pencil. Whether this was done by the AMNH or someone in the textbook publisher’s illustration department is not known. The use of Herm’s and later, Lennart Nilsson’s photographs, show more than a change in attitude toward embryos; they also represent changing technologies that allowed humans to peer into where embryos developed; a place where once it was not possible, either socially or technologically.



118 AN INTRODUCTION TO BIOLOGY

Courtesy Amer. Mus. Nat. Hist.

FIG. 95.—EARLY DEVELOPMENT OF THE CHICK

Gradually the structures develop.

Figure 16. Early 1900s time-lapse photos of chick development. From *An Introduction to Biology* (p. 118). By A. C. Kinsey, 1926, Chicago: Lippincott.

The AMNH chick pictures eventually gave way to more detailed and early photographs of chick development. These were made and sold by the General Biological Supply House (later to become Turtox) and showed the chick at 23 hours, 30 hours, 72 hours, and 96 hours. Unlike Herm's pictures, these embryos were not followed from fertilization through hatching but represented different chick embryos at different times of development before they were sacrificed. Because chick embryos were ever-present in the textbooks that I reviewed, this picture, shown in Figure 17, was seen many times by many different biology students.

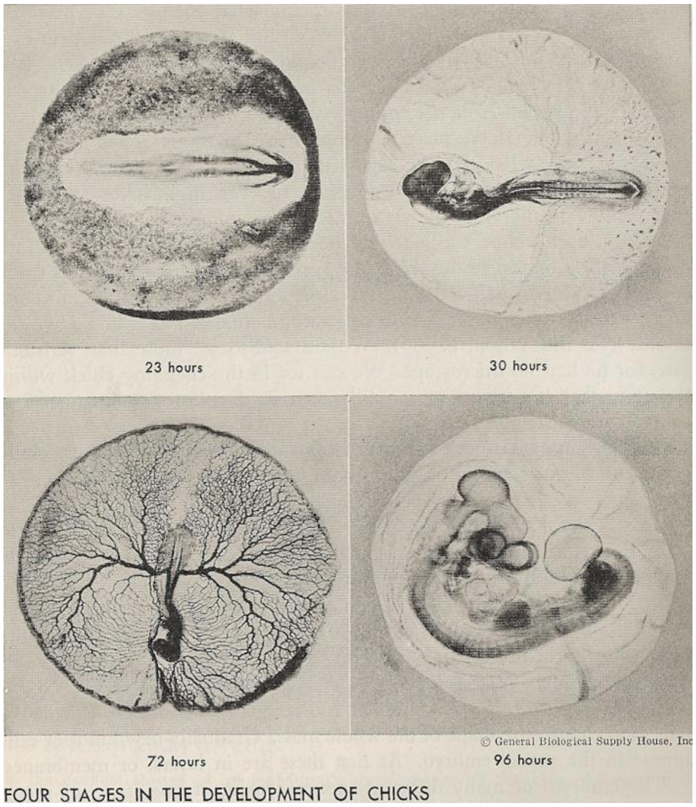
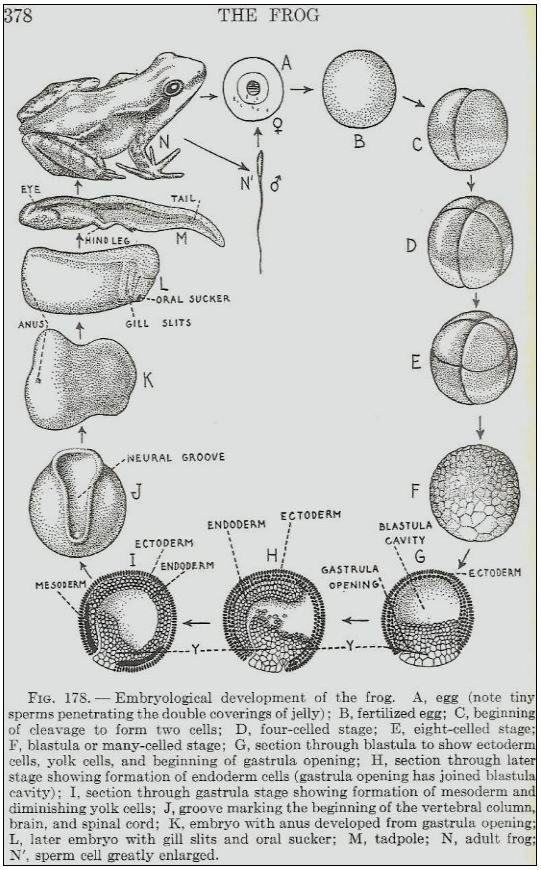


Figure 17. Commonly used series of photos depicting chick development. From *Biology and Man* (p. 350). By B. C. Gruenberg & N. E. Bingham, 1944, New York: Ginn.

Other early illustrations used to describe how embryos developed included those of fish and frogs. Because frog embryology had been so well studied and documented prior to the early twentieth century, pictures of frog development were often the same as those used in college texts. An example of this is shown in Figure 18, a life cycle of the frog in Moon and Mann's 1938 biology textbook. These examples of chick and frog drawings and photographs are typical of a descriptive representation of embryos: detailed and without controversy. Descriptive drawings remained the primary way that embryos were visually represented to students in all textbooks that I reviewed.



378 THE FROG

Fig. 178. — Embryological development of the frog. A, egg (note tiny sperms penetrating the double coverings of jelly); B, fertilized egg; C, beginning of cleavage to form two cells; D, four-celled stage; E, eight-celled stage; F, blastula or many-celled stage; G, section through blastula to show ectoderm cells, yolk cells, and beginning of gastrula opening; H, section through later stage showing formation of endoderm cells (gastrula opening has joined blastula cavity); I, section through gastrula stage showing formation of mesoderm and diminishing yolk cells; J, groove marking the beginning of the vertebral column, brain, and spinal cord; K, embryo with anus developed from gastrula opening; L, later embryo with gill slits and oral sucker; M, tadpole; N, adult frog; N′, sperm cell greatly enlarged.

Figure 18. Typical frog embryology illustration. From *Biology, A Revision of Biology for Beginners* (p. 378). By T. J. Moon & P. B. Mann, 1938, New York: Holt.

Research embryos.

The 1960s is a decade known for many things in science education. One of these is the emergence of the nature of science in biology to help explain how scientific research was done. The majority of visual representations that I found connected with the investigative nature of embryology were drawings, and to a lesser extent, photographs of Spemann’s transplantation studies. This was followed by drawings that helped explain Roux’s and Driesch’s experiments. Spemann’s experiments centered on causes of differentiation and what would happen if bits of tissue were moved to different areas on embryos. In some cases he could get new eyes or ears to grow in odd places. When this happened, Spemann reasoned, there was a type of induction occurring. What the “inducer” was is a still-researched question. Because Spemann was so often encountered in textbooks, it was no surprise that his diagrams were also frequently displayed. But rather than one drawing, there were often many diagrams related to Spemann. There may be several reasons for this. The first is that Spemann and his colleagues made many line drawings that showed their techniques and their results. Second, the drawings have a sort of “freakish” appeal to them, and are interesting, especially to teenagers. This was especially true with Spemann’s transplantation studies shown in Figure 19. Third, the diagrams are simple, clean, and necessary to help explain the complexities of Spemann’s work

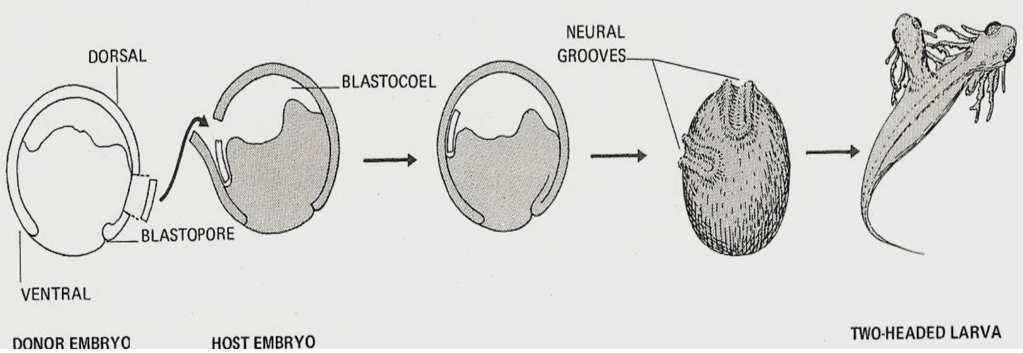


Figure 19. Spemann’s transplantation studies. From *Biology* (p. 393). By J. W. Kimball, 1978, Reading, MA: Addison-Wesley.

Other transplantation experiments were represented by visual representations, including two-headed frogs and salamanders (see Figure 20). The use of actual photographs of research embryos, however, was not common in any of the textbooks. Line drawings are easier to understand from a pedagogical standpoint, but they do detract from the realism of the experiment and the resulting embryos—so much so, that I contend that line drawings detract somewhat from the nature of research and investigation, making research look as if it proceeds with no messiness.

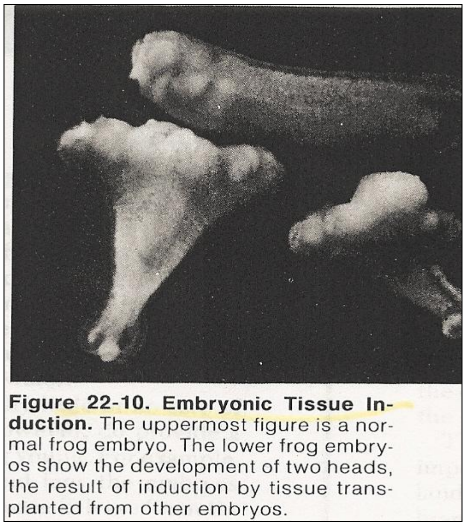


Figure 22-10. Embryonic Tissue Induction. The uppermost figure is a normal frog embryo. The lower frog embryos show the development of two heads, the result of induction by tissue transplanted from other embryos.

Figure 20. Frog transplantation photo. From *Biology the Study of Life* (p. 371). By W. D. Schraer & H. J. Stoltze, 1990, Needham, MA: Allyn & Bacon.

The cloning of embryos was presented in several texts with drawing and a few pictures of frogs, proving that frog embryos had never left the world of embryological research (see Figure 21). Textbooks in the 1990s were surprisingly devoid of any new model organisms, including the zebrafish. Zebrafish had become a popular vertebrate model in the 1990s because of several factors. Its embryology was well understood (indeed, Kimball's 1978 biology text discussed the cleavage of zebrafish embryos) and mass screening of mutants was possible.

Figure 7.3 Diagram of an experiment showing that the nucleus of a differentiated cell contains the same set of genes as the zygote.

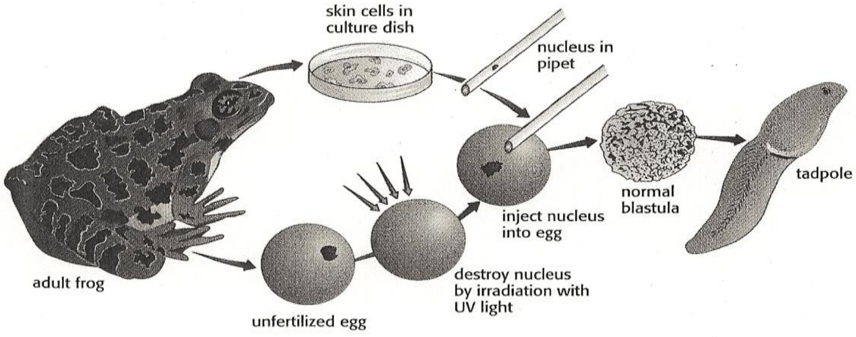


Figure 21. Frogs as cloning research organisms. From *BSCS An Ecological Approach* (p. 145). By BSCS, 1998, Dubuque, IA: Kendall/Hunt.

Within many laboratories, zebrafish mutations had helped to bring genetics and embryology together, showing how genes can affect tissue development (Brown, 1997). However, apart from Kimball's 1987 and 1994 texts, there is no further mention of zebrafish embryos. Textbooks published in the later part of the twentieth century textbooks stuck to what embryologist Wade Roush (1996) called the "fromosken" or the frog-mouse-fish-chicken combo of developmental biology. From my observations, embryos represented in textbooks remained entrenched in the transplantation and neural tube development mode of research, with no mammalian embryos used as research models. The presence of human embryo pictures fell into the realm of "descriptive use" or to show how prenatal diagnostic testing was done, and never for directly stated research.

The evolving human embryo.

Few textbooks before the 1940s showed human embryos because human reproduction was not considered a proper thing to discuss. In the 1950s, as biology texts became a conduit into the world of the pregnant woman, there was a demand for human fetal pictures. The public apparently agreed with educators that teaching high school students about pregnancy and child-bearing was important, as many textbooks published by the late 1950s included pictures of human fertilization, development, and birth. This continued through the 1960s. During the 1970s and 1980s, the human embryo and fetus made up for its years of being shunned by textbook publishers. They were now displayed in color and in a large format style, sometimes taking up a whole page, a layout that had never been seen before in biology texts.

Besides this type of display, embryos were also shown as the subjects of new prenatal diagnosis technologies such as ultrasound and amniocentesis (Morgan 2009). These representations were part of the Visible Human Embryo Research Period when embryo pictures became commonplace, both in magazines and ultrasound photographs. This trend continued into the 1990s, in addition to pictures of what could go wrong for human fetuses and babies—fetal surgery and fetal alcohol syndrome baby pictures were now put on display. These types of illustrations were part of the Constructed Embryo Research Period, where diseases were diagnosed and treated, and in the case of fetal alcohol syndrome, prevented, all leading, where successful to the birth of healthy babies.

***Drawings of human embryos*.**

The first illustration of a human embryo was seen in Woodruff's *Foundations of Biology* (1922). Here a diagrammatic section of the human uterus was shown with a developing embryo (see Figure 22). This diagram served as a template for similar drawings in future textbooks, and was often placed in a discussion about the human placenta

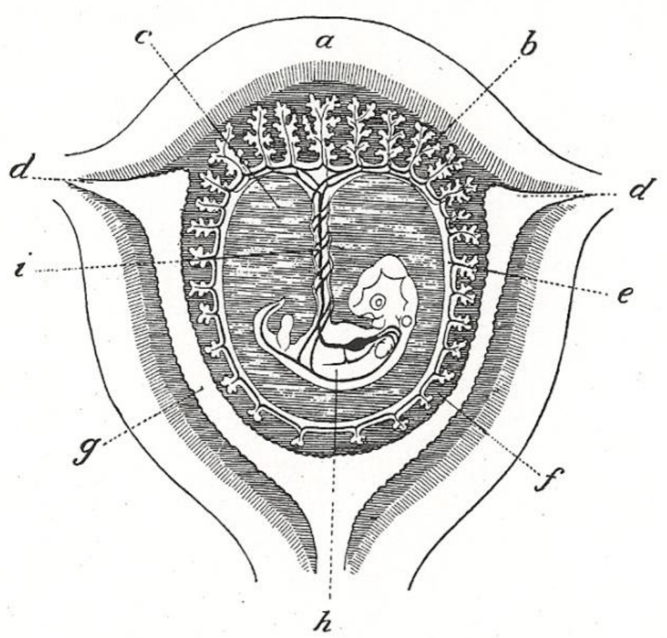


Figure 22. First human embryo diagram in a high school textbook. From *Foundations of Biology* (p. 205). By L. L. Woodruff, 1922, New York: Macmillan.

Sometimes the drawing was slightly altered and the embryo was identified as a "mammal" rather than a human. Such a case is shown in Figure 23. Because human embryos were still considered a topic that was not prudent to discuss in a 1920s high school biology classroom, authors avoided controversy by simply changing the word "human" to "mammal." This illustration also shows the fine details that authors felt were necessary for students to know.

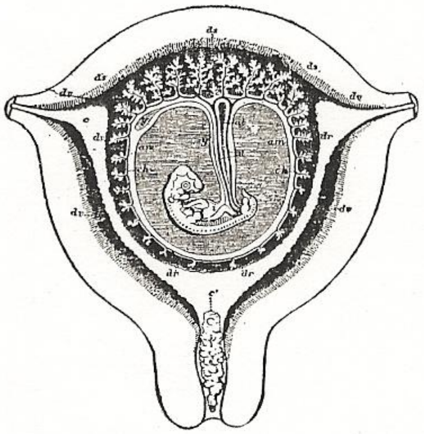


FIG. 118. Diagram of a mammalian uterus, showing attachment of an embryo to the lining (black in the figure). The umbilical cord, from the ventral surface of the embryo's abdomen, extends to the tree-like processes imbedded in the lining of the uterus. The black lines in the umbilical cord indicate arteries and veins connected with the embryo's heart. The openings of the uterus shown at upper right and left are the Fallopian tubes leading to the ovaries, while the lower opening is the mouth of the uterus through which the mature embryo is finally expelled by muscular contraction. (*From Marshall.*)

Figure 23. Avoiding controversy by labeling a human embryo as a mammal. From *Introduction to Biology* (p. 406). By M. A. Bigelow & A. N. Bigelow, 1922, New York: Macmillan.

Pictures of this sort are representative of the Biological Embryo Research Period. During this time (1827 through 1950s) much research was done with model organisms to establish what normal development and life cycles looked like. Manipulation of embryos was also done, but texts in the early 1900s did not seem quite ready to discuss the nature of science with students.

Over time human embryo illustrations became simpler in design and often lost their overly-laden description box. An interesting illustration of this is in a 1969 text by Kraus and Perkins. The illustration of a human-looking embryo was placed in a chapter about sexual reproduction of animals but interestingly, the caption does not indicate that it is a human embryo (see Figure 24).

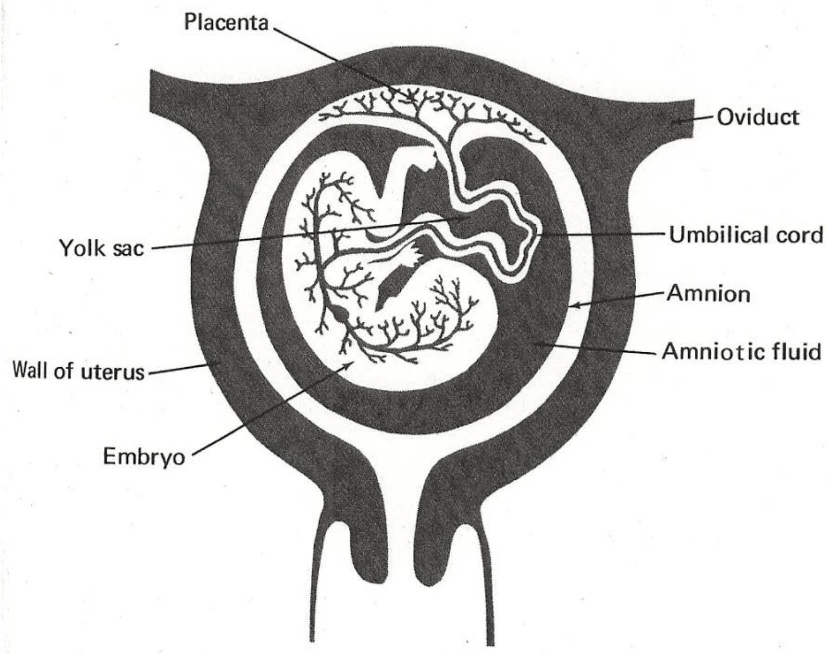


Fig. 18–13. Embryo in uterus, showing embryonic membranes.

Figure 24. The human embryo enters the 1970s. From *Modern Biology* (p. 301). By D. Kraus & O. E. Perkins, 1969, Bronxville, NY: Cambridge Book.

Photographs of human embryos.

One of the first instances where an actual photograph of a human embryo was used was in Smith's *Exploring Biology*, published in 1954. A 60 hour-old human embryo was shown, one of the youngest seen at the time, and credited to Arthur T. Hertig and John Rock of the Carnegie Institution of Washington (see Figure 25). While this was the first human embryo picture, it was a “safe” picture in that it looked no different from any other vertebrate embryo at the two-cell stage. This picture was used as a showpiece to open up Smith’s chapter on “Growth of Animal Embryos.” Educational researchers Pozzer and Roth (2003) call such textbook pictures with no captions “decorative” photographs. These types of pictures became prevalent in the 1970s with the use of Lennart Nilsson’s pictures of human embryos and fetuses. It is interesting that the appearance of Smith’s decorative embryo photos correlates with the occurrence of 1950s textbook statements about how “miraculous” human birth was.

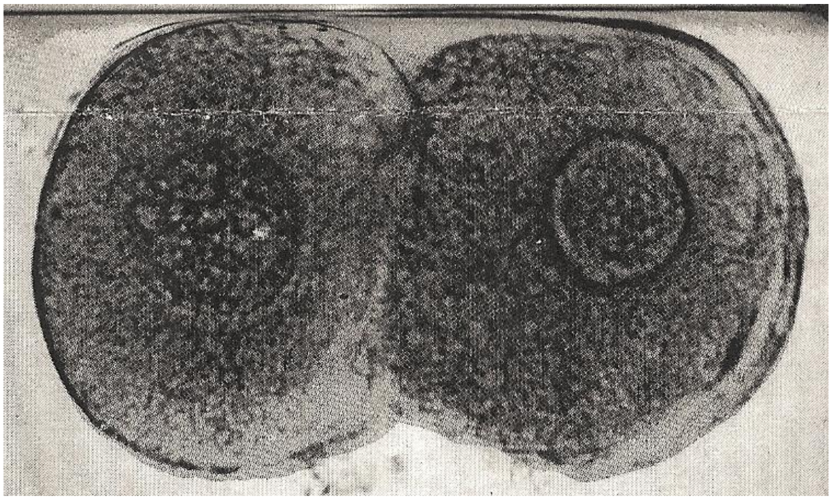


Figure 25. One of the first human embryo photographs in a textbook. From *Exploring Biology* (p. 271). By E. T. Smith, 1954, New York: Harcourt, Brace.

In Smith’s 1959 edition of *Exploring Biology,* the same 60 hour-old embryo picture was moved to a new chapter, “Reproduction in Higher Organisms.” Here, the picture became part of a growing trend to describe the timetable of human development in the late 1950s and 1960s. Other than Smith’s *Exploring Biology* texts, there were very few photographs of human embryos found in textbooks during the 1950s. This all changed in the following decade. One of the first photographs of a recognizable human embryo seen by high school biology students was published in BSCS’s Blue and Green editions in

1963 (see Figure 26). A line drawing was presented on the left and a photo of a human embryo attached to the uterus was shown on the right. The photo was credited to the Gesell Institute of Child Development (GICD), a non-profit institute established in 1950 for child development research.

Soon after the appearance of the GICD picture, embryo pictures taken by the technicians at the Carnegie Institute's Embryology Department became commonplace in biology textbooks and shaped students' views of development. The Carnegie photos, often taken by taken by Chester F. Reather, consisted of a series of three embryos at different developmental stages (see Figure 27).

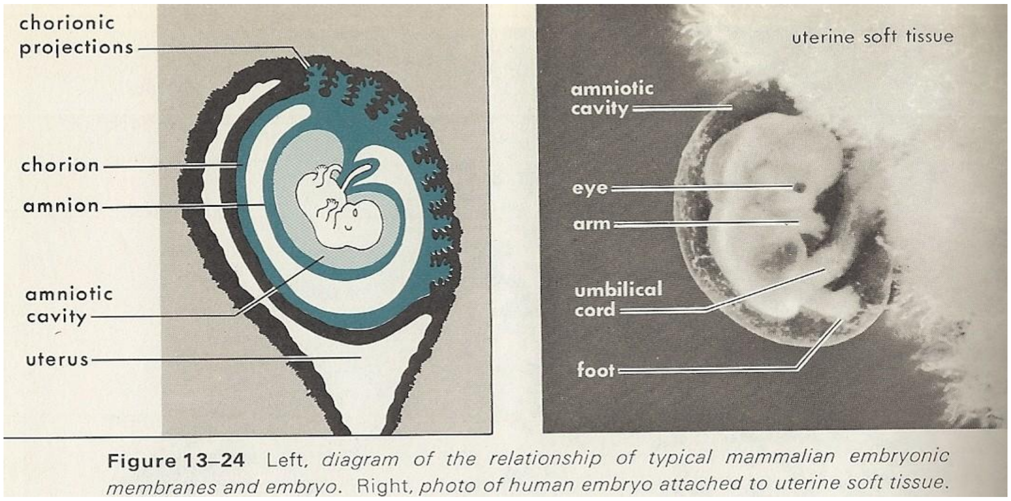


Figure 26. Human embryo photo from 1963. From *BSCS Molecules to Man* (p. 281). By BSCS, 1963, Boston: Houghton Mifflin.

The use of Carnegie embryo photographs assisted in moving the human embryo from the confines of the microscope and microtome to the publicness of schools, homes and libraries. This expanding presence of the embryo helped usher in the Visible Human Research Period beginning in 1978. According to Hopwood (1999, 2005), the use of a series of embryos was not done by accident. Hopwood argues that Carnegie embryologists "produced the concept of human prenatal development as a series of

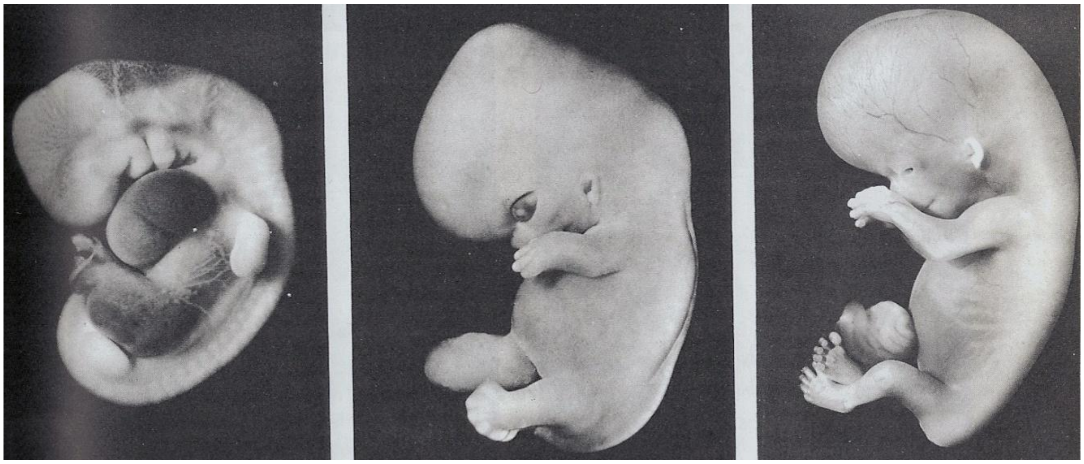
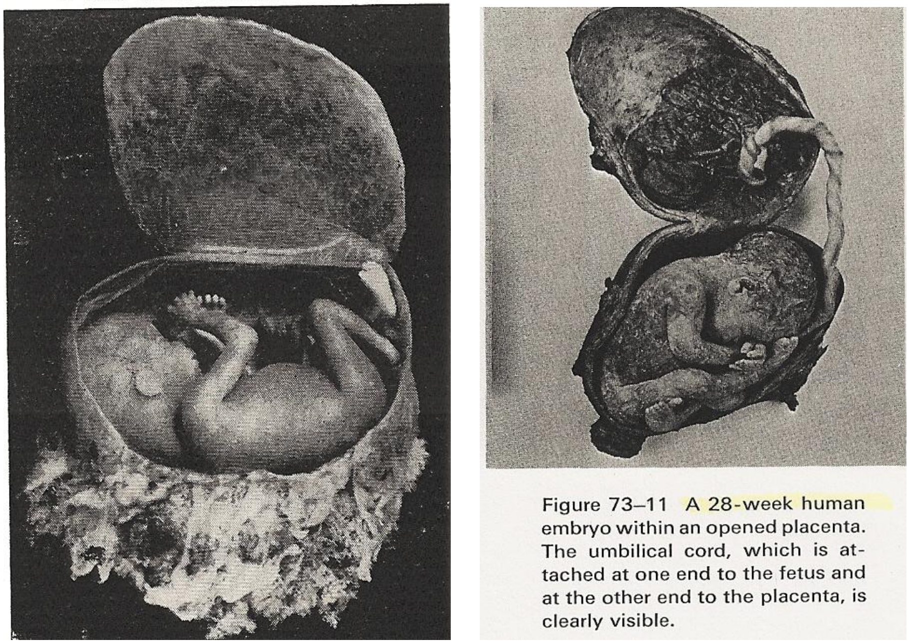


Figure 27. Four-, six-, and eight week-old Carnegie embryos. From *BSCS An Inquiry into Life* (p. 485). By BSCS, 1968, New York: Harcourt, Brace.

chronological steps. This staging of embryos was important because it provided a linear narrative that allowed students to see early embryos taking form and imagining their progression to birth. Arranging the Carnegie embryos may have been new for human embryos, but such staging had been done by Herm with his chick pictures and frogs and others well before the 1960s. By the 1960s, however, students now recognized that all embryos followed some type of linear progression.

One of the ironies of using human embryo photographs in biology textbooks is that while the human embryos and fetuses often look very much alive, they are almost always, quite dead. Because no mention was made of this fact, students probably thought that the pictures that they were seeing were taken of living embryos and fetuses. But one picture that appeared in Smith’s 1966 *Exploring Biology* simply could not be interpreted as “living.” Here, the sixteen-week-old fetus was photographed with the uterus cut and lifted up to reveal a clean but non-living fetus. Any amniotic fluid and blood had been carefully wiped away and disposed of. In effect, the fetus looked laid out in a coffin. This photograph was credited to R. Grill of the Carnegie Institution of Washington (CIW), and it never appeared in any of Smith's later versions, or in any other of the textbooks examined for this study. Another gruesome "fetal coffin" picture was credited to CIW and found in Nason and Goldstein's (1969) *Biology: Introduction to Life* text, shown in Figure 28. It too was a "once only" and was not seen again in any of the textbooks that I reviewed. Such "scientific" photographs, placed in the context of intensifying abortion debates, were probably removed from planned newer editions by publishers as quickly as possible.



R. Grill, Carnegie Institution of Washington

Figure 73–11 A 28-week human embryo within an opened placenta. The umbilical cord, which is attached at one end to the fetus and at the other end to the placenta, is clearly visible.

Figure 28. Examples of dead fetuses. From *Exploring Biology* (p. 501). By E. T. Smith & T. H. Lawrence, 1966, Chicago, Harcourt, (left) and *Biology: Introduction to Life* (p. 537). By A. Nason & P. Goldstein, 1969, Menlo Park, CA: Addison-Wesley (right).

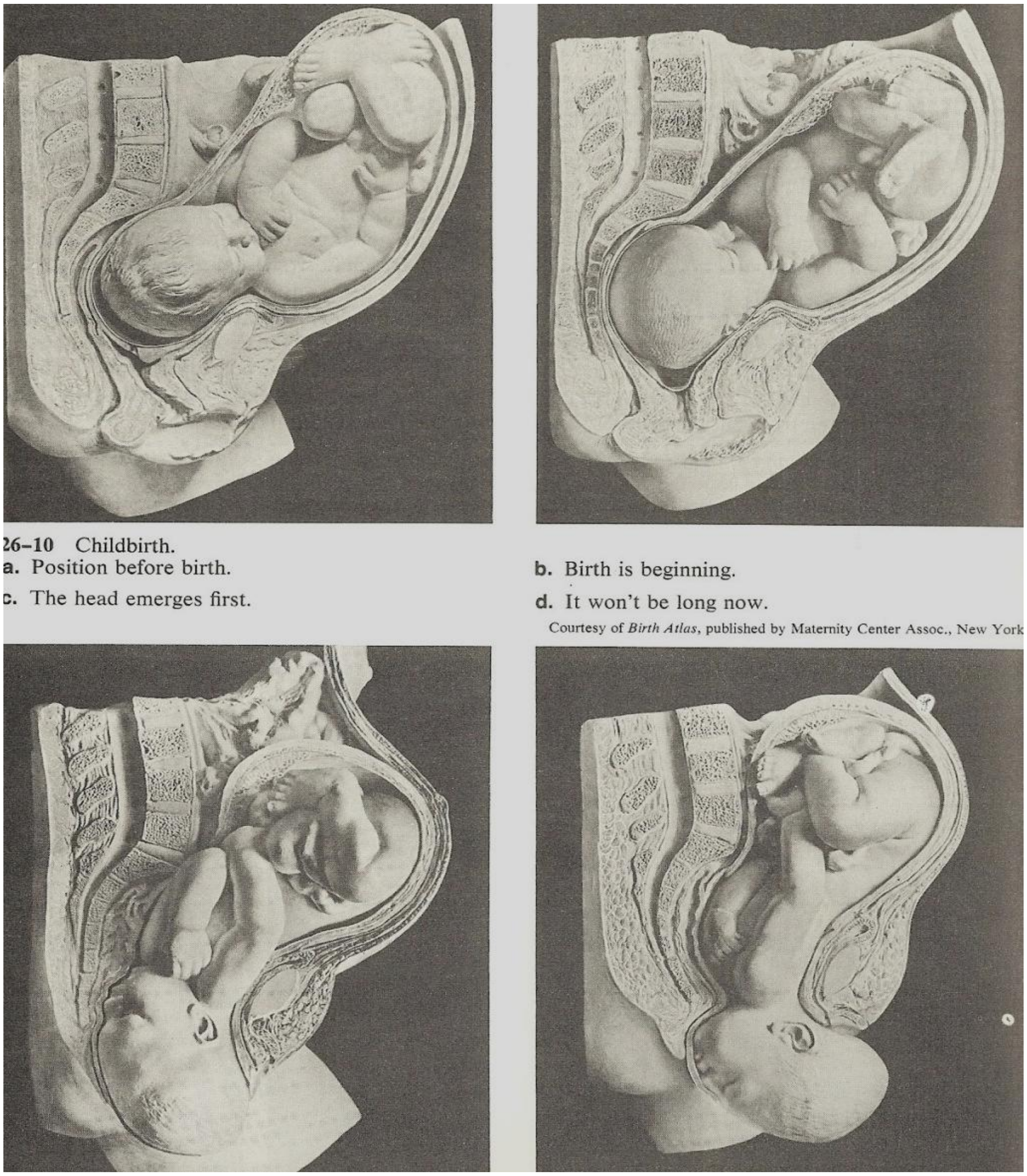
Birth of the fetus.

The 1939 World's Fair held in New York City unveiled many things seen only for the first time by its many fairgoers. One of the exhibits at the fair featured several life size sculptures of the human birthing process. Sculptor Abram Belskie and physician Robert Latou Dickinson had been commissioned by the Maternity Center Association (MCA) to produce life-size models showing how a child was born, especially as it slid through a woman's birth canal. The mother was not completely sculpted, but her child and reproductive anatomy were. These sculptures were later photographed, resulting in nineteen pictures that were included in the1940 publication of *The Birth Atlas* (Dickinson & Belskie, 1940). Published by the MCA, the atlas was an oversized flip-chart book that helped teach prospective mothers about the process of childbirth. Several of these photographs, as shown in Figure 29, became standard in high school texts.

Even though these pictures had been available since 1940, and the 1950s were a time of increased textbook attention to human pregnancy, the pictures were probably considered too revealing and "real" for 1950 textbook publishers to use. From my review of textbooks published during this time, it was more acceptable to show a photograph of a newborn baby in an incubator. It wasn't until 1963 that the first *Birth Atlas* pictures were seen in textbooks (*BSCS Blue Version*, 1963). Most of these photographs appeared in BSCS and *Modern Biology* textbooks, with their last use seen in the 1990 edition of *BSCS Blue*.

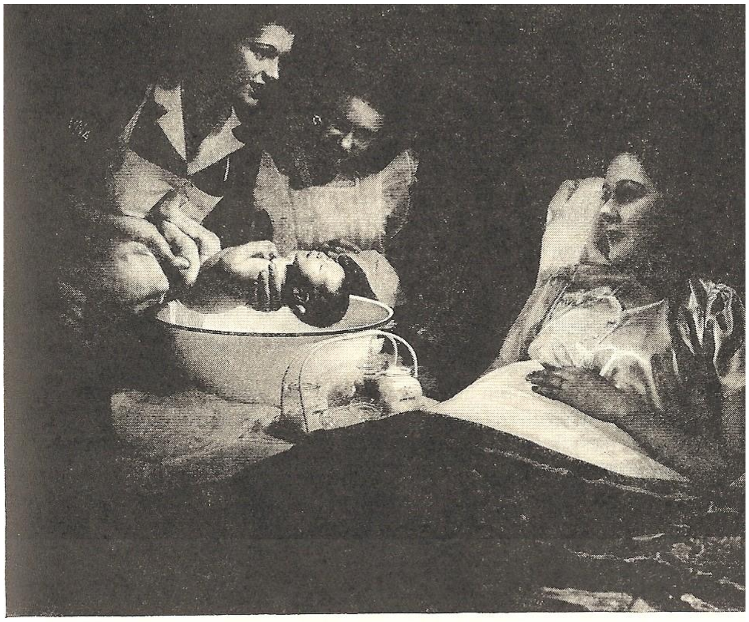
The *Birth Atlas* photos concentrated on a rather "sanitary" birth of a child. Granted, the pictures do show the mother's lower vertebral column and uterus, but the attention is on the fetus, leading to an erroneous assumption that the fetus and mother are independent from one another (Petchesky, 1987). The absence of a "background" in these photographs is a good example of how textbooks segregate human development and birth from the real world (Martin, 2001).

Examples of this segregation were also seen in the 1946 and 1958 editions of *Biology for You* (Vance & Miller) with a quasi-religious photo of a newborn most probably delivered by a midwife (the VNA on her jacket stands for the Visiting Nurse Association). In the 1946 photo, the mother, with makeup still in place, gazes admiringly at her newborn baby. In the 1958 photo, the mother was literally, no longer in the picture (see Figures 30 and 31).



26–10 Childbirth.
a. Position before birth.
b. Birth is beginning.
c. The head emerges first.
d. It won't be long now.
Courtesy of *Birth Atlas*, published by Maternity Center Assoc., New York

Figure 29. Birth Atlas models. From *BSCS Yellow Version* (p. 486). By BSCS, 1968, New York: Harcourt, Brace.



Scott Paper Co.

Care for the young reaches its highest development among the mammals, especially in the complex society of man where both the mother and her child need care for a while after the baby is born.

Figure 30. Childbirth in 1946. Here, an all-female cast proudly looks upon the birth of a new baby. From *Biology for You* (p. 515). By B. B. Vance & D. F. Miller, 1946, Chicago: Lippincott.

Scott Paper Co.

Figure 31. Childbirth in 1958. The mother has been marginalized, but the angelic glow surrounding the baby still exists. From *Biology for You* (p. 466). By B. B. Vance & D. F. Miller, 1958, Chicago: Lippincott.

An actual *photograph* of childbirth wasn't seen until 1973 (see Figure 32). This photograph, undoubtedly staged, showed the backside of a newborn with no umbilical cord or remnants from the mother's amniotic sac or placenta. The rather clean infant was held up by an arm in a lab coat, symbolizing the mighty strength of the physician. There were several messages that this photo gave to students. First, babies are important—much more important than the mother who doesn't even appear in the picture. Second, the male-dominated field of obstetrics is in charge of delivering healthy babies. Third, delivering a baby is pretty simple—much like pulling a rabbit out of a hat.

Figure 32. 1970s childbirth avoids the messiness that comes with deliveries. From *Biology: Living Systems* (p. 273). By R. F. Oram, 1973, Columbus, OH: Merrill.

The human space embryo.

Some pictures of human embryos and fetuses have become deeply embedded in Western culture. During the 1960s and 1970s, the women's rights movement and the movement to legalize abortion in the United States placed greater attention on embryos and fetuses. Lennart Nilsson's photographs of embryos and fetuses that appeared in print brought embryos into living rooms and doctor's waiting rooms and, according to historian Barbara Duden (1993), became the turning point for the emergence of the public fetus. Unlike the Carnegie embryo pictures in which no claim was ever made that the specimens were alive when photographed, Nilsson's fetuses took on the appearance of being alive when their pictures were snapped, but this was not the case for most of them (Matthews & Wexler, 2000). As the abortion debates continued, Nilsson's pictures seemed to touch a chord with everyone, but perhaps more with anti-abortion advocates.

Nilsson used macro-lenses and super wide-angled endoscopic lenses made specifically for his work by Karl Storz in Germany and Jungners Optiska in Sweden (Nilsson, 2006, p. 285). He also used a flexible endoscope to photograph living fetuses, some of which appeared in the April 30, 1965 *Life* publication. This issue sold 8 million copies in only a few days. Nilsson's 1966 book, *A Child is Born*, followed shortly after the *Life* magazine article and became a classic illustrated account of human conception and birth, selling tens of millions of copies and published in several languages (Morgan, 2009).

Nilsson's work represents some of the most dramatic photographs that I saw in biology textbooks. Beginning in 1969 with the first Nilsson photo published in *Modern Biology*, the Nilsson pictures show solitary embryos and fetuses in a heads-up position, wiped clean of any blood or tissue, and set against a black backdrop. Manipulation of photographs in this way enhanced the ethereal beauty of the fetus and led to the term "space embryo" or "space fetus" (Petchesky, 1987). These types of photo displays were particularly popular in the late 1960s as they coincided with the space race and the already published photos of Gemini astronauts floating in space during their space walks.

The photograph that *Life* magazine chose for its cover showed a floating and primary fetus with its mother absent (see Figure 33). I found examples of this cover photograph in the 1971 and 1977 editions of *Biology* by Weinberg, *Modern Biology* (Towle, 1991;

Standafer & Wahlgren, 1999), BSCS Green version (1998); and Smallwood and Green's *Biology* (1977). In all of these texts, the photo was printed in color and took up one whole page. Morgan (2009) argues that when fetal pictures are oversized, they magnify and exaggerate the amount of space that embryos or fetuses take up, especially if no scale is given. She also claims that Nilsson's photographs are one example of how fetal imagery proliferated to the point that solitary embryos came to function as icons of life, beginning in the 1960s.

Figure 33. Fetus-as-spaceman. Lennart Nilsson's 1965 *Life* magazine cover photo that also appeared in several biology textbooks. From *Biology. An Inquiry into the Nature o*f *Life* (p. 365). By S. L. Weinberg, 1971, Boston: Allyn & Bacon.

There were other Nilsson photographs that appeared in biology textbooks. In all, Nilsson's photographs were found in books from 1969 through 1999. The photographs have had great staying power, especially in chapters on reproduction and development. Nilsson's work was soon followed by other books intended for soon-to-be mothers. For example, *A Child is Born* (Nilsson, 1966) and *From Conception to Birth* (1971) by embryologists Roberts Rugh and Landrum B. Shettles. These were popular books with large and colorful photographs and drawings of embryos and fetuses, some of which, found their way into textbooks. But while Nilsson's photos gave no forewarning to the viewer that his pictures were of dead fetuses, the use of Rugh's photos showed no such sleight of hand. Several texts, including the BSCS Green and Blue versions, published Rugh's photos embryos and fetuses displayed in Petri dishes (see Figure 34), making it apparent that the fetus had been surgically removed from the mother.

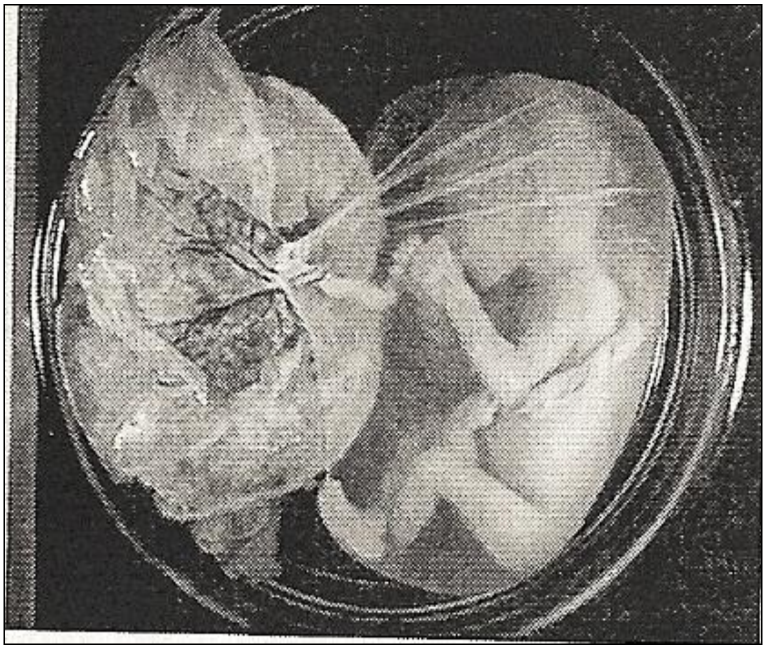


Figure 34. Not all pictures of human fetuses were "space fetuses." This picture has a definite scientific tone to it, rather than the miraculousness associated with Nilsson's photographs. From *BSCS An Inquiry into Life* (p. 208). By BSCS, 1987, Dubuque, IA: Kendall/Hunt.

These types of pictures where fetuses are shown in dishes or placed next to a ruler take on a different tone from the decorative and more natural looking photos of Nilsson. When fetuses and embryos are placed alongside scientific instruments and photographed, the images produced harkens back to the embryo-collecting days of the CIW Embryology Department, when such things were collected for the "good of science" (Morgan, 2009).

The embryo shown in Figure 35, looking remarkably clean and wax-like, appears to be an object of science, rather than a cousin to one of Nilsson's embryos, often admired to the point of worship. With Nilsson's specimens, the embryo was seen as an object of culture rather than as an embryo put on scientific display. Scientifically displayed human embryos and fetuses, although not all that common to begin with, were completely absent from textbooks published in the 1990s, a decade when there was a sharp increase in the use of space embryo photographs.

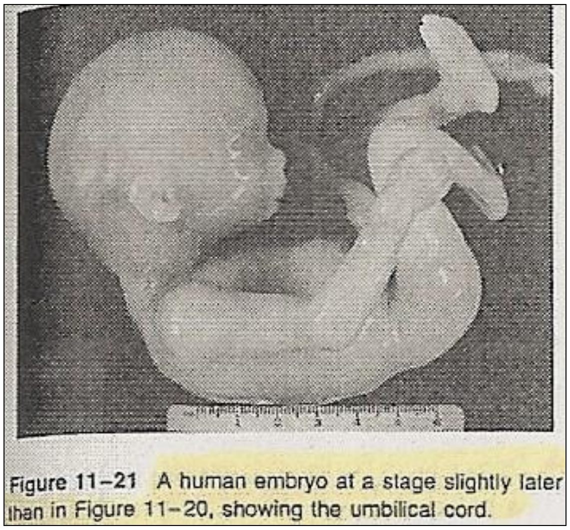


Figure 11–21 A human embryo at a stage slightly later than in Figure 11–20, showing the umbilical cord.

Figure 35. An embryo photographed for the "good of science." From *BSCS A Molecular Approach* (p. 239). By BSCS, 1980, Lexington, MA: Heath.

Obstetrical images.

Ultrasound was introduced in the early 1960s, a period in which the baby boom was ending and a drop in fertility was occurring. The focus of obstetricians was now centered on the use of ultrasound to hone in on the quality of embryos rather than their quantity. Or, as feminist researcher Petchesky argues, ultrasound was promoted to make more money for obstetricians and to control pregnant women. Petchesky also argues that physicians started using ultrasound before knowing precisely what they were looking at. A 1984 report by the NIH and FDA found no clear benefit of ultrasound other than determining gestational age.

Ultrasound procedures soon became part of the routine prenatal care package and ultrasound pictures were placed in biology textbooks during the late 1980s. They were also accompanied by pictures of fetal surgery, chorionic villi sampling, *in vitro* fertilization, and amniocentesis. These pictures of new reproductive technologies helped portray to students the enlarged clinicians' control over reproductive processes and showed treatments that seemed to include the doctor and fetus, only. Much like Nilsson's photographs, the fetus in these images was seen as autonomous, while the mother remained invisible and depersonalized (See Figure 36). These pictures undoubtedly contributed to the growth of feto-centrism in the 1980s and 1990s (Rothman, 1986).

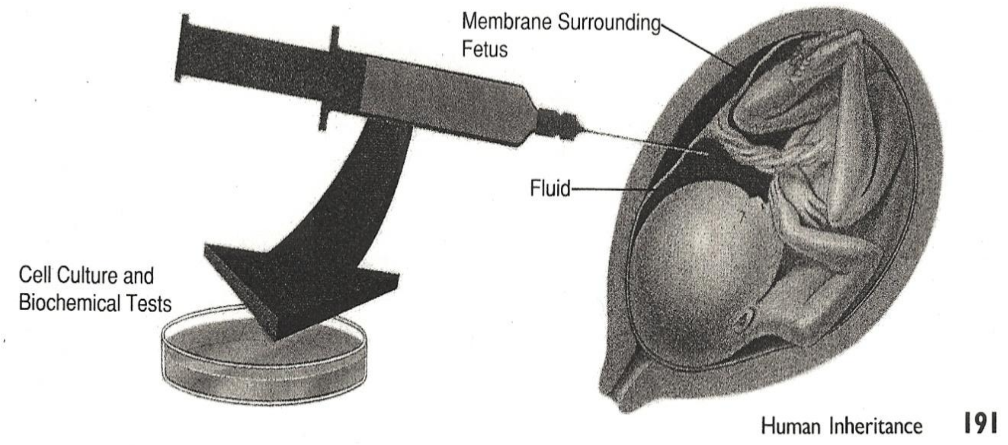


Figure 36. Prenatal testing illustration. From *Heath Biology* (p. 191). By J. E. McLaren, E. Rotundo, & L. Gurley-Dilger, 1991, Lexington, MA: Heath.

Section Four: Analysis of Haeckel's Embryo Drawings

Haeckel's embryo drawings have historically served several purposes, one of which has always been, controversy. In 1997 embryologist Michael Richardson and his colleagues authored an article in *Anatomy and Embryology* about Haeckel's embryo illustrations. Here, they compared Haeckel's hand-drawn illustrations with photomicrographs taken of similar species and similar stages. To the naked eye, Haeckel's embryos and Richardson's photos did not appear to match up well and the authors added their names to an already long list of Haeckel critics.

Richardson's work was further reported by science writer Elizabeth Pennisi (1997) in *Science* and she too, was not kind to Haeckel. Creationists were quick to pick up on Richardson's accusations and "reasoned" that if Haeckel's work was fraudulent, then the theory that Haeckel's embryos were supposed to support was also fraudulent. Never mind that Richardson's photos included yolk sacs (Haeckel's drawings did not), different chick orientations, and disproportionate scaling for the salamander embryo (Richards, 2008, p. 306); the damage was done and a new generation of scientists and non-scientists alike called for the removal of Haeckel's drawings from textbooks.

At least one textbook publisher took quick notice. The 1998 edition of Prentice-Hall's *Biology: The Living Science* by Ken Miller and Joseph Levine used a color illustration of Haeckel's embryos (see Figure 37). At first glance the drawings seem far less detailed than earlier illustrations that the two authors had used. In response to Richardson's article and its aftermath, Miller and Levine had changed their Haeckel drawings to drawings of photomicrographs taken by Swedish photographer Lennart Nilsson. On their website, they declared that Nilsson's photographs were "absolutely" accurate and that their 1998 biology textbook contained accurate drawings of the embryos made from detailed photomicrographs (Miller and Levine, n.d.). Given the fact that the publisher had to probably pay more in royalties and that the authors had to spend time amending their website, one would think that the "new" Haeckel embryos would have added more to the discussion about evolution. This was not the case. The only information about the drawing was a carefully stated sentence about how organisms in early development are similar to each other. It would appear that although the embryo drawing had changed, the story line had not. My review of Haeckel's diagrams saw many of his elaborate drawings in textbooks, but not much actual elaboration about the embryos themselves.

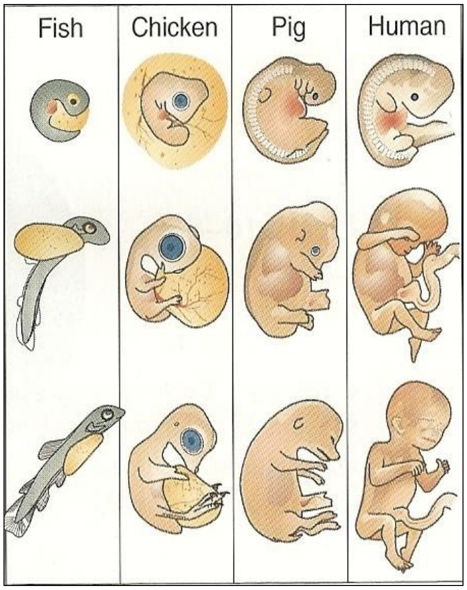


Figure 37. Drawings of embryos from Nilsson's photomicrographs From *Biology: The Living Science* (p. 223). By K. R. Miller and J. Levine, 1998, Upper Saddle River, NJ: Prentice Hall.

Haeckel's embryos.

Ernst Haeckel believed that the comparison of different vertebrate embryos was paramount for understanding evolution. By integrating taxonomy and embryology, Haeckel formulated the Biogenetic Law in the 1860s. This law stated that ontogeny (the development of the individual) recapitulates phylogeny (the evolutionary history of the species to which the individual belongs). Haeckel believed that this process was represented by his embryo diagrams. Recapitulation became a central paradigm to early biology (Gilbert, 2010) but eventually its weaknesses became apparent. Among its faults was the fact that Haeckel's idea was purely speculative. There was no easy way to test recapitulation and there was little empirical evidence that it worked (Allen, 2007). Younger embryologists who were beholden to the more progressive, experimental side of embryology were unable to embrace recapitulation because it relied only on observational, and not testable, methods. Haeckel's linear and progressive evolvement of organisms was dismissed by many, beginning well over 100 years before the Richardson's photomicrograph comparisons.

Opposition to Haeckel's ideas began as early as 1868. A Swiss anatomist, Ludwig Rütimeyer, noticed that Haeckel's woodcuts of dog, chick, and turtle embryos looked amazingly alike. And for good reason—the same woodcut had been used by Haeckel for all three embryos (Ruse & Travis, 2009, p. 625). Haeckel corrected this mistake and all probably would have been forgotten (and forgiven) if not for further accusations of fraud by Wilhelm His. His was a leading German embryologist with many connections. He declared that even with corrections, Haeckel was still guilty of sloppy and misleading work. For instance, His wrote that Haeckel had lengthened the forehead of his dog embryo by 3.5 mm and doubled the length of its tail (Richards, 2008, p. 286). Haeckel tried to explain that he had normalized his drawings so that the embryos would all be the same size, allowing for easier comparisons. He also drew his embryos from the combined examination of many embryos. This resulted in schematic figures that showed standard, essential features. His intent, Haeckel declared, was not to intentionally mislead, but to get rid of extraneous features that could stand in the way of seeing similarities between embryos.

Haeckel’s attempts at defending his work failed and by the twentieth century, his Biogenetic Law was no longer accepted by most comparative anatomists as a legitimate way to help explain evolution. But while Haeckel’s ideas about recapitulation fell out of favor within the scientific community, his famous embryo drawings have found permanent residence in biology textbooks.

The grid.

Haeckel’s famous 8 x 3 grid shows vertebrate embryos at various stages of development. Its use allows for a convenient, high speed comparison of the evolutionary history of several species. The eight species that Haeckel published are arranged in columns and their different stages of development are arranged in three rows. The embryos on the top row are essentially the same in terms of shape and identifying features. They all have a slim trunk region that narrows down into what looks like a tail. Students looking at these would probably erroneously conclude that they are all the same age and size. In the second row, the embryos start to look a bit different, especially fish and salamander embryos compared to the others. The third row depicts organisms at their later stages of development and they all look noticeably different from each other.

Haeckel’s illustrations were first published in 1874 and quickly became part of university zoology texts, followed by printings in some early high school biology books. The embryo grid most commonly found in texts is actually not Haeckel’s illustration, but a redrawing by George John Romanes, an evolutionist who redrew Haeckel’s work for his own book, *Darwin and after Darwin*, published in 1892 (see Figure 38).

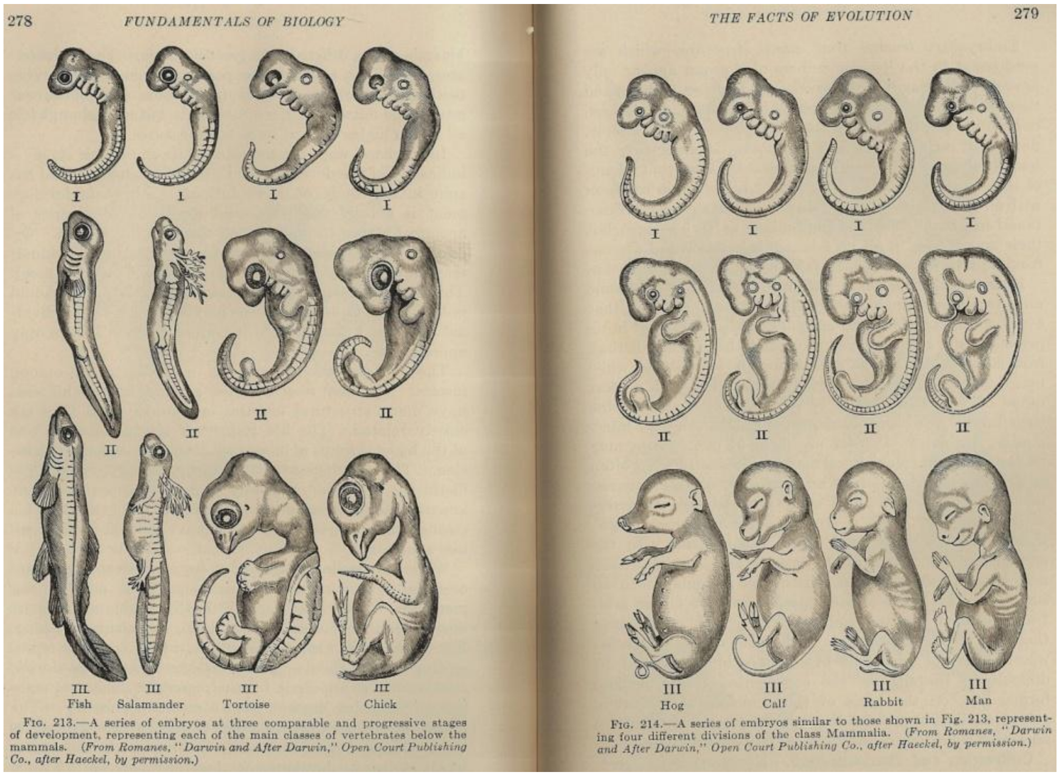


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FIG. 213.—A series of embryos at three comparable and progressive stages of development, representing each of the main classes of vertebrates below the mammals. *(From Romanes, "Darwin and After Darwin," Open Court Publishing Co., after Haeckel, by permission.)*

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FIG. 214.—A series of embryos similar to those shown in Fig. 213, representing four different divisions of the class Mammalia. *(From Romanes, "Darwin and After Darwin," Open Court Publishing Co., after Haeckel, by permission.)*

Figure 38. Romanes' redrawing of Haeckel's embryos. From *Darwin, and after Darwin* by G. J. Romanes, 1892, London: Open Court.

According to Robert J. Richards, author of *The Tragic Sense of Life, Ernst Haeckel and the Struggle over Evolutionary Thought*, the use of Romanes' illustration, rather than Haeckel's, was done perhaps to distance and "sanitize" the drawings from Haeckel (Richards, 2008, p. 341). In this study, the Romanes' version was the most commonly cited secondary source. In most cases, however, it appears that drawings were copied second-hand and no credit was given. In this discussion I will refer to these variations as "Haeckel's embryos" nonetheless.

Textbook embryos.

A tally of Haeckel’s drawings was completed and the results are shown, by decade, in Table 5. The earliest publication date of Haeckel’s embryos that I found was 1911 (Bigelow and Bigelow). By this time, biologists had already begun distancing themselves from Haeckel, but Maurice and Anna Bigelow used Haeckel’s embryos in their text to discuss evolutionary relationships aided by gill-slit evidence. The next occurrence of Haeckel’s drawing is the 1919 edition of *Elementary Biology* by Benjamin Gruenberg. The embryos in Gruenberg’s book have been traced and flip-flopped, with the embryos facing right rather than left. Three other authors of early twentieth century texts used Haeckel’s embryos: William Atwood, Lorande Woodruff, and Bigelow and Bigelow again, all published in 1922. These texts placed Haeckel’s embryos in chapters dealing with animal life or the reproduction of organisms. They were used to illustrate “development” rather than evolution.

Table 5

Use of Haeckel’s Embryos by Decade

Decade	Books with Haeckel’s Diagram	Books without Haeckel’s Diagram	% Using Haeckel’s Diagram
1910s	2	7	22
1920s	3	9	25
1930s	3	10	23
1940s	8	6	57
1950s	11	5	69
1960s	17	1	94
1970s	14	5	74
1980s	8	4	67
1990s	10	4	71
Total	76	51	60% (average)

After the 1930s, however, Haeckel's embryos migrated away from chapters like these and became distant cousins to those embryos used to describe differentiation, transplantation, cloning, and reproduction. In the 1940s and 1950s, Haeckel's illustrations were found in chapters such as "Changes in Living Things" (Benedict, 1941) and "Life Changes through the Ages" (Heiss & Lape, 1958). From the 1960s through 1990s, Haeckel's embryos were almost always found in chapters about evolution. While Haeckel's embryos were still embryos, they were not treated as such. Rarely were these embryos found in indexes referenced under the term "embryo."

An interesting result that may have been influenced by the Scopes Trial can be seen with textbooks published in the 1930s. In 1925, John Scopes was tried in a Tennessee courtroom for violating the state's Butler Act. What Scopes had done was to teach evolution in a public school. The trial became a battleground between science and fundamentalist Christianity. Scopes was found guilty of teaching evolution (although his verdict was later overturned on a technicality), but it is believed that proevolution opinion gained in strength through the court case (Grabiner & Miller, 1974). The proevolution movement, however, had little positive impact on the teaching of evolution, or the incorporation of evolution into biology textbooks.

During the 1920s, 37 bills were introduced in 20 states that proposed to make evolution in public schools illegal to discuss or teach about (Skoog, 1978). Even though only three states actually passed bills that became law (Arkansas, Mississippi, and Tennessee), the teaching of evolution was hampered enough to make publishers and authors either drop evolution entirely or to write around the topic by not using the word "evolution" throughout their entire texts.

In 1925 the state of Texas demanded that school boards only approve textbooks that omitted evolution. Any teacher using a non-approved text would be dismissed and prosecuted (Webb, 1994, p. 101). Not willing to lose out to potential profits, publishers such as Henry Holt, Allyn and Bacon, and Macmillan agreed to rewrite objectionable passages in their biology textbooks to meet the demands of Texas school boards (Webb, p. 101). This insight is backed by my review of the Macmillan texts used in this study. Prior to 1925, *Introduction to Biology* (Bigelow & Bigelow, 1922) and *Foundations of Biology* (Woodruff, 1922) discussed evolution and both had Haeckel diagrams in them. After 1925, no Macmillan texts used Haeckel diagrams again until 1941. The first time that Haeckel's embryos were used in Holt and Allyn and Bacon texts was 1938.

The early 1930s saw the term evolution drop out of use, replaced with such euphemisms as "Changing Forms of Living Things" that Baker and Mills used in *Dynamic Biology* (1933). Baker and Mills go so far as to attack Darwin with the statement that "Darwin's theory, however, like that of Lamarck, is no longer generally accepted" (p. 681). Other texts downplayed evolution and along with it, the use of Haeckel's embryos. Before the Scopes trial, five out of seventeen textbooks were published with Haeckel drawings. After 1925, and until 1938, only one out of eight texts published contained a Haeckel diagram.

There could, however, be another factor. Diagrams and pictures increase the price of production. Coupled with the low margin of profit for textbooks, and the low volume of demand during the Great Depression, I wondered if the lack of Haeckel's drawings in textbooks during and after the Scopes trial could have been due, in part, to cost containment. In examining the average number of pictures dealing with development, I calculated that in the 1920s, the average number of pictures was 4.7; for the 1930s the average was 4.3; and for the 1940s, the average number of pictures was 4.2. The differences in averages were too insignificant to conclude that cost was a contributing factor to the decrease in the number of Haeckel diagrams seen in the 1930s. The most probable cause for the decrease was fundamentalist pressure put on the textbook industry.

By the 1940s, a general improvement in the treatment of evolution as a principle of biology was seen (Grabiner & Miller, 1974; Skoog, 1979). Correlating with this was an increase in the number of Haeckel illustrations published. For some texts, the 1950s were the first time that the drawing was used by authors, who in previous editions, had excluded Haeckel. For example, Smallwood's texts, beginning in 1916 and continuing through to its fourth edition in 1948, were devoid of Haeckel. The 1952 version of *Elements of Life*, with the revisions placed solely in the hands of Ruth Dodge, used Haeckel's illustration. In the case of Gruenberg's textbooks, his 1919 *Elementary Biology* was one of the first American biology textbooks to use Haeckel's embryos. The embryos disappeared in his 1925 text (the year of the Scopes trial), and they finally reappeared in 1944, the last biology textbook written by Gruenberg.

In 1979, an article by Gerald Skoog appeared in *Science Education* dealing with the topic of evolution and high school science. In his often-quoted research, Skoog evaluated 93 high school biology textbooks to determine the extent of their study of evolution. Among other things, Skoog found that in the 1960s, discussion about evolution went up, but decreased in the 1970s. Skoog does not mention Haeckel's illustrations in his study, although they were most certainly present. My examination of textbooks shows a similar upswing in the appearance of Haeckel's embryos in the 1960s and a noticeable decrease in their use in the 1970s and 1980s. The Creation Science movement appeared as a national force in science education in the late 1970s and fundamentalist Christians began insisting that public schools give equal time to teaching the Bible's version of creationism in biology classrooms. Both of these events most probably had an impact on decisions to decrease the amount of evolution coverage in textbooks.

One textbook series singled out in Skoog's textbook research as representative of the failure of high school biology to discuss evolution was the *Modern Biology* series published by Holt. The word "evolution" was not used in the text, glossary, or index in the 1947, 1951, 1956, and 1960 editions. Instead, expressions such as progressive change and racial development were used. To muddle things even further, Haeckel's embryos were found in all seven editions of *Modern Biology* from 1938 through 1963. The drawings were accompanied with similar recapitulation statements about how embryos pass through stages which resemble their remote adult ancestors, and that early developmental similarities are indicative of common ancestry. Six newer editions of *Modern Biology,* from 1965 through 1999, all used Haeckel drawings as embryological evidence for a common ancestor, but unlike earlier versions, they included discussion of how genes assumed the control of differentiation, causing Haeckel's embryos to develop in different ways. There is no other high school biology text series that has used Haeckel's embryos more than *Modern Biology*.

BSCS.

BSCS textbooks have figured prominently in the mid-twentieth century landscape of high school biology. Much has been written about BSCS programs, its progressive treatment of science, and how the power, prestige, and backing of the federal government caused it to change science curricula (Grobman, 1969; Lazarowitz, 2007; Mayer, 1989, Skoog, 1978). By the time that the first editions of the three BSCS textbooks were released in 1963, the public was aware of the need for high school science reform and there would be several legal precedents limiting religious influence in public schools over the next few years (e.g., the 1967 repeal of the Tennessee antievolution law that had prevented the teaching of evolution in Tennessee public schools). I was particularly interested to see how this series of texts used Haeckel's embryos, given the many positive comments about BSCS and evolution by science educators and science education researchers.

BSCS green version.

All seven Green version editions in this study used Haeckel diagrams in chapters titled “Evolution.” The 1963, 1968, 1973, and 1978 editions all used the same 7 x 7 grid and included chimp embryos developing right next to those of a human embryo. The embryos included yolk sacs, something that had rarely been added to Haeckel’s original illustrations. The BSCS captions were the first to inform students that the embryos are not drawn to scale, nor were the embryos in similar stages exactly the same age. Later editions saw a scaling back in the number of organisms used: the 1987 Green edition dropped its shark embryo, while the 1998 edition dropped shark and lizard embryos. In all captions except for 1998, the similarity between embryos was noted, along with how these similarities convinced Darwin that all forms of life shared a common ancestor.

In the 1998 Green edition, a change was apparent. The caption simply told the reader that zygotes were on the left and adults were on the right. There was no mention of embryo similarity, or of Darwin. For a BSCS text, this is rather disturbing, considering that early BSCS writers were subjected to tremendous pressure from state and local education boards to remove evolution from the BSCS texts. The scientist writers at the time refused to do this and published their texts with more discussion about evolution than any textbooks published before 1963 had done.

BSCS blue version.

The BSCS Blue version published Haeckel’s illustrations in a 7 x 7 grid in its 1963 and 1968 versions. After this, editions published in 1973, 1980, 1985, and 1990 did not have any Haeckel diagrams. A possible explanation for this is that the two earliest versions placed Haeckel’s embryos, not in chapters about evolution as seen in the Green and Yellow versions, but in a chapter about development. Although the illustrations did have a caption highlighting the development of various vertebrates, the embryos were never referred to in the text of the chapter. They seemed awkwardly placed and this awkwardness may have led authors of future editions to remove the embryo diagram.

BSCS yellow version.

The four editions of the Yellow version, published in 1963, 1968, 1973, and 1980 all placed Haeckel embryos in a chapter titled “Darwinian Evolution.” Unlike the BSCS Blue and Green editions though, they are not captioned. The text written to accompany the drawings discusses recapitulation but warned that the idea of embryonic resemblances should be viewed with caution and that the “old” idea of recapitulation was not correct.

The Yellow versions had a scaled-down Haeckel diagram, consisting of a 4 x 5 grid that showed human, pig, salamander, and chick embryos. Each version’s drawing was detailed and included new “pre-stages” (egg and blastula) and a new post-stage of adult forms. The 1980 BSCS Yellow version text, the last publication date of this BSCS series, changed something in its Haeckel illustration. For the first time, students saw that human embryos sometimes developed into females and not males (see Figure 39). This was no doubt done in response to a growing feminist influence with textbook publishing that occurred in the 1970s. Also interesting is that the early Yellow versions placed “man” at the bottom left of the grid, rather than the bottom right. In the 1980 edition, the “woman” was placed at the top right and the four embryos were mixed up a bit—the chicken and salamander traded places, countering the idea of evolutionary progress that is seen in Haeckel’s original drawing.

Organisms in the grid.

How true to the original Haeckel illustrations have textbook drawings remained? In particular, which organisms were used in the grid and which fell by the wayside? Haeckel

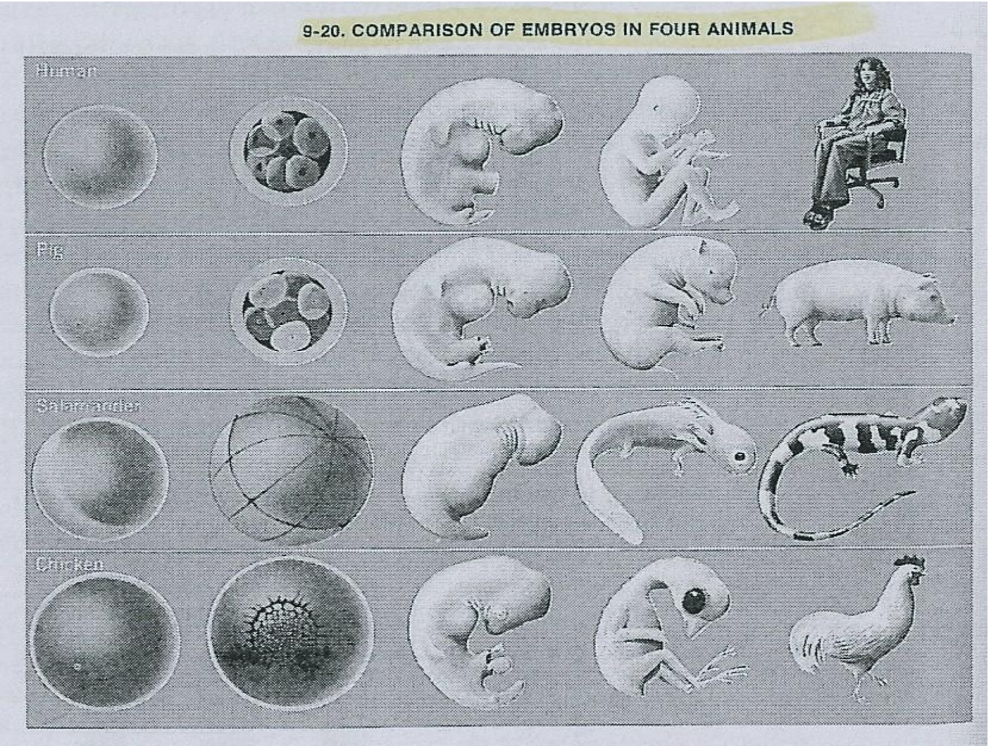


Figure 39. Haeckel illustration in BSCS yellow version, 1980. For the first time a human embryo is shown to develop into a female fetus and eventually into an adult woman rather than into a man. From *Biological Science: An Inquiry into Life* (p. 282). By BSCS, 1980, New York: Harcourt, Brace.

originally used fish, salamander, tortoise, chick, hog, calf, rabbit, and human embryos. Most of the Haeckel diagrams that I reviewed included fish and chick embryos, 93 percent and 84 percent of the time, respectively. Salamanders (representing amphibian embryos) and tortoises (representing reptile embryos) were well represented at 64 percent and 63 percent, respectively. While Haeckel used the tortoise embryo to represent reptiles, textbooks sometimes replaced the tortoise with a lizard embryo, especially in the BSCS biology texts.

Haeckel originally used several organisms to represent mammals: hogs, calves, rabbits, and humans. It appears that textbook authors generally thought that four mammals were too many. The most common mammalian embryo drawn was human (66%), followed by hog embryos (47%), rabbit (28%), and the rare calf embryo, found in only 4% of the drawings. In several instances, Haeckel's calf embryo was somehow transformed into a sheep or dog embryo, but this only occurred in older texts. Thereafter, the calf embryo was dropped from the grid.

The number of organisms used in Haeckel diagrams differed widely, ranging from two to eight and averaging nearly five organisms per grid. The grids with eight organisms were always Romanes' copies. These included textbooks by Bigelow and Bigelow in the early 1900s, textbooks by John Kimball published in the 1970s through 1990s, and a 1994 biology text by Joseph Levine and Kenneth Miller. The smallest grid that I saw was a 2 x 2 that appeared only once, in Charlotte Grant's 1952 text. It was also the only grid represented with plasticene models rather than drawings.

When a grid is small, as in the case of Grant's models shown in Figure 40, there is a tremendous amount of development not presented to the student. Because of this, the dissimilarities of the pig and human fetuses in the bottom row make the embryos presented in the early stages look more similar than perhaps they really are. The accompanying text informed students that development of all life has been from simple to complex, and from similarity to a host of unlike forms. Students were then told to relate this diagram to the idea of recapitulation, where "the development of each embryo, while similar to other embryos at the beginning, repeats the development of its own ancestors as it gradually becomes more different from other embryos, and more and more a specialized organism" (p. 597). The use of this statement with a picture of only two organisms and two stages, perhaps unintentionally manipulated the student into accepting the idea of recapitulation.

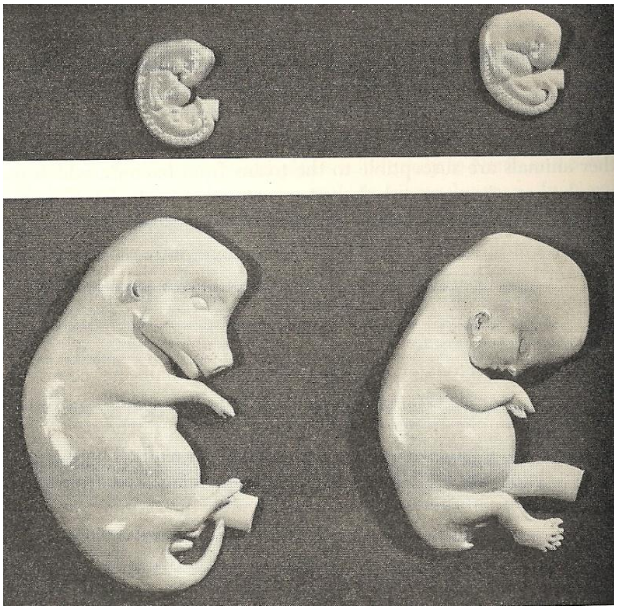


Figure 40. A 2 by 2 grid of pig and human embryos. From *High School Biology* (p. 596) by C. L. Grant, H. K. Cady, and N. A. Neal, 1952, New York: McGraw.

Monkeys and gorillas.

The chimpanzee was not included in Haeckel's original diagram but the chimp embryo was added by different authors and publishers, beginning in 1963 with the publication of BSCS's Blue and Green textbooks. Stanley Weinberg added a monkey to his embryo grids in all four editions of his *Biology: An Inquiry into the Nature of Life* series. Weinberg was the founder of the National Center for Science Education, an organization that opposed creation science and defended the teaching of evolution in biology classrooms. In total there were fifteen textbooks that added non-human primate embryos to their Haeckel grids and all of these texts were published after 1963.

Sometimes primates were use as a replacement embryo rather than just as an add-on to the grid. For example, beginning in 1938, all textbooks by Truman J. Moon, later to be titled *Modern Biology*, had a Haeckel diagram that did not include human embryos. This changed with the 1969 edition when a human embryo was drawn alongside embryos of fish, salamanders, chicks, and rabbits. In 1985, the diagram was streamlined to include only human, fish and chick embryos. In 1991, the human embryo was replaced with that of another primate, in this case, a gorilla (Figure 41). This drawing was also used in the 1999 edition of *Modern Biology*. Such manipulation of the grid shows various authors' attempts to add, remove, and replace human embryos with embryos from less contentious species.

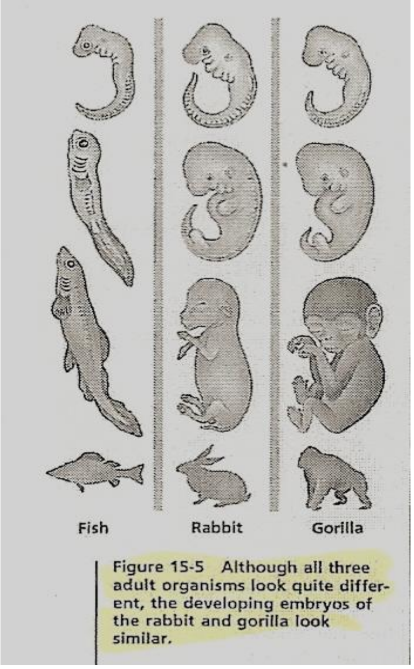


Figure 15-5 Although all three adult organisms look quite different, the developing embryos of the rabbit and gorilla look similar.

Figure 41 . *Modern Biology*'s 1991 Haeckel diagram with gorilla embryos. *From Modern Biology* (p. 224). By A. Towle, 1991, New York: Holt.

The return of man.

Sometimes the controversy about Haeckel's embryos is not so much about Haeckel, but the inclusion of a certain embryo. In most cases this is a human embryo. By including "man" does it seem to place humans on the same level of development as pigs, calves, and rabbits? In 1963, Haeckel's grid got a noticeable update from the publishers of BSCS textbooks. All three versions—Green, Yellow, and Blue—placed human embryos squarely back into the grid. While textbooks had used human embryos in Haeckel diagrams before 1963, their use was scattered and not consistent. Only 32 percent of textbooks with Haeckel diagrams published before 1963 included human embryos; after 1963, this rose to 87 percent. Textbook publishers quickly followed BSCS's lead so that during the 1960s an astonishing seventeen out of eighteen textbooks displayed Haeckel's embryos and of these, thirteen included human embryo drawings in their grids. This trend continued well into the 1990s; even as the number of texts using Haeckel diagrams decreased after the 1960s, most of those texts that *did* use Haeckel's embryos, continued to use drawings of human embryos (Table 6).

Table 6.

Use of Human Embryos in Haeckel Diagrams by Decade

Decade	Texts with Haeckel Diagrams	Haeckel Diagrams with Human Embryos
1910s	22%	100%
1920s	25%	66%
1930s	23%	33%
1940s	57%	13%
1950s	69%	20%
1960s	94%	76%
1970s	74%	92%
1980s	67%	100%
1990s	71%	70%

Recapitulation and evidence of ancestry.

Haeckel's main reason for drawing embryos was to provide evidence for the idea that "higher" organisms like humans had evolved from older and "lesser" organisms like fish. When he looked at embryos of various species he was convinced that he saw remnants of lesser species in the early development of human embryos. One of my framing questions was how were Haeckel's embryos used? Were they used as evidence for evolution, much like Haeckel used them? If yes, I would think this strange since recapitulation had largely been discredited long before any of my textbooks had been published. If no, then what were these embryos really used for?

Most of the textbooks that contained Haeckel's drawings also had accompanying paragraphs that attempted to explain a bit more about Haeckel's embryos. These explanations can be placed into one of three broad categories: (a) a von Baer description of similarity (and in some cases, von Baer erroneously credited with the idea of recapitulation or the Biogenetic Law); (b) a description that contained Haeckel's ideas of recapitulation and common ancestry (although rarely identifying Haeckel as the man behind the idea of recapitulation); and (c) a statement that was purely descriptive and did not draw on either von Baer's or Haeckel's ideas about embryo similarities and differences. In this study, nearly half of the embryo captions gave the former type of description of embryos. That is, the reader was instructed to note similarities in the early stages of embryonic development. No mention was made of common ancestry, or recapitulation.

Nick Hopwood, a noted science historian, argues that the casual assumption that Haeckel's vertebrate embryos must show recapitulation is misleading (2006, p. 273). To Hopwood, Haeckel's embryos show a von Baer view that vertebrate embryos start out looking similar and that they look less similar over time. Intelligent design followers agree that Haeckel's embryos do have similarities in early stages, but they argue that a creator designed the embryos to be like this. A debate about who is right or who is wrong goes beyond the purpose of this study, but one might ask: if Haeckel's embryos cannot be used to provide evidence for evolution in a biology textbook, why are they being used at all?

There is tremendous reaction against Haeckel by both scientists and non-scientists alike (Richards, 2008). To my surprise, Haeckel himself was only mentioned, by name, in 3 out of the 127 texts reviewed for this study. In examining the written text that accompanied Haeckel’s drawings, one thing became apparent: the distinction between von Baer’s and Haeckel’s work was often blurred, and occasionally, downright false. Haeckel’s embryo drawings were mainly used to show how embryos were similar, and nothing more. They were rarely used to help students understand recapitulation or evolution. Out of 76 drawings dealing with the comparison of similar-aged embryos, only 14 addressed recapitulation or made an attempt to discuss common ancestry. Either authors were unclear themselves about Haeckel’s intent with his drawings, or they used von Baer to soften the assumptions of recapitulation, and avoided the contentious debate about human and primate ancestry.

In a few cases, Haeckel’s embryo drawing was revised to better show recapitulation. An example of this was seen in later editions of the textbook series *Elements of Biology*. The early editions of this text were written by William Smallwood, Ida Reveley, and Guy Bailey. They briefly wrote about evolution but did not use any embryo drawings to support embryological evidence for evolution. This changed in 1952 when Ruth Dodge shared with the writing and eventually became the sole author of *Elements of Biology.* In her 1952, 1959, and 1964 editions (the publication of *Elements of Biology* ceased after the 1964 edition), the diagram shown in Figure 42 was used to provide evidence of ancestry with humans, reptiles, fish, birds, and even invertebrates. The figure’s caption states that:

> Each individual passes through stages in its growth and development that are similar to the changes that occurred in the development of the race. Animals still start form a single cell, the simplest form of life in history. Trace the development of the individual (*lower left*), comparing each step to the historical development of the living forms (*right)* (p. 626).

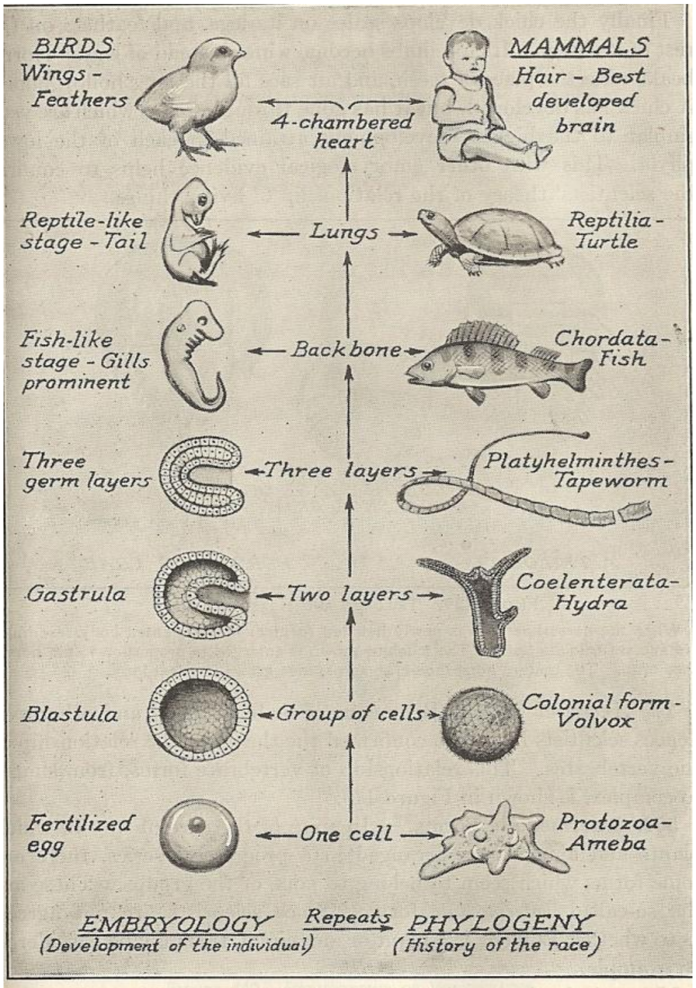
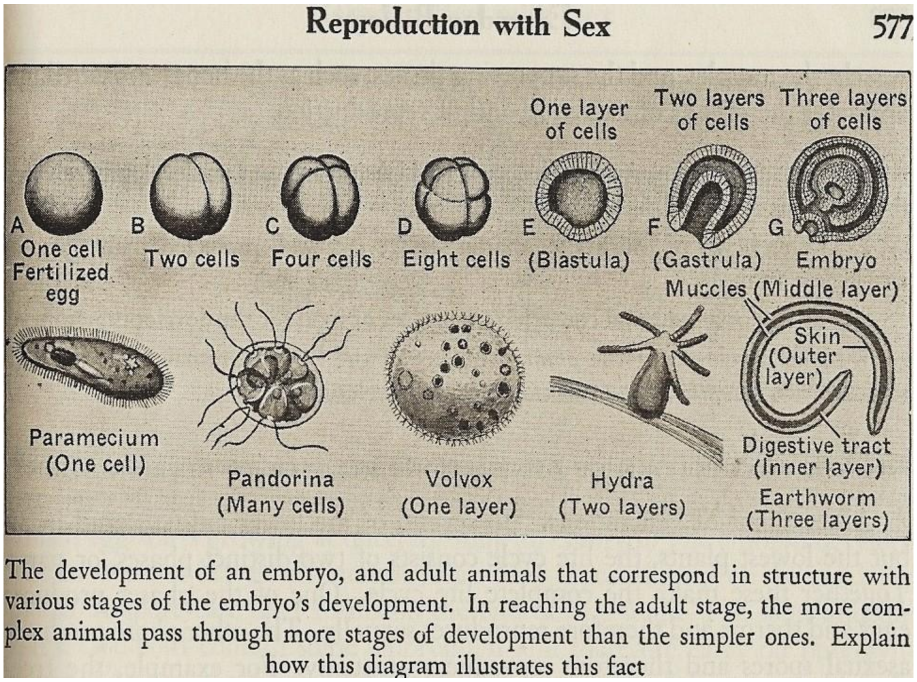


FIGURE 438. EVIDENCE OF ANCESTRY

Figure 42. Evidence of ancestry in *Elements of Biology* textbooks. From *Elements of Biology* (p. 626) by R. Dodge, 1964, Boston: Allyn and Bacon.

The use of this diagram aligned with Haeckel's view of recapitulation: that is, complex animals pass through stages as lower life forms. It is worth repeating that as early as 1900, Haeckel's view that ontogeny recapitulates phylogeny was under attack. And yet, several textbooks continued to present the idea that similar organisms start to look different as they add structures later in their embryological development.

Another quasi-recapitulation diagram was used by Curtis, Caldwell, and Sherman in their *Everyday Biology* textbook series. Over the course of several revised editions (1934, 1940, 1946, 1949, and 1953) the same picture and caption concerning animal development appeared (see Figure 43). Unlike Dodge's pictures though, the embryo develops only to the three germ layer stage. It avoids any discussion of organisms higher than an earthworm. The authors do not state that the complex animals pass through lesser stages but simply that higher organisms pass through more stages of development. Could a student, however, infer this if he or she only looked at the picture?

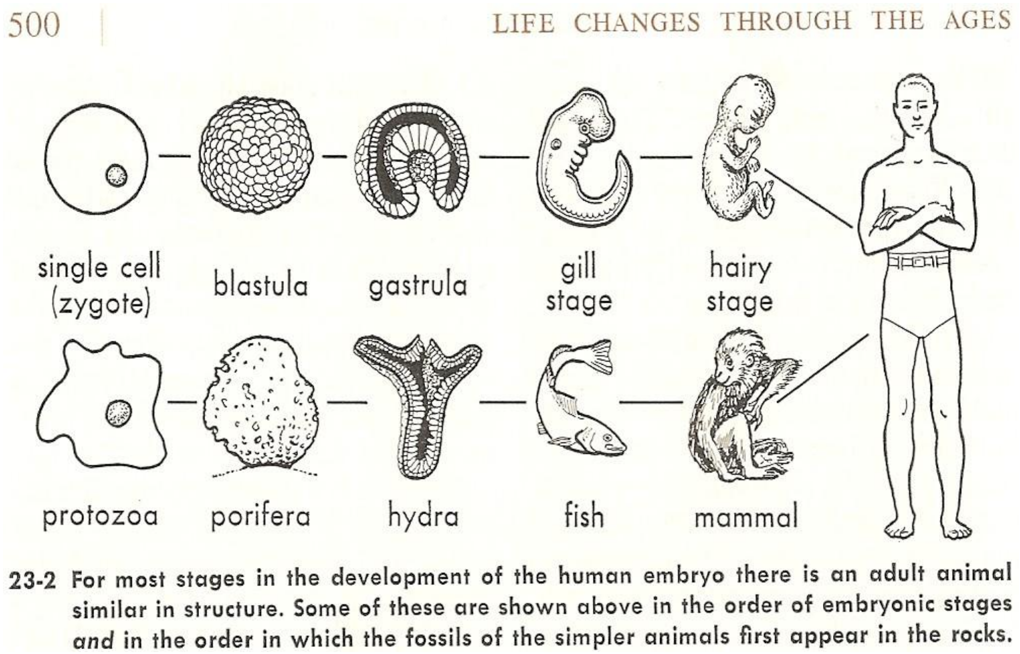


Reproduction with Sex 577

The development of an embryo, and adult animals that correspond in structure with various stages of the embryo's development. In reaching the adult stage, the more complex animals pass through more stages of development than the simpler ones. Explain how this diagram illustrates this fact

Figure 43. Stages of development in *Everyday Biology*, 1946. From *Everyday Biology* (p. 577) by F. D. Curtis, O. W. Caldwell and N. H. Sherman, 1946, Chicago: Ginn.

As late as 1961, illustrations were still used to depict recapitulation as a valid way of looking at human development. In Figure 44, note that this recapitulation diagram from *Biology. A Basic* Science, published in 1961, used a monkey embryo and an adult monkey, giving the impression that humans go through a "monkey" stage and have evolved from primates.



500 LIFE CHANGES THROUGH THE AGES

23-2 **For most stages in the development of the human embryo there is an adult animal similar in structure. Some of these are shown above in the order of embryonic stages *and* in the order in which the fossils of the simpler animals first appear in the rocks.**

Figure 44. Haeckel's idea of recapitulation enters the 1960's classroom. From *Biology. A Basic Science* (p. 500) by E. D. Heiss and R. H. Lape, 1961, New York: Van Nostrand.

A recapitulation oddity occurred in Alvin Nason and Philip Goldstein's 1969 textbook, *Biology, Introduction to Life.* Here, the two authors presented a "tree of embryo development" as shown in Figure 45. A cursory look at the diagram makes one think of Haeckel's phylogenetic trees while an examination of the figure's caption makes one think of linear and progressive development, as evidenced by the statement that "less advanced animals break away from the general line of development at an earlier stage than the more advanced" (p. 684). There were probably few, if any, biologists in 1969 that would have agreed with such an approach to describe how phyla developed at the time that this was published. The embryo tree made only one appearance as Nason and Goldstein wrote no further editions of this high school biology text.

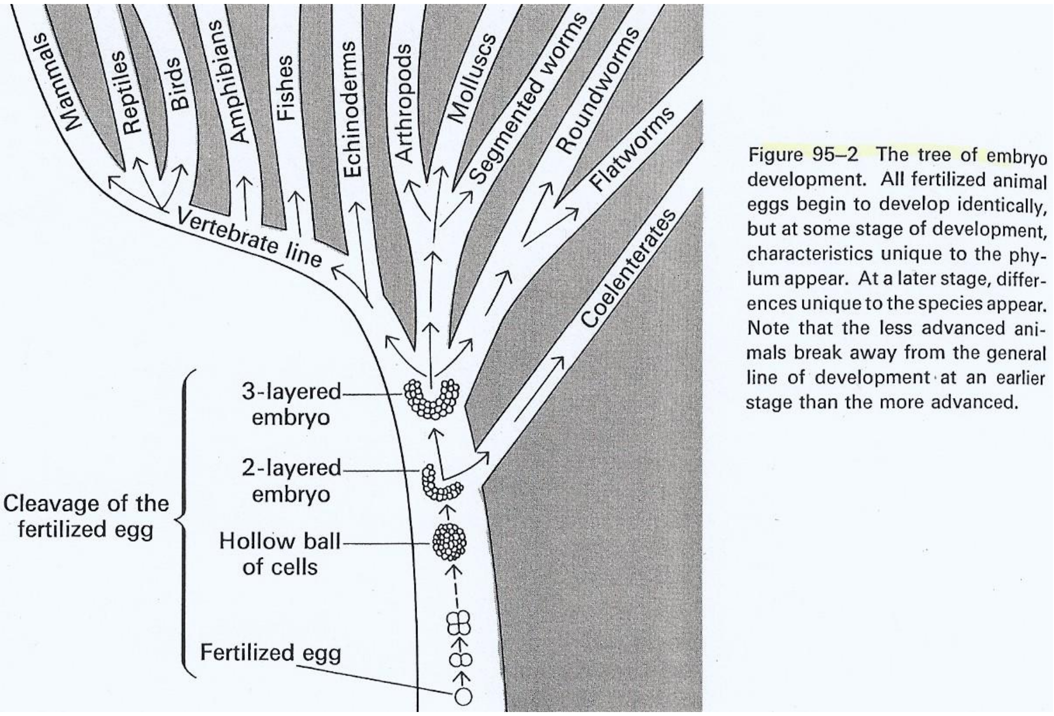


Figure 95–2 The tree of embryo development. All fertilized animal eggs begin to develop identically, but at some stage of development, characteristics unique to the phylum appear. At a later stage, differences unique to the species appear. Note that the less advanced animals break away from the general line of development at an earlier stage than the more advanced.

Figure 45. The embryo development tree. From *Biology, Introduction to Life* (p. 684). By A. Nason and P. Goldstein, 1969, Menlo Park, CA: Addison-Wesley.

Although recapitulation was usually explained with the aid of embryo morphology, there was one instance where biochemical recapitulation was shown with a graph (see Figure 46). Interestingly enough, this figure in Kimball’s 1965 edition of *Biology* was one of the very first graphs to appear in high school biology textbooks. The figure showed how biochemical, as well as anatomical, recapitulation occurred. It was accompanied by an explanation of how fish excrete a large part of their waste nitrogen as ammonia, while amphibians have the less toxic urea as their chief nitrogenous waste. The fishlike tadpole excreted ammonia until it underwent metamorphosis into an adult frog.

Disclaimers.

Overall, I found that many of the texts that used Haeckel’s embryos did two things: first, the authors stated that recapitulation was not entirely accepted in the scientific

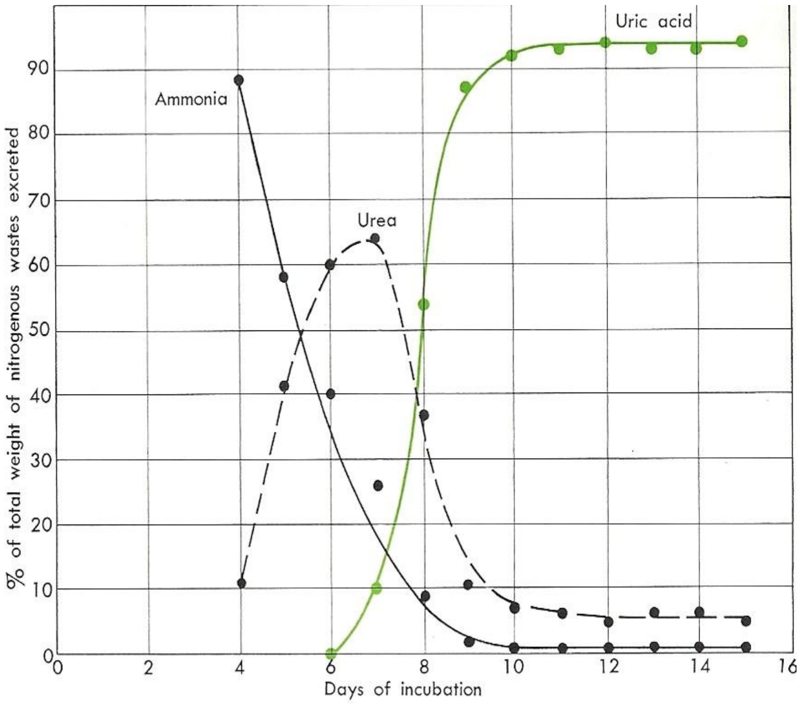


Fig. 31–7. Biochemical recapitulation in the chick embryo.

Figure 46. Biochemical recapitulation in an embryo. From *Biology* (p. 707). By J. Kimball, 1965, Reading, MA: Addison-Wesley.

community and second, the embryos were used to illustrate a discussion about "development." One of the first books to use a disclaimer about recapitulation was *Elementary Biology* (Gruenberg, 1919):

> Some biologists have gone so far as to say that each individual passes through stages representing all the types of his ancestors. In a general way this is true only as a restatement of von Baer's law. But, strictly speaking, is it not true, for example, that you once passed through a hydra stage or a fish stage. All we can say is that we have passed through stages that are similar to corresponding stages in many classes of animals" (p. 278).

Note the error that could be made in associating von Baer with recapitulation. This happened more than once. In fact, six textbooks credited the discovery of the Biogenetic Law or recapitulation to von Baer and two give credit to Darwin. Sometimes this error was directly stated as in the case of Weinberg's 1974 and 1977 editions of *Biology*:

> How can we explain vestiges and embryonic resemblances? According to one concept proposed by von Baer about 1830, each animal in its development passes through the stages through which its ancestors evolved. Early embryonic stages resemble the more primitive ancestors. Recent evolutionary changes are tacked on to later stages. (p. 81)

More often though, the von Baer-recapitulation mix-up was due to a poor layout design. In some cases, the authors wrote about von Baer and placed a picture of Haeckel's embryos in close proximity. Because students were not presented with any distinction between von Baer and Haeckel, it appeared that von Baer was responsible for the drawing of Haeckel's embryos.

With all of the discussion about von Baer, did Haeckel get mentioned at all? The answer is, rarely. Not only did Haeckel not receive credit for his illustration, he was also absent from any discussion about recapitulation. Only three texts mentioned Haeckel by name, and two of these were critical of Haeckel's ideas. Interestingly, one of these texts was the 1999 *Modern Biology.* Prior to 1999, there had been eleven editions of *Modern Biology* that had discussed recapitulation and stated that similarities between organisms in the embryo stage also seemed to show descent from a common ancestor. It wasn't until after a flurry of publications in the late 1990s, condemning Haeckel's diagrams and evolution in general (see for example Wells, 1999), that *Modern Biology* identified Haeckel, by name, and labeled his idea of recapitulation "an exaggeration." The 1999 version also stated that "in no stage of development does a gorilla look like an adult fish" (p. 291). It seemed clear that the publisher had responded to fundamentalist pressure that was growing in the 1990s. Other texts published in the 1990s seemed to follow suit; discussing only how embryos were similar and that there was no reason to believe that these similarities were due to common lineage. There was no discussion of recapitulation and rarely was the word "evolution" even mentioned in combination with Haeckel's embryos.

One criticism of the use of Haeckel's embryos has been that the illustration persuades students to accept the idea of evolution, and that textbooks do not point out problems with the idea of Haeckel's Biogenetic Law. This is not true. There were many textbooks that made strong statements against the idea of recapitulation. For example, all of BSCS's Yellow versions addressed the idea of recapitulation with the statement, "Today the idea of embryonic resemblances is viewed with caution. We can see and demonstrate similarities between embryos of related groups. However, while a certain amount of recapitulation is unquestioned, the old idea that a human passes through fish, amphibian, and reptile stages during early development is not correct" (BSCS Yellow, 1963, p. 608).

Some texts that did not raise the idea of inconsistencies with recapitulation, also did not present recapitulation in such a manner that one could find fault with it. In a writing style that seemed to try to appease all readers, Haeckel's embryos were simply described as having similarities such as gill slits or that these embryos began their development in the same way. Such recapitulation-lite descriptions overgeneralized to the point that they strayed from the idea of evolution, and this may be what publishers wanted.

Another way that authors wrote around recapitulation was their use of the "I don't want to get involved" approach and letting students decide whether to accept evolution or not. This is a common way to avoid controversy and was seen as early as 1948 in a text by John W. Ritchie:

> The theory that each individual in its development repeats the stages its ancestors went through in the development of the race is called the recapitulation theory; sometimes it is spoken of as the biogenetic law. In their adult stages organisms may seem very different, but they all start life as a single cell and it is believed that they all have a common ancestry and trace back to one simple life form. It is well to remember, however, that in science, fact and theory are different and separate, and that the biogenetic law is a theory and not a fact. In the facts of growth and development scientists find what they consider very convincing evidence for the oneness of the world of life. The facts are unquestioned, but you can form your own judgment as to the correctness of the conclusion that has been drawn from them. (p. 62-64)

It became clear that some authors just had a hard time letting Haeckel's embryos go. During the height of the creation science arguments, one textbook tried to appease both sides of the debate. Wallace and Simmons wrote *Biology for Living* (1987) and used Haeckel's drawing to show how early embryos had similar morphologies. They pointed out that "recapitulation, if taken literally, is nonsense: there is no fish stage in the development of a mammal" (p. 267). But they believed that if taken less literally, the idea of recapitulation had merit *and* that it could perhaps stand the test of both creationists and evolutionists. Wallace and Simmons stated that "A Creator, as a Master Engineer, might have planned independent pathways from egg to adult for each organism, but evolution, which virtually by definition builds on what has been accomplished before, lacks the ability to construct theoretical plans in advance; evolution resembles a tinkerer" (p. 268). It seemed that Wallace and Simmons were trying to say that evolution seemed more logical, but they were not willing to rule out intelligently designed embryos, either.

For the most part, however, recapitulation is discussed so briefly in most of these texts (on average, in only one paragraph) that students really were given only two options for understanding–either embryos of different species are similar early in their lives, or we have a common ancestor, but usually not both.

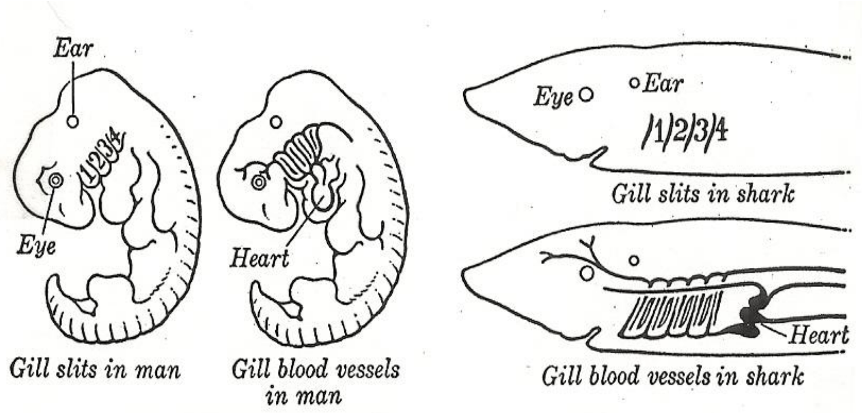
Gill slits and biological reality.

Many a high school biology student has undoubtedly come away from his or her coursework with the misconception that humans have gills early in their development and that the presence of these structures is proof that the evolutionary development of humans has also involved fish. Can this erroneous idea be traced to Haeckel's embryos? While Stephen J. Gould (1977) remarks that "…in Haeckel's evolutionary reading, the human gill slits are the adult features of an ancestor" (p. 7), Michael Richardson and Gerhard Keuck (2002) believe that this is an overstep. In their review of Haeckel's writings, the two researchers argue that Haeckel is often accused of advocating absurd recapitulatory scenarios like fish gills in human embryos, but that he did not believe the pharyngeal apparatus in organisms represented adult fish gills. Whatever Haeckel did or did not believe, gill slits, like Haeckel's embryos themselves, have shown lasting presence in textbooks.

In the neck region of vertebrate embryos are prominent structures that have been called various names in the scientific literature: branchial or pharyngeal pouches, grooves, or ridges. Human pharyngeal ridges and folds develop into parts of the human face, ear cavities, thyroid, thymus gland, and muscles for chewing. Early in the field of embryology, observers noted that these repeating structures resembled the repeating gill-forming structures of fish embryos and they were given the colloquial name "gill slits." The term stuck. They are not, however, and never have been claimed to be human gills. The use of the term "gill slits" continues today, in both scientific journals and textbooks. Unfortunately, the term has a dual meaning. To those who study embryos, gill slits refer to common structural elements of vertebrate facial development and evidence for evolution. To non-experts, the term means that humans have evolved from fish. And that, while scientifically false, has semantically proved to be a bone of contention.

Haeckel's diagrams were often modified by publishers who labeled structures common to all embryos. The two most common structures that were pointed out for students were gill slits and tails. The earliest mention of gill slits occurred in the 1922 publication of *Foundations of Biology* by Woodruff. A simple drawing of a fish, bird, and human embryo showed that all three embryos have gill slits. All seven editions of *Modern Biology*, beginning in 1938 and through 1969, instructed the reader to note gill slits in the earliest stages of embryonic life. The term gill slits was dropped from the 1973 and 1977 editions, reappeared in the 1985 edition, and disappeared again from the 1991 and 1999 editions. The most recent textbook in this study to point out gill pouches in a Haeckel diagram was *Biology, Discovering Life* by Joseph Levine and Kenneth Miller (1994). Their Romanes' drawing, including a human embryo, instructed students that "…during the earliest stages of development, all these embryos have gill pouches and a tail—remnants of structures needed by our aquatic ancestors" (p. 163).

In some cases, texts tried to show that the gill slits in a fish and the gill slits in a human developed into different organs. This was seen as early as 1941 in Benedict's *Life Science* (see Figure 47) and continued through every decade of this study. Authors seemed to go out of their way to make clear that no one was claiming that humans at one time in their embryonic development possessed gills or breathed like a fish.



Embryo structures which become gills in fish develop into entirely different structures in other vertebrates.

Figure 47. Development of gill slits in man and fish. From *Life Science Based on High School Biology* (p. 138). By R. C. Benedict, 1941, New York: MacMillan.

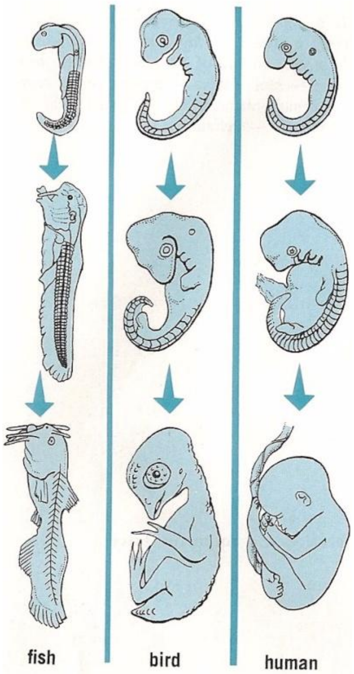
Human embryos and tails.

In Lynn M. Morgan's *Icons of Life: A Cultural History of Human Embryos* (2009), the author writes about Amenouhie T. Lamson (1916), a medical artist and writer who published a book written from the perspective of a developing embryo. The embryo discusses its life in the womb and along with it, states that its tail, suggestive of earlier ancestors, remained hidden from sight and fortunately was never observable at birth. Embryologists at this time probably would not have given the use of the word “tail” with a description of an embryo much thought. In 1916 most embryologists recognized a tail-like structure in human embryos that appeared at approximately forty-one days. The public, however, was shocked.

Morgan credits a Carnegie Department of Embryology anthropologist, Adolph Hans Schultz, as the main propagandist for associating tails with humans. In the early 1920s, Schultz wrote several scientific articles about the embryological evidence for evolution. In these he discussed tails in humans, macaques, orangutans, chimpanzees, and gorillas. He also included a drawing of a twelve-year-old boy from French Indo-China with a twenty-three centimeter long “soft” tail. Such vertebrae-less tails are occasionally seen on adult chimpanzees and orangutans, although these species are usually tail-less, just like humans. The presence of a tail was just one of several examples that Schultz offered in order to conclude that there was one common origin for all primates, including man (Schultz, 1925).

Morgan credits Lamson and Schultz for making embryo tails popular but she does not look at textbooks as a possible source of keeping the “tale alive.” By declaring that “the tail had largely vanished from public debates over embryos by the late twentieth century” (p. 167) Morgan perhaps inadvertently leads us to believe that embryos really do not have tails. But this is not true, in a scientific sense and in a science education sense: many textbooks that I examined pointed out that human embryos have tails. Most embryologists would agree with the present-day statement that human embryos do develop tails. At about four to five weeks of age, human embryos have a tiny vertebrate tail, extending outside of their body (Moore & Persaud, 1998). Sometime during the eighth week of age most human embryos’ tails have regressed due to cell death.

Even though Morgan writes about how people were horrified to think that apes and humans were related, humans and tails have existed rather peacefully in the educational picture. While the public may see tails as silly, embryonic tails are serious business in the realm of laboratory science. One of the texts that consistently discussed tails and human embryos was the popular *Modern Biology* textbook series. In the 1938, 1947, 1951,1956, 1960, and 1965 editions the same 5 x 3 grid of fish, salamander, turtle, bird and pig embryos were presented, with captions noting the presence of tail and gills slits in the earliest stages. In the 1985 revised edition of *Modern Biology* human embryos were represented for the first time, accompanied by a caption that explained how gill slits and tail buds are present in early embryos (see Figure 48).



13.7 Different stages in the development of three vertebrate organisms. Note their similarities in the very early stages. There is a stage in human development in which gill slits and a tail bud are present!

Figure 48 .Tails and gill slits in embryos. From *Modern Biology* (p. 188). By J. H. Otto and A. Towle, 1985, New York: Holt.

Modern Biology was not the only text to illustrate human embryos with tails. The first and second editions of *Biology: A Basic Science* by Heiss and Lape in 1958 and 1961 used the same 6 x 3 grid, including human embryos, to show that "all vertebrate embryos have long tails and gill slits in their early stages" (p. 499). In 1991's publication of *Heath Biology* , authors McLaren, Rotundo, and Gurley-Dilger used a modified type of Haeckel drawing to show how humans, birds, reptiles, and fish, in early stages of development, all have gills slits and tails. The second edition of *Biology, Discovering Life* by Joseph Levine and Kenneth Miller (1994) not only identified all early embryos in its Romanes' drawing as having gill pouches and a tail, but also stated that these remnants of structures were needed by our aquatic ancestors (see Figure 49).

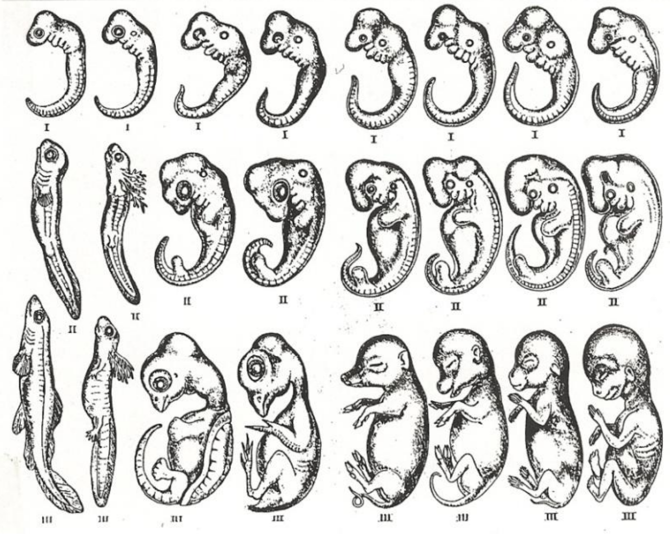


Figure 8.15 The early embryos of humans and other vertebrates look so similar that it takes an expert to tell them apart. During the earliest stages of development, all these embryos have gill pouches and a tail—remnants of structures needed by our aquatic ancestors.

Figure 49. Gill pouches, tails, and Haeckel embryos in 1994. From *Biology Discovering Life* (p.162). By J. Levine and K. Miller, 1994, Lexington, MA: Heath.

Because gill slits and tails are terms commonly used in texts, authors need to realize that gill slit and tail arguments are not viewed in the same way by scientists and the lay public. School science is what is presented in textbooks—rational, empirical, and authoritative. To students and the lay public, however, school science sometimes does not seem to be based on reality. That is, why would you label something as a “gill” or a “tail” if that isn’t exactly what it is?

The treatment of Haeckel’s embryos in textbooks.

It is well known that most biologists did not agree with the idea of recapitulation or Haeckel’s Biogenetic Law, starting as early as the late 1860s. One would think that by the time biology textbooks were published in the early 1900s, that Haeckel’s work might be hard to find. In the twentieth century though, Haeckel’s embryos were redrawn, revamped, and reproduced in many biology textbooks. There is something obviously appealing, and at the same time, problematic about his embryos. Examining Haeckel’s embryos has led me to conclude several things. First, embryos found within the context of Haeckel’s drawings have taken on many meanings. What started out as “embryos as comparative anatomy” has turned into “embryos as controversy.”

Prior to the 1940s, Haeckel’s embryos were associated with discussions about classification and animal reproduction. Beginning in the 1950s and rapidly expanding in the 1960s, the embryos were once again used as embryological evidence for evolution, just like they had been used in the late 1800s by Haeckel. In the 1980s and 1990s there were heated debates about the “rebirth” of recapitulation in high school and college biology textbooks. Text authors were accused of using Haeckel’s diagrams as a sort of conspiracy theory to push the idea of evolution. This study finds such assumptions an overreach. Are Haeckel’s drawings still found in texts? Yes. Are they used to justify recapitulation? No. Starting in fact, as early as 1919, textbook authors such as Gruenberg have stated that a strict interpretation of recapitulation was incorrect. I would add though, that even with disclaimers, the drawing speaks for itself: comparing Haeckel’s embryos looks like progressive evolution to the public.

My second conclusion is that while Haeckel's embryos are everywhere, Haeckel the man, is not. Authors still cling to Haeckel's embryos while distancing themselves from what Haeckel believed his embryos could show us. There is something missing in most of biology textbooks and that is a full explanation of the underlying complexity to Haeckel and his Biogenetic law. Recapitulation and embryogenesis are complex subjects that have been oversimplified to the point that serious omissions of controversy have simply weakened the concepts. Because of this, the manner in which Haeckel's diagrams are presented does little to promote student understanding and continues to muddle the evolution debate.

Third, whether knowingly done or not, Haeckel's embryos have been used by authors to transmit knowledge more about development than evolution. This is due in part to the blurring between von Baer and Haeckel's work. Ironically, von Baer is sometimes credited for Haeckel's embryo drawing and the Biogenetic Law, when in reality, von Baer was critical of Haeckel, recapitulation, and the theory of evolution (Pickett et al., 2005).

Last, there are certain periods where societal influence has impacted on the use of Haeckel's embryos. This occurred most noticeably with the decline of their use after the 1925 Scopes' Trial; in the 1970s and 1980s as creation science gained a foothold in public education and litigation surrounding the teaching of evolution increased (Ravitch, 2003, p. 71); and in the late 1990s with revived attention to Haeckel's "fraudulence." The latter is an unfortunate circumstance because with the advancement of molecular studies of embryo development in the 1990s, there has been renewed interest in the conservation of early development and the evolution of developmental mechanisms (Slack, Holland, & Graham, 1993). Numerous studies in the 1990s described possible evidence in favor of the Biogenetic Law (Richardson & Keuck, 2002), but this was excluded from textbooks in the 1990s. One of the purposes of textbooks is to make research science understandable and available to the public, but in this case, the only “renewed” interest with Haeckel’s embryos has been that of criticism. When textbook authors use Haeckel’s drawings to simply disparage Haeckel, or use them in a way that does not allow Haeckel’s work to be seen in its historical context, it does not encourage students to see comparative embryology as a serious scientific field of study.

CONCLUSIONS

As science and the public have changed the ways in which they use and perceive embryos, so too have textbooks changed their own use of embryos as teaching tools. When I first started this project I saw textbooks as a liaison between research and public science, but I tended to see the information going in only one direction, that of research going into a text and then read by a student. The word “liaison” though, means that there is a two-way street. While research and content come to textbooks from one side, educational and societal concerns often come in from another. All of these interests may converge to influence how and what gets published.

After examining so many textbooks, I returned to my framing questions to see if I could answer the questions that had driven my research. There are some types of textbook content, especially from the Biological Embryo Research Period (1827 to 1950s) that is consistently found in biology textbooks of the twentieth century. The tremendous amount of research done with various organisms to establish what “normal” development looked like resulted in new terminology and new facts that have continued to be presented as “new” to students. This includes descriptions of how normal embryos undergo cleavage to Hans Spemann’s studies with frog and salamander embryos. Such “reuse” of content would be expected since content is what the public has come to expect as “school science” (Lazarowitz, 2007). But descriptive statements were not the only way that embryos and fetuses were used. My examination has shown that the stability, organization, and emphasis on development has changed through the years in response to educational, political, and social forces. The story is in the textbooks.

Lag Time

Publishers are often criticized for the amount of time it takes for new scientific information to find its way to textbooks. I found this to be largely true, although there were exceptions, especially in the latter quarter of the twentieth century. For the most part, “new” embryology information in textbooks tended to lag behind one embryological research period. For example, when I looked at textbooks published from 1900 through 1949, a time representing the Biological Embryo Research Period, the texts remained highly descriptive and more representative of the previous Observed Embryo Research Period that occurred in the early 1800s. This was a time period characterized by the observation of many embryos of many different species.

In the 1950s, scientists began to see the embryo as inherited, in the sense of DNA and genes, but textbook embryology was still presenting the embryo as an outcome of marriage. The 1960s texts presented much more about the nature of science and brought in some developmental biology, but publishers seemed focused on bringing texts up to speed from a nature of science point of view and this did not always include recent developments in embryology.

Lag times decreased as the information age expanded, resulting in more updated information for texts published from the 1970s through the 1990s. This may have been due to several factors, including author preferences and the fast pace in which new research was published in journals, magazines, and on the internet. Because of this shortened lag time, the embryo now wore several hats: it was seen as a reproductive tool, a research tool, a clinical tool, and even a legal tool. The embryo, which had always been under the control of researchers, mothers, and doctors, had now developed a voice of its own—namely in courts that debated the legal rights of the unborn.

Levers

There were certain events that coincided with noticeable changes of how embryos were presented. Human embryos, in particular, exhibited a certain type of plasticity whereby they took on several different meanings, all within the same textbook. I have identified these social, political, and educational events that changed the perception of embryos as levers.

Lever 1: 1950s and baby production.

After WWII there was a growing awareness about increasing fertility rates and the growth of the AMA's position and power in American medicine. This can be seen in textbooks published during the late 1940s and through all of the 1950s. Here, the teaching of human reproduction in chapters about mammals was removed and placed in chapters on human reproduction, alone. The human embryo was now something to be taken care of and was placed entirely under the confines of medicine. Compared to the early 1900s when human reproduction was not publically written about, the 1950s textbooks presented the birth of a healthy child as a miraculous event, culminating from nine months of differentiation and development.

Lever 2: 1960s and BSCS.

The emergence of BSCS educational materials and the field of developmental biology in the 1960s helped change textbook embryology. As part of the Inherited Embryo Research Period, genes and differentiation had become part of the study of embryos in many laboratories. With efforts by BSCS writers to update curricular materials, molecular biology and genetics quickly became part of the discussion about embryos.

Textbooks were also used to address problems of overpopulation that were common during this time. BSCS in particular targeted this by introducing birth control methods as an aid to the problem of population growth. In what seemed a contradiction, the birth control methods discussion, implied for women in developing countries, was placed next to the *Birth Atlas* photos of childbirth, obviously intended for the more acceptable births of American children.

Lever 3: Roe vs. Wade (1973).

Although many texts avoided the contentious issue of abortion, the legalization of this medical procedure in the United States opened doors for textbook discussion about termination of pregnancies. In a few cases, BSCS authors reminded students that women could choose to have an abortion even in the absence of an unhealthy fetus and that abortion was a form of birth control to prevent overpopulation. For the most part though, when abortion was written about, it was presented to students as a last-resort option for women who learned that they were carrying a baby with serious defects. Discussion about abortions quickly dropped out of most textbooks starting in the late 1980s. If abortion was mentioned during this time, it was not done in the context of population control or simply because a woman did not want a child.

Lever 4: *In vitro* fertilization and Lennart Nilsson.

In vitro fertilization changed the way that textbooks presented human fertilization during the 1980s. It wasn't just the "birds and bees" anymore, but for the first time, fertilization of humans was shown occurring outside of the woman's body. Accompanied by Lennart Nilsson's large and colorful pictures of "space embryos and fetuses," the human embryo went from being highly descriptive to being more visible and manipulated. Textbooks helped cast the fetus into the feto-centrist spotlight, much like that of the seemingly never-ending supply of coffee table books and pamphlets designed for soon-to-be-parents that were popular at the same time. Embryos and fetuses in schoolbooks, however, have always been shown detached from their anatomical context. Even more, texts have rarely illustrated the fact that embryos actually develop inside a woman's body. I contend that the human embryo has *always* been a solitary being in biology textbooks.

Lever 5: Prenatal technologies and healthy embryos.

The coming together of the legalization of abortion in the United States and an era of technological enthusiasm acted as a lever to ramp up the need to take care of the embryo. More importance was now placed on diagnostics to keep embryos healthy. Compared to the 1950s where the risks of environmentally induced (and hence preventable) birth defects were discussed, the 1980s ushered in amniocentesis, ultrasound, and fetal surgery to help identify and “fix” non-preventable birth defects. The manner in which the fetus was viewed in the 1980s, with respect to human reproduction, was quite similar to that of the 1950s. That is, a healthy baby was the responsibility of mothers and their doctors (and in the 1980s, their scientists).

Lever 6: Genetic engineering and STS.

The technological revolution of the 1970s, combined with an STS approach to teaching biology in the 1990s, once again changed the way that embryos were viewed. Embryos were now presented as biosocial entities with a long list of technologies available for screening and therapies, including sex determination and genetic engineering. Outside of the classroom, questions about the fetus’ right to privacy, protection of the “defenseless,” and abortion debates grew louder. The public high school biology student saw all of this by the manner in which textbooks presented human embryos as clinical tools that could be manipulated in a seemingly fast and relentless pursuit of new reproductive technologies.

Lever 7: Fundamentalist reach into the classroom.

The teaching of evolution with biology textbooks has always been contentious, and there have been several periods in American history where the public’s acceptance of evolution as a natural process and as a valid area of study in high school biology have not matched the views of most scientists. These periods have directly affected the emphasis of evolution in texts as a result of publishers, authors, educators, and politicians responding to antievolutionists who have called for a suppression of the study of evolution (Skoog, 1978). These levers for change occurred in the 1930s and post-1960s. Evolution in 1930s texts had to cope with the aftermath of the Scopes Trial. Textbooks published in the 1970s through the 1990s had to appease both a growing American public that did not understand evolution and the rise of Intelligent Design in the 1990s. As publishers tried to keep their sales up, the attention given to evolution diminished and this impacted on the presence and use of Haeckel diagrams in textbooks.

Unease about what to do with Haeckel's embryos was apparent in the 1990s. It seems as if simply placing Haeckel's embryos in the "Evolution" chapter had become good enough for most authors. The captions that accompanied the drawings did little to explain how the embryos supported evolution or common ancestors. Haeckel's drawings have always been associated with the support of evolution but authors and publishers did not seem willing to go past the illustration and tie embryos and evolution together. It is as if authors wanted students to view the embryos and find the hidden message of support for evolution *for themselves*, without the text having to state, in print, that there was embryological evidence for evolution.

The levers did not always decrease the presence of Haeckel. In the 1960s, the use of Haeckel and discussion of evolution saw an unprecedented emphasis. This can be traced to the publication of six BSCS textbooks during the decade and the swift changes by other textbook authors to follow the lead of the BSCS writers. The validity and value of evolution as a biological concept during the 1960s had a direct impact on the inclusion of Haeckel's embryos in textbooks.

Future Textbook Presentations

By the end of the twentieth century, it was apparent that the embryo was no longer a fixed natural object but one that could be manipulated, socially constructed, and contested. The changing role of the embryo was inevitably shaped by not just what scientists did, but also by the social and political context in which the embryos and textbooks developed. As well-known anthropologist Sarah Franklin (1995) has written, the blastocyst is no longer confined to the clinic, but has been domesticated and is no longer strange. One reason for this is the manner in which textbooks have recently placed blastocysts in descriptive and ethical realms for student consumption. It would therefore be interesting to examine textbooks in the early 2000s to see how stem cell research, the Human Genome Project, and further cloning experiments have been presented. I would predict that texts addressed these avenues of research, but I also know that the textbook industry has undergone major consolidation and instead of many authors, there are now just a few. Even those few are becoming one voice. And that voice is heavily sanctioned.

Over the past two decades, textbook publishing has undergone tremendous change. From acquisitions, mergers, and exits, textbooks are now in the hands of mega-publishers (Ravitch, 2003). If an error or bias occurs in one text, there is a good chance that it will be repeated in other texts since they originate from the same company. Another change that has occurred is that textbooks are more and more being written by contract writers who work alongside the author(s). Contract writers may or may not have expertise in all aspects of biology. Given that writers bring in their own biases, the chapters covering development, reproductive science, and evolution may reflect their beliefs in language, tone, and examples. This is a poor substitute for genuine scholarship.

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APPENDIX A

BIBLIOGRAPHY OF BIOLOGY TEXTBOOKS

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BIBLIOGRAPHY B

MULTIPLE BIRTHS: ONE FAMILY’S SAGE

“Multiple Births: One Family’s Sage” from *Biology for Living* (1987) by Bruce Wallace and George M. Simmons.

May 22, 1985 (First page headline)
SIX BABIES BORN TO CALIFORNIAN, 7th IS STILLBORN
“It’s a neat experience.” (father)

May 23, 1985 (first page headline)
SIX SURVIVING SEPTULPLETS WEAKEN BUT DOCTORS SAY THEY’RE “FIGHTERS”
“There is no impending death right now, but they’re all critically ill.”(attending physician)
“The babies are “kicking around like polliwogs.”(father)

May 24, 1985 (12th page headline)
FOUR OF SURVIVING SEPTUPLETS ARE SHOWING IMPROVEMENT
“We were not out to set any records.” (father)

May 25, 1985 (first page headline)
SMALLEST SURVIVING SEPTUPLET DIES; DOCTORS GIVE REST 50-50 CHANCE

May 27, 1985 (8th page headline)
MOTHER OF 7 VISITS SURVIVING INFANTS
Prognosis is “hopeful and for some of the babies quite good.” (attending physician)

May 29, 1985 (14th page headline)
BABIES A TO G ARE NAMED ON WEST COAST
“There is no reason for me to think these babies won’t have a full chance for survival and normal development.” (attending physician)

October 9, 1985 (small news item)
PARENTS OF SEPTUPLETS DUE DOCTOR AND CLINIC
The parents of three surviving septuplets filed a malpractice and wrongful death suit today seeking more than $2.2 million from the doctor and clinic that gave the mother fertility drugs…The three surviving children face a lifetime of medical problems including optic nerve damage, hernias, chronic lung disease, and heart damage according to the family attorney.