Proposed Revisions to Kansas Science Standards Draft 1[1] With Explanations

December 10, 2004

SUMMARY OF PROPOSED REVISIONS

1. Revisions to the Introduction (page 2):

a. Add the word "informed" to the mission statement
b. Use an evidence based rather than a naturalistic definition of science.
c. Permit teachers to discuss evidence for and against evolution in a neutral way.
d. Incorporate advice provided by Congress in adopting the No Child Left Behind Act of 2001
e. Acknowledge the fact that science has answered some important questions, but not all of them.

2. Revisions to 8th Grade Standard 3, BM 5 (dealing with evolution) and Standard 4, BM 2, dealing with earth sciences (page 7). A minor addition makes it clear that evolution is a theory, and not a fact. An additional indicator should help students understand how the historical nature of many aspects of paleontology and earth science affects investigation, testing and explanation.

3. Revisions to 12th Grade, Standard 1, Benchmark 1 dealing with procedures for scientific investigations and the testing of scientific hypotheses (page 11). The suggestions make it clear that students should consider the possibility of institutional as well as personal bias and be aware of how scientists seek to test historical hypotheses.

4. 12th Grade, Standard 3, Benchmark 2, dealing with DNA and the genetic code (page 13). This suggestion will have students understand that the order of the nucleotide sequences within genes are not dictated by any known chemical or physical law, a fact critical to evolutionary theory and the origin of life.

5. 12th Grade, Standard 3, Benchmark 3, dealing with evolution (page 14). This proposal offers a more complete description of biological evolution, the evidence that supports it and the scientific controversy that surrounds it.

6. 12th Grade, Standard 7, dealing with the history and nature of science (page 18). These proposals encourage students to understand that science:

a. affects beliefs about a broad range of issues.
b. uses empirical methods where possible; and
c. has influenced both positive and negative cultural consequences.

7. Revisions to the glossary to reflect the above suggestions (page 21).

Notes: page 21

Proposed Revisions to
Kansas Science Standards Draft 1

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(Proposed additions are shown in ***bold italics*** and deletions in ~~strikeouts~~)

Introduction to Explanations

Sound reasons exist for the Board to consider the Proposals at this time. They raise substantive issues of policy and science and reflect the recommendations of a significant segment of the entire writing committee. Submission is timely because the process for public comment, outside review and Board Consideration has commenced. Furthermore, the extent of support for Draft 1 and even the Proponents Proposals within the full committee is uncertain. [2] None of Draft 1 or the Proposals have been voted on by the full committee. The only proposals put to the vote of the full committee has been the evolution Benchmark. That vote resulted in no committee consensus on any evolution proposal. Accordingly, the evolution benchmark in Draft 1 merely reflects the existing evolution benchmark by default. Given these circumstances, Proponents believe the Board and the public should now be provided an opportunity to consider this alternative viewpoint.

The proposed revisions are reflected within the context of other provisions so that their significance may be more fully understood. Following each set of proposals is a brief narrative under the caption **"Explanation."** The narratives seek to provide general rather than detailed explanations. Further detail will be provided as requested.

1. Proposed changes to the Introduction

a. Introduction - Mission of science education

Mission Statement
Kansas science education contributes to the preparation of **all** students as lifelong learners who can use science to make ***informed and*** reasoned decisions that contribute to their local, state, national and international communities.

Explanation: This two-word change perhaps reflects the core of the controversy between Proponents and Opponents. Opponents seek to significantly limit the amount of scientific information provided to students about the most fundamental question humanity may address – What is the origin of life and its diversity? Where do we come from? They would narrow the scope of information to that which will not contradict the naturalistic claim that life is adequately explained by chance interactions of matter according to the laws of physics and chemistry. This philosophy allows only "natural" or mechanistic material causes for the origin and diversity of life. It requires that evidence and criticisms that challenge Darwinian evolution (the primary theory that supports the philosophy of Naturalism) not be permitted.

It is reasonable to expect that this viewpoint discrimination will necessarily have the effect of causing students to reach an uninformed, but "***reasoned"*** decision that they, and all other human beings, are merely natural occurrences, accidents of nature that lack intrinsic purpose. The proponents do not believe that this is a correct deduction to draw from current science evidence. For reasons explained elsewhere, we believe that limiting the mix of information not only does violence to good science, but it will tend to indoctrinate rather than to inform and educate.

Further, an indoctrination in the philosophy of Naturalism would seem to offend Constitutional principles. It causes the State of Kansas to take sides in a debate that unavoidably impacts both theistic and non-theistic religious beliefs. The antidote to all of these scientific and Constitutional problems is to present additional relevant scientific information regarding origins, evidence that tends to support and refute the competing claims, so that origins science is presented objectively and without religious or naturalistic bias and assumption. This will reflect the best of science while also putting the State in a position of Constitutional neutrality rather than that of an advocate for Naturalism, a philosophy key to non-theistic belief systems.

Absent complete information, reason is hobbled. For example, those who purchased Enron stock made "reasoned" decisions regarding the financial state of the company that turned out to be quite faulty due to incomplete information regarding off-balance sheet liabilities. The primary function of education is to inform – to impart knowledge. According to the National Science Standards we are to become a scientifically literate society where "scientific information and scientific ways of thinking" will influence "informed decision making" in practically all areas of one's life.[3]

The guiding rationale for these Proposals is to achieve this educational objective so that students will be better equipped to make reasoned decisions that are "informed."

b. Introduction – Nature of Science

As an alternative to the proposal of the Chair and Co-Chair[4] for a completely revised "Nature of Science" section in Draft 1, this proposal recommends the retention of the existing material under the Nature of Science in the current standards except for a revision to the definition of science and the addition of two new paragraphs at the end of the section. Accordingly, the changes shown below reflect changes to the Nature of Science section in the existing standards adopted by the Board on February 14, 2001.

Nature of Science

Science is a systematic method of continuing investigation, that uses observation, hypothesis testing, measurement, experimentation, logical argument and theory building, to lead to more adequate explanations of natural phenomena. ~~Science is the human activity of seeking natural explanations for what we observe in the world around us.~~ Science does so ~~through the use of observation, experimentation, and logical argument~~ while maintaining strict empirical standards and healthy skepticism. Scientific explanations are built on observations, hypotheses, and theories. A hypothesis is a testable statement about the natural world that can be used to build more complex inferences and explanations. A theory is a well-substantiated explanation of some aspect of the natural world that can incorporate observations, inferences, and tested hypotheses.

Scientific explanations must meet certain criteria. Scientific explanations are consistent with experimental and/or observational data and testable by scientists through additional experimentation and/or observation. Scientific explanation must meet criteria that govern the repeatability of observations and experiments. The effect of these criteria is to insure that scientific explanations about the world are open to criticism and that they will be modified or abandoned in favor of new explanations if empirical evidence so warrants. Because all scientific explanations depend on observational and experimental confirmation, all scientific knowledge is, in principle, subject to change as new evidence becomes available. The core theories of science have been subjected to a wide variety of confirmations and have a high degree of reliability within the limits to which they have been tested. In areas where data or understanding are incomplete, new data may lead to changes in current theories or resolve current conflicts. In situations where information is still fragmentary, it is normal for scientific ideas to be incomplete, but this is also where the opportunity for making advances may be greatest. Science has flourished in different regions during different time periods, and in history, diverse cultures have contributed scientific knowledge and technological inventions.

Changes in scientific knowledge usually occur as gradual modifications, but the scientific enterprise also experiences periods of rapid advancement. The daily work of science and technology results in incremental advances in our understanding of the world about us.

According to many scientists a core claim of evolutionary theory is that the apparent design of living systems is an illusion.[5] Other scientists disagree. These standards neither mandate nor prohibit teaching about this scientific disagreement. However, to promote good science, good pedagogy and a curriculum that is secular, neutral and non-ideological, school districts are urged to follow the advice provided by the House and Senate Conferees in enacting the No Child Left Behind Act of 2001:

> ***"The Conferees recognize that a quality science education should prepare students to distinguish the data and testable theories of science from religious or philosophical claims that are made in the name of science. Where topics are taught that may generate controversy (such as biological evolution), the curriculum should help students to understand the full range of scientific views that exist, why such topics may generate controversy, and how scientific discoveries can profoundly affect society."***

Explanation:

The principle change here is to replace a naturalistic definition of science with a traditional definition. The current definition of science is intended to reflect a concept called ***methodological naturalism***, which irrefutably assumes that cause-and-effect laws (as of physics and chemistry) are adequate to account for all phenomena and that teleological or design conceptions of nature are invalid. Although called a "method of science," the effect of its use is to limit inquiry (and permissible explanations) and thus to promote the philosophy of Naturalism. In effect, this "method" is actually a doctrine because its key tenets or "assumptions" are not refutable and are not generally disclosed. Whether or not intended, the effect of this construct is to cause students to accept as true its unstated premise. This can be reasonably expected to lead one to believe in the naturalistic philosophy that life and its diversity is the result of an unguided, purposeless natural process. This is both scientifically and Constitutionally problematic.

Methodological naturalism is scientifically problematic in origins science because it violates two key aspects of the scientific method. It philosophically limits both the formation and testing of competing hypotheses. It limits hypothesis formation by philosophically ruling out a logical, evidence-based competitor to the evolutionary hypothesis, that is, that life and its diversity are the result of a process that is at least partially guided. Criticisms of the naturalistic hypothesis are also disallowed to ensure that the outlawed competitor does not intrude through the back door. Without any substantive competitor, evolution cannot be effectively tested or falsified, and is thereby converted into a dogma, doctrine or ideology. As such, naturalistic evolution actually ceases to fall within the realm of science.

In a recent paper the kind of materialistic reductionism required by methodological naturalism has been charged with actually being detrimental to the conduct of science.[6] It is even questionable whether methodological naturalism is actually used by scientists who seek to understand the function of biological systems. In many cases these systems are treated as if they were actually designed; assembled to perform a function. This was recently discussed by a Michael Ruse, a prominent philosopher of science:

> "Both history and present Darwinian evolutionary practice have shown us that this kind of design-type thinking is involved in the adaptationist paradigm. We treat organisms – ***the parts at least*** -- as if they were manufactured, as if they were designed, and then we try to work out their functions. End-directed thinking – teleological thinking – is appropriate in biology because, and only because, ***organisms seem as if they were manufactured***, as if they had been created by an intelligence and put to work."[7]

Ruse's comment is reflected in a recent anthology that contains a long list of questions unanswered by standard evolutionary theory. In describing these problems, the authors repeatedly refer to them as problems of "design."

> "The nature of the determinants and rules for the organization of **design** elements constitutes one of the major unsolved problems in the scientific account of organismal form."[8]

Thus, rather than using methodological naturalism in the actual work of science, it seems that scientists are actually using "methodological design."

Methodological naturalism has also served as a science stopper in our understanding of biochemical systems. For example, for many years scientists predicted that the non-coding portions of the genome were merely evolutionary "junk" that accumulated over eons of time and were not worthy of scientific study. Scientists are now finding these portions to be functional, and some have expressed frustration that the "junk" assumption has actually held back scientific progress.[9]

The irrefutable nature of Methodological Naturalism renders it inconsistent with the key tenet of science that all explanations are subject to refutation. This need for criticism is expressed as follows on page 4 of the current Introduction:

> "The effect of these criteria is to insure that scientific explanations about the world are open to criticism and that they will be modified or abandoned in favor of new explanations if empirical evidence so warrants." [Nature of Science, page 4]

Although the current standards use methodological naturalism, they do not inform students of its use, purpose or effect. That need is explained in *Science for All Americans, On-Line,* Chapter 1:

> THE SCIENTIFIC ENTERPRISE. "When faced with a claim that something is true, scientists respond by asking what evidence supports it. ***But scientific evidence can be biased*** in how the data are interpreted, in the recording or reporting of the data, ***or even in the choice of what data to consider in the first place.***
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> "Bias attributable to the investigator, the sample, the method, or the instrument may not be completely avoidable in every instance, but ***scientists want to know the possible sources of bias and how bias is likely to influence evidence.*** Scientists ***want***, and ***are expected***, to be as ***alert to*** possible ***bias*** in their own work ***as in that of other scientists***, although such objectivity is not always achieved.**"** (emphasis added)

In addition to being scientifically problematic, the use of an irrefutable assumption in origins science may be Constitutionally problematic. During the meeting on October 28, 2004, John Calvert, a lawyer who has studied the constitutional issue for the last five years, explained why the current definition of science (the one proposed by our Opponents) is not consistent with the requirement that educational materials be secular, neutral and non-ideological. Methodological naturalism effectively converts evolution into an irrefutable ideology that is not secular or neutral. Naturalism is the fundamental tenet of non-theistic religions and belief systems like Secular Humanism, atheism, agnosticism and scientism.

Proponents believe the most effective way to solve both the scientific and constitutional problem is to use a traditional definition of science that will encourage thinking "outside of the box" and open up the discussion to multiple scientific viewpoints. This idea is reflected in the sentiment of the Congress when it adopted the No-Child Left Behind Act. We believe that perspective should be included in the Introduction so that school districts and teachers will understand that they are empowered to address origins science objectively.

c. Introduction – Teaching With Tolerance and Respect.

A teacher is an important role model for demonstrating respect, sensitivity, and civility. Science teachers should not ridicule, belittle or embarrass a student for expressing an alternative view or belief. In doing this, teachers display and demand tolerance and respect for the diverse ideas, skills, and experiences of all students. ~~If a student should raise a question in a natural science class that the teacher determines to be outside the domain of science class, the teacher should treat the question with respect. The teacher should explain why the question is outside the domain of natural sciences and encourage the student to discuss the question further with his or her family and other appropriate sources.~~

Explanation: The parameters defining "the domain of science" are ambiguous and scientifically controversial, and thus teachers cannot be expected to be able to accurately identify such questions. We should encourage children to ask questions and critically analyze theories and hypotheses. This provision has previously been identified as a mechanism for suppressing classroom discussions that may conflict with Naturalism or scientific materialism, a philosophy that the Proponents contend should not guide science education about origins. Again the effect of this provision is counter to the mission of public education which is to inform rather than to indoctrinate.

d. Introduction – Unifying Concepts …. Patterns of Cumulative Change

"**Patterns of Cumulative Change**: Accumulated changes through time, some gradual and some sporadic, account for the present form and function of objects, organisms, and natural systems. The general idea is that the present arises from materials and forms of the past. An example of cumulative change is the biological theory of evolution, which explains the process of descent with modification of organisms from common ancestors. Additional examples are continental drift, which is part of plate tectonic theory, fossilization, and erosion. Patterns of cumulative change also help to describe the current structure of the universe. ***Although science proposes theories to explain changes, the actual causes of many changes are currently unknown (e.g. the origin of the universe, the origin of fundamental laws, the origin of life and the genetic code, the origin of major body plans during the Cambrian explosion, etc.).***

Explanation: This change is self explanatory. We should not lead students into believing that science is all-knowing and has the answers to all questions.

2. The following proposals relate to 8th_Grade Standards

a. Revise the "Teacher's Notes" to Standard 3, Benchmark 5 as indicated:

STANDARD 3: LIFE SCIENCE **Eighth Grade**

As a result of activities in grades 5-8, the students will apply process skills to explore and understand structure and function in living systems, reproduction and heredity, regulation and behavior, populations and ecosystems, and diversity and adaptations of organisms.

Benchmark 5: The students will observe the diversity of living things and relate their adaptations to their survival or extinction.

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TEACHER NOTES:

Millions of species of animals, plants and microorganisms are alive today. Animals and plants vary in body plans and internal structures. Biological evolution ***theorizes that*** gradual changes of characteristics of organisms over many generations, has resulted in variations among populations and species. Therefore, a structural characteristic, process, or behavior that helps an organism survive in its environment is called an adaptation. When the environment changes and the adaptive characteristics are insufficient, the species becomes extinct.

As they investigate different types of organisms, teachers guide students toward thinking about similarities and differences. Students can compare similarities between organisms in different parts of the world, such as tigers in Asia and mountain lions in North America to explore the concept of common ancestry. Instruction needs to be designed to uncover and correct misconceptions about natural selection. Students tend to think of all individuals in a population responding to change quickly rather than over a long period of time. Using examples such as Darwin's finches help develop understanding of natural selection over time. Providing students with fossil evidence and allowing them time to construct their own explanations is important in developing middle level students' understanding of extinction as a natural process that has affected earth's species over time.

= Recommended Grade 7 Assessed Indicator (Grade 8: Also see Grade 10 Assessed indicators in Science Standards for Gr. 9-12.)

Explanation: It is important to distinguish between theory and fact. The statement that evolution has accomplished a variety of things in many cases does not represent a statement of fact, but rather represents a theoretical explanation in part supported by philosophical assumptions that may or may not be true. The insertion of "***theorizes that"*** is intended to reflect this important distinction. The argument is frequently heard that evolution should not be singled out from among many scientific theories for special treatment. We believe the theoretical modifier is needed for this concept given a) the many evolutionary problems that remain unanswered,[10] b) its unique impact on religion, c) its historical nature, and d) the strident efforts by many in the scientific community to suppress critical analysis of its claims and to discourage teachers from discussing the theory with candor.

b. Revise 8th Grade, St. 4 (Earth and space science), Benchmark 2 to add indicator 4 and additional explanatory material to the Teachers Notes:

STANDARD 4: EARTH and SPACE SCIENCE **Eighth Grade**

As a result of activities in grades 5-8, the students will apply process skills to explore and develop an understanding of the structure of the earth system, earth's history, and earth in the solar system.

Benchmark 2: The students will understand past and present earth processes and their similarity.

Eighth Grade Indicators	Instructional Examples
The student… 1. # understands that earth processes observed today (including movement of lithospheric plates and changes in atmospheric conditions) are similar to those that occurred in the past; earth history is also influenced by occasional catastrophes, such as the impact of a comet or asteroid. 2. models geologic time to scale and relates geologic evidence to a record of earth's history. 3. understands that matching coastlines, similarities in rock types, similarities in fossils and life forms suggest that today's continents are separated parts of what was long ago a single continent. ***4. Tests an historical hypothesis by formulating a competing hypotheses and then describing the kinds of data (evidence) that would support one and refute the others.***	The student… 1a. constructs models of rock types using food. (Peanut brittle without the peanuts can illustrate a molten material crystallizing to form a solid substance similar to an igneous rock.) 1b. uses an acid (vinegar or dilute HCl) to show the chemical similarity of limestone rock and fossilized shells. 1c. takes a piece of sandstone and applies destructive forces to change it into sand. 1d. observes the effects of weathering on various rock types. 2a. plots the major events (last ice age, beginning of Paleozoic Era, etc.) of earth history on a roll of adding machine tape. 2b. locates the same rock layer in two local road cuts; gives fossil evidence and other kinds of evidence that the layer is the same in both exposures. 2c. compares the types of organisms shown in the fossils found in a Kansas shale (mudstone) and a Kansas limestone and infers the ocean depositional environment from which the rock layer was formed. 3. cuts out continents from a world map and slides them together to see how they fit. Plots each continental plate's latitude and longitude through earth's history. Compares the current arrangement of the continents with the arrangement of continents throughout earth's history. ***4. Develops a "best current explanation" of what caused dinosaur extinction by reviewing the evidence for the asteroid theory vs. disease, volcanism and other theories. [See Carol Cleland, Historical Science, Experimental Science and the Scientific Method, Vol 29 No. 11, 987-990 (Geology, November 2001)].***

TEACHER NOTES:

The constructive and destructive forces we see today are similar to those that occurred in the past. Earth's history is written in the layers of the rocks, and clues in the rocks can be used to piece together a story and picture. Geologic processes that form rocks and mountains today are similar to processes that formed rocks and mountains over a long period of time in the distant past.

Teachers can provide opportunities for students to observe and research evidence of changes that can be found in earth's crust. Sedimentary rocks, such as limestone, sandstone, and shale show deposition of sediments over time. Volcanic flows of ancient volcanoes and earthquake damage can show us what to expect from modern day catastrophes. Glacial deposits show past ice ages and global warming and cooling. Some fossil beds enable the matching of rocks from different continents, and other fossil beds show how organisms developed over a long period of time. Students will need to apply knowledge of earth's past to make decisions relative to earth's future.

Students should understand that many aspects of paleontology and earth science are historical in nature where one seeks to explain the cause of singular unobserved past events from presently existing evidence. Techniques used in science to explain the cause of past events are similar to techniques used by forensic scientists. Like detectives, historical scientists develop tentative competing hypotheses and then seek clues that will rule in one while ruling out others. In many cases historical hypotheses may not be confirmed by experiment due to unknown variables and the inability to replicate conditions in the laboratory. As new clues are developed, historical hypotheses frequently change or are discarded entirely. As a consequence, in historical sciences one generally seeks "an inference to the best current explanation," with the understanding that the explanation may not be the "best" in the future.

= Recommended Grade 7 Assessed Indicator (Grade 8: Also see Grade 10 Assessed indicators in Science Standards for Gr. 9-12.)

Explanation: The additions are fairly self-explanatory. Although historical sciences remain in the realm of science, they differ from sciences like physics and chemistry that seek to understand what things are composed of and how they work in the present. This was explained by Ernst Mayr, a highly regarded evolutionary biologist, in an essay that touched on the differences between evolutionary biology and physics and chemistry:

> ".....Darwin introduced historicity into science. Evolutionary biology, in contrast with physics and chemistry, is a historical science – the evolutionist attempts to explain events and processes that have already taken place. **Laws and experiments are inappropriate techniques for the explication of such events and processes.** Instead **one constructs a historical narrative**, consisting of a tentative reconstruction of the particular scenario that led to the events one is trying to explain." (emphasis added) [Ernst Mayr, "*Darwin's Influence on Modern Thought,*" p. 80, (July 2000, Scientific American)].

Historical hypotheses, which are not susceptible to confirmation by experiment, are tested by seeking to rule out competing hypotheses on the basis of the available evidence. Historical sciences seek to find the current "best explanation."[Carol Cleland, *Historical Science, Experimental Science and the Scientific Method,* Vol 29 No. 11, 987-990 (Geology, November 2001)]. According to Cleland, the failure to rule out (or to even seek to rule out) a competing historical hypothesis leaves the favored hypothesis as nothing more than a speculation or a "dreaded just-so story."

Many scientists argue that historical hypotheses are not truly scientific because they cannot be tested by experiment. Kenneth Miller, a cell biologist and professor of biology, notes that: "Unfortunately there is a school of thought that rejects the very idea that any theory about the past can be scientific." According to this theory "Science is based on experiment and direct, testable observation…" and is therefore limited to laboratory sciences. Kenneth Miller, *Finding Darwin's God*, (Cliff Street Books, 1999), pp. 22-23. See also, Carol Cleland (*Historical Science, Experimental Science and the Scientific Method,*(Geology, November 2001, Vol 29 No. 11, 987-990)]. Kenneth Miller recognizes that the way one confirms an historical hypothesis is the same method used by the police department in their forensic investigations:

> "Is scientific inquiry restricted to what we can actually bring into the laboratory and see happening right in front of us? Is there really any scientific way that we can know *anything* about the past at all? There is indeed a way to do this, and the process is so ordinary that most of us take it for granted. .....**The simple fact is that we can learn about the past by applying good, old fashioned detective work to the clues that have been left behind.** The same rules applies to science. We may not be able to witness the past directly, but we can reach out and analyze it for the simple reason that the past left something behind....." (Miller, p. 22-23)

Both Miller and Cleland argue that historical inquiries do fall within the scope of science because they are amenable to forensic techniques that essentially seek evidence that both rules in a particular hypothesis and, at the same time, rules out the competing hypotheses. Failure to allow this competition, however turns the favored claim into nothing more than a speculation or "just-so" story. Miller and Cleland would agree that students should understand that the credibility of any historical explanation is significantly influenced by strength of the available "clues," by the assumptions made (which may or may not be stated and which may or may not be evidentially supported), by the imagination of the investigator as she draws inferences from the data, and by the extent to which the investigation has considered and responded to competing hypotheses.

3. The following proposal relates to 12th Grade Standard 1, Benchmark 1

Revise instructional example 4.c. and add a new indicator 6.

STANDARD 1: SCIENCE AS INQUIRY **Twelfth Grade**

As a result of their activities in grades 9-12, all students will develop the abilities necessary to do scientific inquiry and develop an understanding of scientific inquiry.

Benchmark 1: Students will demonstrate the abilities necessary to do scientific inquiry.

Twelfth Grade Indicators	Additional Specificity
The student… 1. Develops an understanding of the natural world through experience in order to ask and evaluate research questions.	# = Recommended Sr. High Assessed Indicator
2. # identifies and utilizes concepts that guide scientific investigations, including developing questions, gathering data, and design and conducting research	2. Further concepts include, when appropriate, a. formulating a testable hypothesis, b. utilizing variables, such as independent, dependent, and controls c. determining methods for gathering data that is observable, measurable, and replicable d. using statistical and graphing data analysis techniques e. evaluating the results in order to clarify the questions and hypotheses, and to refine methods for further research.
3. # uses technological tools and mathematics in scientific investigations.	3. a. uses a variety of technologies, such as hand tools, measuring instruments, calculators, and computers as an integral component of scientific investigations. b. uses common mathematical functions (linear, exponential, etc.) to analyze and describe data c. recognizes that the accuracy and precision of the data, and therefore the quality of the investigation, depends on the instruments used. d. uses equipment properly and safely.
4. # as part of conducting an inquiry, formulates and revises his or her scientific explanations and models (physical, conceptual, or mathematical) using logic and evidence, recognizing that potential alternative explanations and models should be considered.	4. a. engages in discussions that result in the revision of his/her explanation. b. analyzes their explanation by reviewing current scientific understanding, weighing the evidence, and examining the logic so as to decide which explanations and models have the greatest explanatory power. c. evaluates ~~personal~~ preconceptions and biases with respect to his/her conclusions.

5. communicates and defends the design, results, and conclusion of his/her investigation.	5. a. writes procedures, expresses concepts, reviews information, summarizes data, and uses language appropriately, b. develops diagrams and charts to summarize and analyze data c. presents information clearly and logically, both orally and in writing d. constructs reasoned arguments e. responds appropriately to critical comments.
6. understands methods used to test those historical hypotheses that cannot be confirmed by experiment and/or direct observation, including the development of multiple competing hypotheses and the collection of evidence that both rules in one hypothesis while ruling out others.	***6*** ***a. Formulates multiple hypotheses about a singular historical event such as the origin of a formation of sandstone or the cause of a fire or death.*** ***b. Postulates multiple competing explanations for the event*** ***c. Predicts the kinds of circumstantial evidence that one would observe under each hypothesis.*** ***d. Collect evidence and draw an inference as to the best explanation and whether the evidence fits either hypothesis. Explain why either explanation can not be entirely validated by a laboratory experiment.***

Explanation:

The revision to paragraph 4(c) under Additional Specificity is necessary to ensure that the recipient of the explanation evaluates the effect of any material bias or preconception that affects the explanation, whether or not "personal."

This Standard and Benchmark seek to inform students about the scientific method and how one forms and tests a hypothesis. However, most of the discussion is implicitly focused on the formation and testing of hypotheses that may be tested in the laboratory or the field by direct experimentation. What the Benchmark lacks is a discussion of methodology for testing historical hypotheses about the cause of unobserved past events that may not be rigorously confirmed by observation and experiment. This omission is cured by the addition of a new indicator 6.

See also the discussion regarding the addition to Eighth Grade, Standard 4, Benchmark 2 regarding earth sciences. It is important for students to recognize that different methods are used in the testing of historical hypotheses about the cause of a past event as opposed to an hypothesis about what something is made of or why a living system behaves in a particular way. These may be tested under controlled conditions by experiment. Explanations about the cause of past events are inherently more subjective because they rely to a large extent on imagination and inference to supply missing evidence. Even a laboratory demonstration that an outcome is physically possible (e.g., amino acids forming in a defined chemical atmosphere), does not mean that such an outcome actually occurred in the history of nature.

4. The following proposal revises Indicator 1 of 12th Grade, Standard 3, Benchmark 2 to add an additional item explaining that the order of the nucleotide sequences within a gene is not dictated by any known chemical or physical law.

STANDARD 3: LIFE SCIENCE **Twelfth Grade**

As a result of their activities in grades 9-12, all students will develop an understanding of the cell, molecular basis of heredity, biological evolution, interdependence of organisms, matter, energy, and organization in living systems, and the behavior of organisms.

Benchmark 2: Students will demonstrate an understanding of chromosomes, genes, and the molecular basis of heredity.

Twelfth Grade Indicators	Additional Specificity
The student understands that … 1. # all living organisms contain DNA or RNA as their genetic material, which provides the instructions that specify the characteristics of organisms. 2. …….	# = Recommended Sr. High Assessed Indicator 1. a. **Nucleotides** (adenine, thymine, guanine, cytosine and uracil) make up DNA and RNA molecules. b. Sequences of nucleotides that either determine or contribute to a genetic trait are called genes. **c. *The order of the nucleotide sequences within the gene is not dictated by any known chemical or physical law.*** d. DNA is replicated by using a template process that usually results in identical copies. e. DNA is coiled in chromosomes during cell replication. 2.…….

Explanation. The lack of any law that dictates the sequence was actually predicted by Watson and Crick and aided their discovery of the structure of DNA:

> "So in building models we would postulate that the sugar-phosphate backbone was very regular, and the order of bases of necessity very irregular. If the base sequences ***were always the same***, all DNA molecules would be identical and there would not exist the variability that must distinguish one gene from another." **[James Watson,** *The Double Helix:A Personal Account of the Discovery of THE STRUCTURE OF DNA,* p 52-4 (Touchstone 1968)]

This fact was described by Jacques Monod in his famous essay *Chance & Necessity* as the principle mystery in biology.[11]

5. The following revisions relate to 12th Grade, Standard 3, Benchmark 3. They seek to more fully inform students regarding the theory of biological evolution

These Proposals include a substantial increase in the amount of information presented about biological evolution. Structurally, the indicators in existing Standard 3, Benchmark 3 have been reordered and renumbered in order to improve their logical flow and clarity. Indicator 2 was reordered and renumbered as Indicator 4, and Indicators 3 and 4 were reordered and renumbered as Indicators 2 and 3, respectively. In addition, the "additional specificity" (i.e., information in the right column) under renumbered indicator 4 has been reordered to show the first expression last. In all cases the additional specificity has been divided into subparagraphs and assigned subparagraph letters not found in the existing benchmark.

STANDARD 3: LIFE SCIENCE **Twelfth Grade**

As a result of their activities in grades 9-12, all students will develop an understanding of the cell, molecular basis of heredity, biological evolution, interdependence of organisms, matter, energy, and organization in living systems, and the behavior of organisms.

Benchmark 3: Students will understand the major concepts of the theory of biological evolution.*

The student understands…	Additional Specificity
1. the theory of evolution is both the history of descent, with modification of different lineages of organisms from common ancestors, and the ongoing adaptation of organisms to environmental challenges and changes (modified from Futuyma, et al., 1999).	**1. *a. Biological evolution postulates an unpredictable and unguided natural process that has no discernable direction or goal. [see NABT Statement on teaching evolution]*** ***b. It assumes that life arose from an unguided natural process.***
2. ~~biologists recognize~~ that the primary mechanisms of evolution are natural selection and genetic drift.	2. Natural selection includes the following concepts: a. heritable variation exists in every species; b. some heritable traits are more advantageous to reproduction and/or survival than are others; c. there is a finite supply of resources required for life; not all progeny survive; d. individuals with advantageous traits generally survive to reproduce; e. the advantageous heritable traits increase in the population through time. ***f. changes in allelic frequency (genetic drift)***

3. the sources and value of variation.	*a.* **Advantageous** *variation of organisms within and among species increases the likelihood that some members will survive under changed environmental conditions.* *b. New heritable traits primarily result from new combinations of genes and secondarily from* **random** *mutations or changes in the reproductive cells.* **Except in very rare cases, mutations that may be inherited are, neutral, deleterious or fatal. [Douglas J. Futuyma *, Evolutionary Biology,* p.278 (1999)]** *c*. changes in ***somatic*** ~~other~~ cells of a sexual organism are not passed to the next generation.
4. ~~biologists use~~ evolution theory ***is used*** to explain the earth's present day biodiversity—the number, variety and variability of organisms.	a. Natural selection, and other processes, can cause populations to change from one generation to the next, ***a process called "microevolution."*** A single population can separate into two or more independent populations. Over time, these populations can also become very different from each other. If the isolation continues, the genetic separation may become irreversible. This process is called speciation ***or "macroevolution."*** b. Populations, and entire lineages, can go extinct. One effect of extinction is to increase the apparent differences between populations. As intermediate populations go extinct, the surviving lineages can become more distinct from one another. c. ***Whether microevolution can be extrapolated to explain macroevolutionary changes (such as new complex organs or body plans and new biochemical systems which appear irreducibly complex) is not clear. These kinds of macroevolutionary explanations generally are not based on direct observations and are historical narratives based on inferences from indirect or circumstantial evidence. [Ernst Mayr, "Darwin's Influence on Modern Thought," p. 80, (July 2000, Scientific American)]*** d. patterns of diversification and extinction of organisms are documented in the fossil record. The fossil record provides evidence that simple, bacteria-like life ***may*** have existed as far back as *3.8*+ billion years ago ***(about the time earth first became habitable to any form of life)***, ***In many cases the fossil record is not consistent with gradual, unbroken sequences postulated by biological evolution.***

5. that evolution is a broad, unifying theoretical framework in biology.	**a.** ***Micro***evolution provides the context in which to ask research questions and yields valuable insights, especially in agriculture and medicine. ***Reverse engineering and end-directed thinking are used to understand the function of bio-systems and information [Michael Ruse, Darwin and Design: Does evolution have a purpose?, p. 268 (Harvard, 2003)].*** b. The ***postulated*** common ancestry of living things allows them to be classified into a hierarchy of groups; these classifications or family trees follow rules of nomenclature; scientific names have unique definitions and value. ***Such classifications have been used to support common ancestry.*** c. ~~Natural selection and its evolutionary consequences~~ ***Evolutionary theory*** provides a scientific explanation for ***certain aspects of*** the fossil record that correlates with geochemical (e.g., radioisotope) dating results. The distribution of fossil and modern organisms is related to geological and ecological changes (i.e. plate tectonics, migration). ***d. The view that living things in all the major kingdoms are modified descendants of a common ancestor (described in the pattern of a branching tree) has been challenged in recent years by:*** ***i. Discrepancies in the molecular evidence (e.g. differences in relatedness inferred from sequence studies of different proteins) previously thought to support that view.*** ii. ***A fossil record that shows sudden bursts of increased complexity (the Cambrian Explosion), long periods of stasis and the absence of transitional forms rather than steady gradual increases in complexity, and*** iii. ***Studies that show animals follow different rather than identical early stages of embryological development.***

6. Students will be able to explain proposed scientific explanations of the origin of life as well as scientific criticisms of those explanations. ****Understand**: "Understand" does not mandate "belief." While students may be required to understand some concepts that researchers use to conduct research and solve practical problems, they may accept or reject the scientific concepts presented* **so long as they are provided with material information necessary for an informed decision. Presenting only one side of a controversial issue tends to indoctrinate and foster ideologies, while good science education seeks to inform.** ~~*This applies particularly where students' and/or parents' beliefs may be at odds with current scientific theories or concepts. See Teaching About Evolution and the Nature of Science, National Academy of Sciences, 1998, page 59*~~	***a. Life is proposed to have arisen from organic molecules by chemical evolution in a "prebiotic soup" (whether hot springs, lagoons, hydrothermal vents, etc.).*** ***b. Chemical evolutionary theory has encountered a number of difficulties, including:*** ***i. A lack of empirical evidence for a "primordial soup" or a chemically hospitable pre-biotic atmosphere;*** ii. ***The lack of adequate natural explanations for the genetic code, the sequences of genetic information necessary to specify life, the biochemical machinery needed to translate genetic information into functional biosystems, and the formation of proto-cells; and*** iii. ***The sudden rather than gradual emergence of organisms near the time that the earth first became habitable.***

Explanation:

Indicator 1 and 6:
Indicator 1 reflects two critical claims of evolutionary biology, the first of which is described in the National Association of Biology Teacher's statement on teaching evolution. The second assumption is also critical to biological evolution. If life arises due to an intelligent cause rather than a process of chemical evolution, then intelligent causes for subsequent modifications to life become a much more viable competitor for biological evolution. The natural, unplanned occurrence of life is an assumption required by methodological naturalism but which lacks a plausible, evidence-based explanation.

Because biology textbooks uniformly describe speculations about a chemical evolution of life, we believe it important that students be informed of the many scientific problems that render these explanations speculative. For these reasons, we have added Indicator 6.

Indicators 2 and 3

The changes are self-explanatory.

Indicators 4 and 5

Indicators 4 and 5 seek to explain the extrapolation from microevolutionary processes, which are not generally disputed, to macroevolutionary changes. This extrapolation is the underpinning for the claim made in indicator 5 that all life forms are ancestrally linked in an unbroken chain that may be traced back to a single common ancestor in a pattern that resembles a branching tree. This extrapolation and the claim of common ancestry for all life forms are the most controversial aspects of current evolutionary theory. The changes to these indicators are designed to inform students about this controversy.

6. The following proposals relate to Benchmarks 1, 2 and 3 of 12th Grade Standard 7 regarding the history and nature of science.

Material in non-bold Arial font reflect material found in the existing 12th Grade Standard 7, but not necessarily in the order shown below. Since these revisions reflect a general reworking of the entire standard, deleted material is not shown.

STANDARD 7: HISTORY AND NATURE OF SCIENCE Twelfth Grade

As a result of activities in grades 9-12, all students will develop understanding of science as a human endeavor, the nature of scientific knowledge, and historical perspectives.

Benchmark 1: Students will develop an understanding that science is a human endeavor.

Twelfth Grade Indicators	Additional Details
The student… 1 Recognizes that people engage in science as part of a vocation and/or of an avocation.	1. ***Science is used by research scientists to develop new medicines and by parents to promote the health of their families.***
2. Recognizes that scientific knowledge is used for personal, community and cultural decisions that affect beliefs and attitudes about health, natural resources and the environment, global and national politics, moral and ethical standards, and religion.	***2. For example, decisions the culture makes about bioethics and the use and extraction of natural resources are significantly impacted by scientific knowledge.***
3. Recognizes that personal and cultural beliefs about science influence ways of thinking that are required for scientific advances, both towards training scientists and towards educating the populace to utilize benefits of science, such as standards of hygiene~~,~~ attitudes toward forces of nature, etc.	***3. Members of the public are the patrons and beneficiaries of science and their support for scientific research may be influenced by the responsiveness of science to the needs of that constituency.*** .

Explanation: The changes to this indicator are self-explanatory.

Benchmark 2: Students will develop an understanding of the nature of scientific knowledge.

Twelfth Grade Indicators	Additional Details
The student recognizes …	
1. that scientific knowledge is (when possible) based on empirical information (observable and measurable data).	**1. *a. Scientific inquiry typically produces knowledge based on experimental and observable (empirical) findings that are usually measurable and repeatable and that produce hypotheses that may be tested and falsified. The more of these criteria met, the more reliable is the scientific knowledge.*** ***b. Some critical features of biological systems such as the semantic (meaningful) character of biological information (e.g., DNA) and some other aspects of nature are not currently measurable or observable (e.g. consciousness and the location of an electron).***
2. that science seeks to understand the underlying principles or laws that govern the natural world by hypothesis testing and theory building.	
3. that scientific knowledge of a remote historical nature frequently cannot be confirmed by direct experimentation and observation.	***3. Hypotheses about the cause of remote historical events depend heavily on circumstantial evidence, and thus conclusions are frequently less certain than those drawn from direct observation and experimentation.***

Explanation: The changes are self-explanatory.

Benchmark 3: Students will understand science from historical perspectives.

Students will understand 1. the history of science and ***how science has influenced culture in both positive and negative ways.***	1. ***a. Science progresses by robust debate and analysis of existing theories and hypotheses, which can lead to major new scientific advances (e.g., relativity, plate tectonics, quantum theory, biological evolution).*** ***b. Well-established scientific theories can sometimes blind the scientific community to the need for revisions in existing scientific explanations (see Kuhn, The Structure of Scientific Revolutions; Scientific American, pp 60-67, October 2004).*** c. ***Science has led to significant improvements in physical health and economic growth; however, modern science can sometimes be abused by scientists and policymakers, leading to significant negative consequences for society and violations of human dignity (e.g., the eugenics movement in America and Germany; the Tuskegee syphilis experiments; scientific justifications of eugenics and racism; Social Darwinism).***

Explanation: The changes are self-explanatory.

7. The following are proposed changes to the indicated terms in the Glossary in the current standards.

Evolution - Biological: A scientific theory that ~~accounts for~~ ***seeks to explain*** present day similarity and diversity among living organisms and changes ~~in non-living entities~~ over time. ~~With respect to living organisms,~~ ***Biological*** evolution has two major perspectives: The long-term perspective ***(macro-evolution)*** focuses on the branching of lineages; the short-term perspective ***(microevolution)*** centers on changes within lineages. In the long term, evolution is the descent with modification of different lineages from common ancestors. In the short term, evolution is the on-going adaptation of organisms to environmental challenges and changes. ***The modern theory of evolution postulates that change occurs through an unguided combination of chance circumstances and the operation of the physical and chemical laws alone. (See 12th Grade Standard 3, Benchmark 3, Indicator 1 for a discussion of the various meanings of evolution.)***

Evolution - Cosmological: With respect to non-living entities, ***the theory of*** evolution ***seeks to explain*** ~~accounts for~~ sequences of natural stages of development. Such sequences are postulated to be a natural consequence of the characteristics of matter and energy. Stars, planets, solar systems, and galaxies are examples. ***The theory of cosmological evolution postulates that change occurs through an unguided combination of chance circumstances and the operation of the physical and chemical laws alone.***

Evolution - Macroevolution*:* The theory of evolution above the species level; the evolution of higher taxa and the product of evolutionary novelties such as new structures (May 1991). Macroevolution continues the genetic mechanisms of microevolution and adds new considerations of extinction, rate and manner of evolution, competition between evolving units, and other topics relevant to understanding larger-scale evolution. ***(See 12th Grade Standard 3, Benchmark 3, Indicator 1 for a discussion of the various meanings of evolution.)***

Evolution - Microevolution: The processes (mostly genetic) that operate at the population level: Natural selection, genetic drift, gene flow, and others. These processes may produce genetic differences in populations. ***It is postulated that*** these genetic differences, along with reproductive isolation, can lead to speciation, the development of new species. ***(See 12th Grade Standard 3, Benchmark 3, Indicator 1 for a discussion of the various meanings of evolution.)***

Science: ***Science is a systematic method of continuing investigation, that uses observation, hypothesis testing, measurement, experimentation, logical argument and theory building to lead to more adequate explanations of natural phenomena.*** ~~The human activity of seeking natural explanations for what we observe in the world around us. These explanations are based on observations, experiments, and logical arguments that adhere to strict empirical standards and a healthy skeptical perspective.~~

Science Literacy: The scientific knowledge and inquiry skills which enhance a person's ability to observe objects and events perceptively, reflect on them thoughtfully, ~~and comprehend~~ ***and evaluate the adequacy of*** explanations offered***, and formulate rational scientific alternative explanations.*** ~~**for them.**~~

Explanation: The changes are self-explanatory and simply revise existing explanations to conform to the Proposals.

Notes

[1] Draft 1 is dated October 28, 2004 and was delivered to the Kansas State Board on December 7, 2004. A copy is posted at www.kansasscience2005.com and at the KSBE web site at http://www.ksde.org/outcomes/sciencestd.html.

[2] Proponents have made a number of efforts to have the Proposals voted on by the full committee without success.

[3] "The *National Science Education Standards* are designed to guide our nation toward a scientifically literate society. Founded in exemplary practice and research, the *Standards* describe a vision of the scientifically literate person and present criteria for science education that will allow that vision to become reality..... Americans are confronted increasingly with questions in their lives that require scientific information and

scientific ways of thinking ***for informed decision making.*** "The Goals of the National Science Education Standards are "to educate students who are able to.....use ***appropriate scientific*** processes and ***principles*** in ***making personal decisions"*** [National Science Education Standards, Chapter 1 – Introduction – Goals for School Science, http://books.nap.edu/html/nses/html/index.html (1995, National Academy of Sciences)]

[4] The introduction reflected in Draft 1 merely reflects a proposal of the Chair and Co-Chair of the committee and no review or consideration by any recognized subcommittee or of the committee as a whole. Requests to vote on the Proponents suggested revisions to the Introduction were ruled out of order by the Chair.

[5] James Barham, *The Emergence of Biological Value,* p. 210 (*Debating Design,* Editors Michael Ruse and William Dembski , 2004); Richard Dawkins, *The Blind Watchmaker: Why The Evidence of Evolution Reveals A Universe Without Design"* p. 1, 21 (W.W. Norton & Company, 1996); Michael Ruse, *Darwin and Design: Does evolution have a purpose?,* p. 268 (Harvard, 2003); Kenneth R. Miller, *Finding Darwin's God: A Scientist's Search for finding common ground between God and Evolution,* pp.92, 139, (Cliff Street Books, 1999); Douglas J. Futuyma, *Evolutionary Biology, Third Edition,* p. 10 (Sinauer Associates, Inc. 1998); *The Origination of Organismal Form,* edited by Gerd B. Muller and Stuart A. Newman (MIT Press 2003,); and Francisco J. Ayala, *Darwin's Revolution,* p.4-5 (*Creative Evolution,* John Campbell & J. William Schopf, Editors, Jones & Barlett 1994).

[6] Marc H.V. Van Regenmortel, *Reductionism and complexity in molecular biology,* p 1016, (European Molecular Biology Organization, EMBO reports, Vol 5, No. 11, 2004): "The reductionist method of dissecting biological systems into their constituent parts has been effective in explaining the chemical basis of numerous living processes. However, many biologists now realize that this approach has reached its limit. Biological systems are extremely complex and have emergent properties that cannot be explained, or even predicted, by studying their individual parts. The reductionist approach – although successful in the early days of molecular biology – underestimates this complexity and therefor has an increasingly detrimental influence on many areas of biomedical research, including drug discovery and vaccine development. …..As the value of methodological reductionism has been particularly evident in molecular biology, it might seem odd that, in recent years, biologists have become increasingly critical of the idea that biological systems can be fully explained using physics and chemistry."

[7] Michael Ruse, *Darwin and Design: Does evolution have a purpose?,* p. 268 (Harvard, 2003)

[8] In *Origination of Organismal Form* pp 1-9, (MIT Press, 2003) Gerd Muller and Stuart Newman compile articles by seventeen scientists. In the introductory chapter they develop a list of the questions addressed and that remain unanswered. In undertaking this task they note that "The nature of the determinants and rules for the organization of **design** elements constitutes one of the major unsolved problems in the scientific account of organismal form." The "unsolved problems" include the following:

"Why did metazoan body plans arise in a burst?
"Why do similar morphologies arise independently and repeatedly?
"Why do distantly related lineages produce similar **designs?** (my emphasis)
"Why do building elements organize as fixed body plans and organ forms?
"How are new elements introduced into existing body plans?
"Why are **design** units reused repeatedly?
"Why are all **design** options of a phenotype space realized?
"Why do characters long absent in a lineage reappear?
"Why are the rates of morphological change unequal?
"Does the genetic code contain the complete information of organismal form?
"Do new structural elements arise from mutations?"
"Why can identical genetic content be associated with very different morphological phenotypes?
"Why are there multiple genetic and biochemical pathways to the realization of biological forms? "Why do morphological and genetic evolution proceed at different paces?
"How is the geneotype-phenotype relationship mediated in development?
"Does the developmental generation of organismal form result from deterministic programs?
"How are developmental processes modulated by epigenetic context?
"What is the role of physicochemical properties of biological materials?
"What is the role of the external environment in development?
"What generative mechanism are responsible for the origin and innovation of phenotypic characters?

"Are developmental response capacities specifically evolved, or is plasticity a primitive property? "Do the rules of developmental transformations shape evolution?
"Is the evolutionary potential of a lineage associated with the capacity of its developmental system to respond to the environment?
"What is the role of genetic co-option and assimilation in the evolution of organismal form?

[9] John S. Mattick, *The Hidden Genetic Program of Complex Organisms: RNA "junk" inside cells may directly regulate how a fertilized egg becomes the trillions of cells in a human body*, (*Scientific American*, October 2004): "Assumptions can be dangerous, especially in science. They usually start as the most plausible or comfortable interpretation of the available facts. But when their truth cannot be immediately tested and their flaws are not obvious, assumptions often graduate to articles of faith, and new observations are forced to fit them. Eventually, if the volume of troublesome information becomes unsustainable, the orthodoxy must collapse. We may be witnessing such a turning point in our understanding of genetic information. The central dogma of molecular biology for the past half a century and more has stated that genetic information encoded in DNA is transcribed as intermediary molecules of RNA, which are in turn translated into the amino acid sequences that make up proteins. The prevailing assumption, embodied in the credo "one gene, one protein," has been that genes are generally synonymous with proteins. A corollary has been that proteins, in addition to their structural and enzymatic roles in cells, must be the primary agents for regulating the expression, or activation, of genes...."

[10] See Note 8.

[11] "The *ultimate ratio* of all the teleonomic structures and performances of living beings is thus enclosed in the sequences of residues making up polypetptide fibers …. In a sense, a very real sense, it is at this level of chemical organization that the secret of life lies, if indeed there is any one such secret. And if one were able not only to describe these sequences but to pronounce the law by which they assemble, one could declare the secret penetrated, the *ultimate ratio discovered."* [Jacques Monod, *Chance and Necessity,* pp 95-6 (Vintage Books 1971)]. Due to the lack of any law that dictates the sequence, Monod attributes the cause of the chemical sequence (DNA, protein, carbohydrate, lipid, etc.) wholly to chance, a hypothesis that is subject to significant scientific debate.