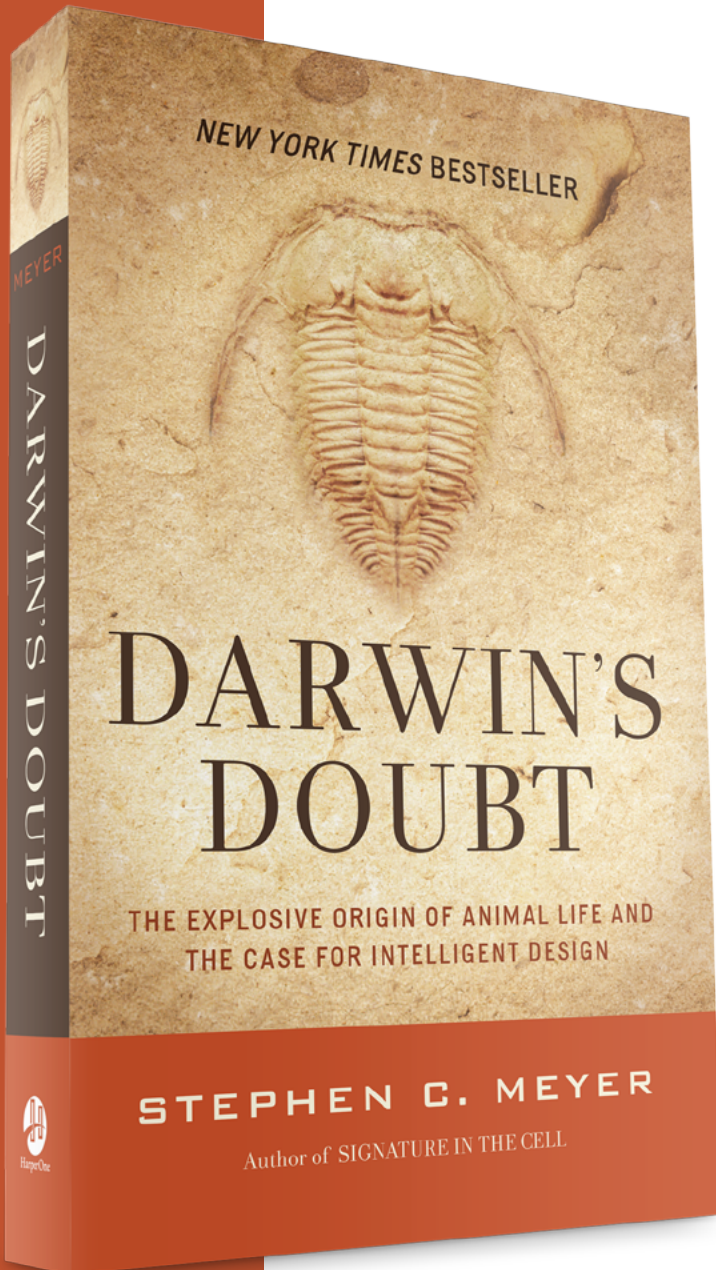


DARWIN'S DOUBT

A Discussion Guide

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Darwin's Doubt: A Discussion Guide

Introduction

This discussion guide is designed to facilitate the use of Stephen Meyer's book *Darwin's Doubt: The Explosive Origin of Animal Life and the Case for Intelligent Design* in small groups, adult education classes, and book discussion clubs. The guide contains brief summaries of each chapter grouped into eight total discussion sessions. Each discussion session also contains discussion questions for the chapters covered by that session.

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Session 1

Prologue; Chapter 1: Darwin's Nemesis; Chapter 2: The Burgess Bestiary

Prologue

In his 2009 book *Signature in the Cell*, Stephen Meyer argues that the information necessary for the first life is best explained by intelligent design (ID) rather than the blind and unguided mechanisms invoked by theories of chemical evolution. In the prologue to *Darwin's Doubt*, he explains his surprise when critics responded to *Signature in the Cell* by appealing to the creative power of random mutation and natural selection—processes that could not have operated before life began. In 2013, Meyer published *Darwin's Doubt* to answer critics who argue that Darwinian evolution can produce new biological information. In the process, the book explores a mystery that has puzzled biologists since Darwin's time.

Ch. 1 Darwin's Nemesis

Darwin's argument in *Origin of Species* rests upon two pillars: common ancestry and natural selection, where species arise gradually as selection preserves small, step-by-step variations. Darwin recognized that the fossil record did not demonstrate this gradual change. Instead, major groups ("phyla") of complex animals—like shelled brachiopods or multisegmented trilobites—appear suddenly in the fossil record, without evolutionary precursors, in an event that paleontologists today call the Cambrian explosion. Leading contemporaries of Darwin, like Harvard's Louis Agassiz, cited the Cambrian explosion as a challenge to Darwin's theory. Darwin responded by arguing the fossil record must be incomplete, but he nonetheless admitted that the lack of fossil ancestors for the Cambrian animals "may be truly urged as a valid argument against" his theory.

Ch. 2 The Burgess Bestiary

Discovered in 1909 by Smithsonian Institution director Charles Walcott, the fossils of the Burgess Shale in the Canadian Rockies reveal a stunning assortment of animal diversity, including oddball creatures unlike any living phyla. All told, representatives of about twenty of the roughly twenty-six total animal phyla known from the entire fossil record appear abruptly in the Cambrian. This pattern is the opposite of the gradual branching tree predicted by Darwin's theory, where small-scale differences between lower-level taxonomic categories (diversity) should accumulate before the appearance of major differences between higher-level taxonomic categories (disparity). Puzzled by the absence of ancestral fossils in Precambrian rock, Walcott followed Darwin's approach, proposing that the Cambrian explosion was merely an artifact of an incompletely sampled fossil record. Walcott thought the ancestors of the Cambrian animals were waiting to be found in as-of-yet undiscovered strata, but history proved him wrong.

Discussion Questions

Session 1

1. Stephen Meyer opens the prologue to *Darwin's Doubt* by discussing his previous book, *Signature in the Cell*, published in 2009.
 - a. What was Meyer's argument in *Signature in the Cell*?
 - b. Why was he surprised by the responses of critics to that book?
 - a. How is *Darwin's Doubt* intended to be an answer to critics of *Signature in the Cell*?
2. Before you started reading *Darwin's Doubt*, what had you already heard about the Cambrian explosion?
3. After reading the prologue, would you recommend *Darwin's Doubt* to a friend? Why or why not?
4. Darwin's theory of evolution:
 - a. What are the twin pillars of Darwin's theory of evolution?
 - b. Are they in tension with belief in God? Why or why not?
5. In *Origin of Species*, Darwin explained that "If numerous species, belonging to the same genera or families, have really started into life all at once, the fact would be fatal to the theory of descent with slow modification through natural selection."
 - a. What solution did Darwin propose for the abrupt appearance of organisms in the Cambrian?
 - b. Do you feel Darwin's solution is satisfactory?
6. Louis Agassiz, a famous natural scientist at Harvard University, has been criticized by historians of science for his rejection of Darwin's theory. Do you think their criticisms are founded?

Discussion Questions

Session 1 (continued)

7. What was the Burgess Shale and how does it challenge a Darwinian view of life?
8. How does Darwin's famous tree of life compare with the actual pattern that emerges in the fossil record?
9. Of the different animal forms which appear in the Cambrian, which do you find the strangest?
10. In the prologue, Meyer writes: "Rarely has there been such a great disparity between the popular perception of a theory and its actual standing in the relevant peer-reviewed scientific literature."
 - a. What does he mean by this statement?
 - b. Do you agree with the statement?

Session 2

Chapter 3: Soft Bodies and Hard Facts; Chapter 4: The *Not* Missing Fossils?

Ch. 3 Soft Bodies and Hard Facts

Another location bearing beautifully preserved Cambrian fossils—including vertebrate fish—was discovered in Chengjiang, China in the 1980s. These finds further confirmed the abrupt appearance of animal body plans in the Cambrian, with the main burst of diversity appearing in less than 5 or 6 million years. Evolutionary scientists have tried to explain this unexpected pattern through the artifact hypothesis, claiming the ancestors of the Cambrian animals were too small, or too soft-bodied to have been preserved as fossils. This argument is contradicted by the existence of numerous fossils of small and soft-bodied organisms from Cambrian and Precambrian strata. Such fossils include bacteria, algae, and tiny sponge embryos—though they aren't the missing ancestors of the Cambrian animals. The artifact hypothesis is also challenged by studies showing that our knowledge of the fossil record is mature enough to conclude that if evolutionary precursors existed, we should have found them.

Ch. 4 The *Not* Missing Fossils?

Evolutionists sometimes attempt to minimize the “explosive” appearance of new animal phyla in the Cambrian fossil record by asserting that the Ediacaran or Vendian fossils of the late Precambrian provide the missing ancestors. However the consensus of paleontologists is that these organisms are ambiguous, enigmatic, and difficult to match to the Cambrian animals. Many have turned out to not be animals at all, and some may not even be fossils. At most, Precambrian fossils (including trace fossils) provide possible ancestors for only four of the twenty-three animal phyla present in the Cambrian. The vast majority of Cambrian animals have no apparent precursors in Precambrian rocks.

Discussion Questions

Session 2

1. Chapter 3 discusses many beautifully preserved fossils found near Chengjiang, China. What fossil discoveries did you find particularly fascinating or surprising?
2. How have evolutionary scientists used the “artifact hypothesis” to attempt to explain away the lack of ancestors in the fossil record for the Cambrian animals? What evidence contradicts their hypothesis?
3. The Chinese paleontologist J.Y. Chen stated, “In China we can criticize Darwin, but not the government. In America, you can criticize the government, but not Darwin.”
 - a. Do you agree with Dr. Chen’s statement? Why or why not?
 - b. Are you aware of incidents where scientists faced discrimination or persecution because they challenged Darwin?
 - c. How might this debate be different if scientists had academic freedom to express doubts about Darwinian theory?
4. Meyer opens chapter 4 by retelling the story of a tense presentation at the Sam Noble Science Museum at the University of Oklahoma where he and biologist Jonathan Wells discussed a film that challenged Darwinism.
 - a. What was the name of the film, and what did it discuss?
 - b. Have you ever encountered open hostility toward your viewpoint like what Meyer and Wells encountered?
 - c. What is the best way to respond when someone is attacking you personally, or criticizing you, because you are expressing an unpopular view (like dissent from Darwinism)?
5. Fossils in Precambrian sediments:
 - a. What kinds of fossils have been discovered in Precambrian sediments?

Discussion Questions

Session 2 (continued)

- b. What challenges have scientists faced when trying to establish these fossils as evolutionary precursors of Cambrian animals?
 - c. Do paleontologists agree that these fossils were ancestral to the Cambrian phyla?
- 6. Why do some scientists suggest the Ediacaran fauna represent an “explosion” in the fossil record?
- 7. A 2005 article in *Scientific American* called the Precambrian fossil *Vernanimalcula* the “oldest fossil animal with a bilaterian body plan yet discovered.”
 - a. What is a “bilaterian” animal?
 - b. Who are some of the paleontologists that criticized such descriptions of *Vernanimalcula*, and what counterarguments did they raise?
- 8. Based upon what you have learned so far in the book, do you think the Cambrian explosion was a real event, or is it just an artifact of an imperfect fossil record?
- 9. Towards the end of chapter 4, Meyer quotes two paleontologists who say in a peer-reviewed technical paper that, “The expected Darwinian pattern of a deep fossil history of the bilaterians, potentially showing their gradual development, stretching hundreds of millions of years into the Precambrian, has singularly failed to materialize.”
 - a. Meyer then suggests there is a disparity between what scientists know about the Precambrian fossil record, and what is often told to the public. Do you agree?
 - b. Can you think of other cases where the public has been misled about the evidence for evolution?

Session 3

Chapter 5: The Genes Tell the Story; Chapter 6: The Animal Tree of Life;
Chapter 7: Punk Eek!

Ch. 5 The Genes Tell the Story

After the fossil record failed to produce ancestors of the Cambrian animals, some evolutionary biologists turned to genetic evidence to establish the branching pattern predicted by Darwin's theory. Using "molecular clock" techniques, they propose that by measuring the differences between the genes of living animals and estimating mutation rates, they can establish "deep divergence"—the claim that animals shared common ancestors far back into the Precambrian. Molecular clocks, however, are notoriously unreliable, as different studies give widely varying dates for when those ancestors existed. Some have proposed the common ancestor of animals lived after the Cambrian period, or *prior to the beginning of the universe*—obviously absurd results. These widely divergent results stem from dubious assumptions made by molecular clock studies, such as the constancy of mutation rates or the precise dates of fossils. These discrepancies mean molecular clocks cannot reliably establish deep divergence and resolve the Cambrian enigma.

Ch. 6 The Animal Tree of Life

Biologists also attempt to establish animal evolution by comparing the genetic and anatomical traits of living species to produce phylogenetic trees showing evolutionary relationships. If there is one true history of animal evolution, the evidence should consistently suggest the same tree. But molecule-based trees often conflict with one-another: one gene yields one version of the tree of animal life, and another gene yields an entirely different and conflicting tree. Molecule-based trees also frequently conflict with trees based upon anatomy, and anatomy-based trees often conflict with one another. Such conflicts force evolutionary biologists to appeal to convergent evolution, where the same traits arise independently. This undermines a basic assumption of treebuilding which holds that biological similarity implies inheritance from a common ancestor. Difficulties reconstructing the animal tree of life have caused some biologists to conclude that the animal phyla diverged too abruptly to reveal their evolutionary relationships. Phylogenetic studies have led us right back to where the fossil evidence did: an explosive appearance of diverse animal phyla that contradicts Darwinian predictions.

Ch. 7 Punk Eek!

In the 1970s, paleontologists Stephen Jay Gould and Niles Eldridge proposed a new model of evolution called punctuated equilibrium, where populations experience long periods without change (called stasis), punctuated by short periods of rapid evolution. Hoping to explain why the fossil record lacked transitional forms, they postulated that if evolutionary change took place rapidly, in small populations that were short-lived, then transitional forms

Ch. 7
Punk Eek!
(continued)

would be less likely to become fossilized. Gould and Eldredge also proposed species selection, where interspecies competition would cause some species to dominate over others. Punctuated equilibrium cannot explain the missing precursors to the Cambrian animals for multiple reasons. Species selection eliminates forms, and does not generate new traits. The “top down” pattern of abrupt appearance of the Cambrian animals contradicts the pattern of “bottom up” evolution required by punctuated equilibrium. No genetic mechanism has explained how evolutionary change can occur rapidly. Thus, Cambrian paleontologists James Valentine and Douglas Erwin concluded that punctuated equilibrium cannot explain the origin of new body plans.

Discussion Questions

Session 3

1. At the beginning of chapter 5, Meyer compares the task scientists face when reconstructing the history of life to detective work. Do you agree with this analogy?
2. Many evolutionary biologists claim that similarities (homologies) among vertebrate limb bones or biomolecules suggest common ancestry. Can you think of other possible explanations for the similarities?
3. Molecular clock studies:
 - a. Meyer writes that molecular clock studies “assume the existence of such ancestors, and then merely attempt, given that assumption, to determine how long ago such ancestors might have lived.” Should that assumption be granted?
 - b. What are some other assumptions made by molecular clock studies?
 - c. Why do you think molecular clock studies vary so widely in the dates they give for the common ancestors of different animal groups?
4. Deep divergence hypothesis:
 - a. What is the deep-divergence hypothesis and what problem did it attempt to solve?
 - b. Do you think molecular clock studies have successfully established the deep divergence hypothesis? Why or why not?
5. When discussing phylogenetic trees in chapter 6, Meyer quotes a 2012 paper in *Biological Reviews of the Cambridge Philosophical Society* observing that “phylogenetic conflict is common, and frequently the norm rather than the exception.”
 - a. How does this pose a problem for phylogenetic trees?
 - b. Meyer also quotes a biologist who stated in *New Scientist*, “We’ve just annihilated the tree of life.” Who was that scientist, and why does he say that?

Discussion Questions

Session 3

6. In a murder investigation, the testimony from witnesses should produce a single, clear, and consistent story of the main elements of the crime. As scientists attempt to reconstruct the evolutionary history of the Cambrian animals, what or who are the witnesses and how consistent are their testimonies? To put it another way, what are the sources of evidence scientists use to reconstruct evolutionary trees and how well do they corroborate with one another?
7. Convergent evolution:
 - a. What is convergent evolution?
 - b. Do you think that convergent evolution is a satisfactory explanation for why complex traits or features arise in organisms not expected to be closely related?
 - c. Near the end of chapter 6, Meyer writes, “the repeated need to posit convergent evolution ... negates the very logic of the argument from homology, which affirms that similarity implies common ancestry, except—we now learn—in those many, many cases when it does not.” What does he mean by this?
8. If common ancestry were true, would that refute ID?
9. What is punctuated equilibrium? How does it propose to account for the lack of transitional forms in the fossil record?
10. Can species selection explain how new body plans arise? Why or why not?
11. Why does Meyer compare the “top down” appearance of animal phyla in the Cambrian to the “bottom up” pattern predicted by punctuated equilibrium?
12. Do you find that punctuated equilibrium provides an adequate explanation for the absence of transitional fossils in the Cambrian and Precambrian, and the rapid production of new body plans?

Session 4

Chapter 8: The Cambrian Information Explosion;

Chapter 9: Combinatorial Inflation; Chapter 10: The Origin of Genes and Proteins

Ch. 8

The Cambrian Information Explosion

Having established that the Cambrian explosion was real, Meyer considers what is needed to produce the new animal body plans that appeared during that event. Discoveries since Darwin's time reveal that biological traits are determined (at least in part) by genes, which are encoded by sequences of nucleotides in protein-coding stretches of DNA. Building a new body plan requires new organs, which in turn requires new tissues, which requires new cell types, which requires new proteins, which at base requires new genetic information in the form of new nucleotide sequences in DNA. Building a body plan thus requires adding new functional information or specified complexity in DNA—like generating meaningful language or computer codes. It follows then, that the Cambrian explosion was an *information* explosion.

Ch. 9

Combinatorial Inflation

At the Wistar Conference in 1966, MIT professor Murray Eden postulated that mutations will degrade protein function just as randomly changing letters in written language will garble the meaning. Eden's argument challenged neo-Darwinian theory, which holds that random mutations can *improve* protein function, conferring a survival advantage on an organism. As the length of a protein increases, the number of possible combinations of amino acids grows at an exponential rate. This is called "combinatorial inflation." Mutagenesis experiments show that functional amino acid sequences are extremely rare, meaning many mutations must be "just right" in order for them to function. MIT molecular biologist Robert Sauer found that only 1 in 10^{63} sequences of about 100 amino acids in length will yield a functional protein. This suggests long periods of time are necessary for random mutations to "stumble upon" functional protein sequences. But long periods of time were not available during the Cambrian explosion.

Ch. 10

The Origin of Genes and Proteins

Protein scientist Douglas Axe suspected Robert Sauer's research underestimated the rarity of functional protein sequences because it failed to consider simultaneous changes to multiple amino acids. Axe conducted more stringent mutagenesis experiments on enzymes to determine the rarity of amino acid sequences that yield stable protein folds—the smallest, most fundamental unit of structural innovation possible, key to generating macroevolutionary change. Axe's research found that only 1 in 10^{77} sequences of 150 amino acids in length can yield a stable protein fold. Richard Dawkins compares Darwinian evolution to climbing a mountain peak, but Axe's work suggests functional amino acid sequences are so rare in sequence space that random mutation could never successfully find

Ch. 10
The Origin of
Genes and Proteins
(continued)

a peak, and once on a peak, could never leave one peak and successfully find another. Indeed, since only 10^{40} organisms have ever existed on Earth, random mutations could never find even one functional protein fold over life's entire history, much less in the timespan of the Cambrian explosion.

Discussion Questions

Session 4

1. How has our understanding of inheritance changed from Darwin, to Mendel, to the present?
2. What similarities and differences can you think of between language and our genetic code?
 - a. How do random changes to letters in written language impact the meaning of the message?
 - b. How do you think random mutations affect our DNA and proteins?
3. Meyer notes that DNA contains both Shannon information and specified complexity. What is the difference between these types of information, and why are those differences important?
4. Animal body plans and information explosion:
 - a. What different kinds of parts are necessary to build an animal's body plan?
 - b. Why does Meyer say the Cambrian explosion was an information explosion?
5. What led MIT professor Murray Eden to question neo-Darwinism as a viable explanation for how functional genes and proteins arose?
6. Meyer uses a bike lock analogy to explain the problem of combinatorial inflation.
 - a. How does the addition of more digits on a bike lock impact a thief's ability to "crack the code"?
 - b. In the analogy, what did the "digits" of a bike lock correspond to in genes and proteins?

Discussion Questions

Session 4 (continued)

- c. How does this analogy illustrate the difficulties faced by random mutations to generate new functional gene and protein sequences in a limited period of time?
 - d. What does Meyer mean by combinatorial inflation?
7. Dawkins' *The Blind Watchmaker*:
- a. In his book, *The Blind Watchmaker*, Richard Dawkins described a computer program which could "evolve" the famous Shakespearean phrase, "Me thinks it is like a weasel." Did this program successfully demonstrate, as Dawkins intended, that random mutations and natural selection can generate new functional information? Why or why not?
 - b. Dawkins also compares Darwinian evolution to climbing "Mount Improbable." What might make it difficult for random mutation and natural selection to scale "Mount Improbable"?
8. Douglas Axe's protein research:
- a. Why did Douglas Axe feel that Robert Sauer might have wrongly estimated the rarity of functional protein sequences?
 - b. Axe focused his research on generating functional protein folds. Why did he do that?
 - c. According to Axe's work, how rare are amino acid sequences that yield stable, functional protein folds?
 - d. How does the fact that only 10^{40} organisms have lived on Earth's entire history impact the likelihood that Darwinian evolution has produced new functional proteins?
 - e. What do you think Axe's research says about the ability of neo-Darwinian evolution to explain the information which appeared in the Cambrian explosion?

Session 5

Chapter 11: Assume a Gene;

Chapter 12: Complex Adaptations and the Neo-Darwinian Math

Ch. 11 Assume a Gene

Evolutionary attempts to explain the origin of genes typically take a gene, and then seek another gene that is similar (homologous), and then invoke various mutational mechanisms (e.g., duplication, exon shuffling, retropositioning, lateral gene transfer, point mutations, etc.) to explain how those two genes diverged from a hypothetical common ancestor gene. These methods presuppose, rather than demonstrate, that biological similarity is the result of common ancestry, and ignore other possibilities like common design. They frequently presuppose the existence of biological information without explaining its origin. These studies attempt to explain ORFan genes—unique genes with no known homology to other genes—through *de novo* gene origination, which amounts to evolution out of nothing, and gives no explanation for how new information arises. Stories of gene evolution either provide plausible but irrelevant scenarios describing minor genetic changes that fail to account for new protein folds, or promote implausible but relevant scenarios that also fail to produce new folds. At best, gene evolution studies demonstrate where genes have been slightly modified, but offer no mathematical validation nor experimental evidence demonstrating nontrivial gains in biological information.

Ch. 12 Complex Adaptations and the Neo-Darwinian Math

Complex adaptations (also called multi-mutation traits) require multiple coordinated mutations before providing any advantage to an organism. Evolving complex adaptations is like playing the lottery: the more time (i.e., number of generations) and opportunities (i.e., number of individuals in a population) available, the greater the likelihood the trait will arise. Michael Behe and David Snoke calculated that in multicellular organisms, population sizes are too small, and too few generations have lived, to produce a complex adaptation requiring only two mutations before providing an advantage. Even Behe's critics calculated that a complex adaptation requiring two or more mutations could not arise in humans within a reasonable timescale. Ann Gauger and Douglas Axe tried to convert one bacterial enzyme into another closely related enzyme, and found that the conversion would require at least seven coordinated mutations. This exceeds a six-mutation-limit Axe established as an upper boundary of what Darwinian evolution could produce, and confirmed that genes and proteins are complex adaptations which cannot be produced by Darwinian mechanisms.

Discussion Questions

Session 5

1. Chapter 11 describes the discrimination faced by Richard Sternberg at the Smithsonian Institution's National Museum of Natural History after he allowed Meyer's paper to be peer-reviewed and published.
 - a. Why did the paper cause such uproar?
 - b. Do you feel the Smithsonian's response was warranted?
2. Does shared sequence similarity (homology) between two genes necessarily indicate inheritance from a common ancestor? What other explanations might account for these similarities?
3. Types of mutations:
 - a. What are some of the types of mutations that Meyer describes in his chapter on the evolution of genes?
 - b. How do some of these types of mutations assume the prior existence of biological information?
4. ORFan genes and *de novo* gene origination:
 - a. What are ORFan genes and why do they pose a challenge to Darwinian evolution?
 - b. Why does Meyer compare *de novo* gene origination to "evolution *ex nihilo*"?
 - c. Do you find *de novo* origination a convincing explanation for how new genes originate?
5. Gene evolution and protein folds:
 - a. Why is it important that accounts of gene evolution explain the origin of new protein folds?
 - b. Do you think that studies of gene evolution explain new protein folds?

Discussion Questions

Session 5 (continued)

6. Why does Meyer say that evolutionary explanations for the origin of genes are like a “word salad”?
7. Meyer quotes evolutionary biologists Paul Ehrlich and Richard Holm stating:

One need not go into the details of the evolution of the bird’s wing, the giraffe’s neck, the vertebrate eye, the nest building of some fish, etc., as the selective origins of these and other structures and of behavioral patterns may be assumed to be basically the same in outline as those, such as industrial melanism, which have already been discussed. Even a slight advantage or disadvantage in a particular genetic change provides a sufficient differential for the operation of natural selection.

Do you find it convincing when evolutionary biologists claim that one need not investigate the details of the evolution of complex features?
8. Complex adaptations (also called multi-mutation traits):
 - a. What are complex adaptations?
 - b. If evolving a complex adaptation is like winning the lottery, what can increase the likelihood that evolution will “win”?
 - c. Why do complex adaptations pose a challenge to Darwinian explanations?
9. Why does Meyer observe that the research of Michael Behe and David Snoke showed that Darwinian evolution faces a catch-22?
10. What did Behe’s critics find when they sought to assess his conclusion that there is insufficient time in the fossil record for multmutation features to evolve?
11. Experimental research of Ann Gauger and Douglas Axe sought to convert one bacterial enzyme, Kbl₂, into another enzyme, BioF₂.
 - a. Why did they choose to experiment upon those two enzymes?
 - b. At least how many mutations did they find would be necessary for this evolutionary conversion?

Discussion Questions

Session 5
(continued)

- c. How does this number compare with Axe's calculations about the maximum number of mutations that Darwinian evolution could produce to build a multi-mutation feature over Earth's entire history?
 - d. What is co-option?
 - e. How did the research of Axe and Gauger challenge co-option theory?
12. A friend taking an evolutionary biology class argues that random mutation and natural selection can produce new functional proteins. After telling your friend that these functional amino acid sequences are incredibly rare, your friend says that Darwinian evolution has "all the time" in the world to generate these sequences. What response might you give?

Session 6

Chapter 13: The Origin of Body Plans; Chapter 14: The Epigenetic Revolution

Ch. 13 The Origin of Body Plans

Since events that occur early in development have a greater impact on the body plan than those occurring later, evolutionary biologists have hoped that early-acting mutations might cause large-scale changes and explain the evolution of new body plans. However, changes to early animal development require many other coordinated changes in order to yield beneficial effects. Saturation mutagenesis experiments trying to reverse-engineer fruit fly development found that random changes to developmental genes always resulted in dead larvae. Early in development, signaling molecules interact in a coordinated manner to form circuits or developmental gene regulatory networks (dGRNs) which ensure proper development of cell types that build a body plan. Research shows that mutations which interrupt dGRNs cause embryo death. A dilemma thus arises: the kind of mutations needed for major evolutionary change—beneficial regulatory changes expressed early in development—don't occur; the kind that do occur—viable genetic mutations in DNA generally expressed late in development—don't cause major evolutionary change.

Ch. 14 The Epigenetic Revolution

DNA contains information necessary for building proteins, but biological information is needed at many other levels to generate cell types, tissues, organs, and a body plan. These features often require epigenetic information—heritable biological information that exists outside of DNA. A cytoskeletal array of microtubules determines cell shape and function, but the information for building the array exists apart from the DNA. Patterns of regulatory proteins on the interior surface of an egg are crucial for fruit fly development, but their arrangements are not determined by DNA information. Electromagnetic fields generated by ion gradients across cell membranes are crucial for development, but the field locations are not determined by genetic information. Complex patterns of sugars on cell surfaces influence the arrangements of cell types during development, but this “sugar code” is not determined by DNA. Neo-Darwinism requires that new species form when mutations in DNA produce beneficial variation that is preserved by natural selection. But epigenetic information does not exist within DNA, and thus cannot be produced by changes to DNA. DNA could mutate indefinitely and it would not produce the epigenetic information needed for new animal body plans.

Discussion Questions

Session 6

1. In chapter 13, Meyer discusses the Nobel Prize-winning research that Christiane Nüsslein-Volhard and Eric Wieschaus performed on fruit flies.
 - a. Why was their research important?
 - b. What happened to the fruit flies they studied?
 - c. What did Wieschaus say their results meant for macroevolution?
2. Early acting body plan mutations:
 - a. What are early acting body plan mutations?
 - b. Why do evolutionary biologists hope these mutations will help explain the origin of new body plans?
 - c. What is the result of early acting body plan mutations?
3. Caltech biologist Eric Davidson has discovered that developmental gene regulatory networks (dGRNs) are crucial to the early development of animals.
 - a. In your own words, what is a dGRN?
 - b. What happens when mutations disturb the normal operation of a dGRN?
4. What is the “great Darwinian paradox” that Meyer describes in chapter 13?
5. How would you explain the difference between genetic and epigenetic information to a friend with limited biology background?
6. Epigenetic information:
 - a. What are some of the different types of epigenetic information you encountered in this chapter?

Discussion Questions

Session 6

- b. Why does epigenetic information pose a challenge to neo-Darwinian evolution?
- 7. One of the examples of epigenetic information Meyer gives is the arrangement of microtubules inside of a cell which build a cytoskeletal array. Watch the video “The Workhorse of the Cell: Kinesin” at <http://www.youtube.com/watch?v=gbycQf1TbM0> to see how kinesins walk along microtubules to carry cargo inside a cell. Does this sort of complexity speak to purposeful design or blind Darwinian evolution?
- 8. At the end of Chapter 14, Meyer provides a long list of mainstream scientists who have challenged the adequacy of neo-Darwinian explanations.
 - a. Have you heard of any of these scientists?
 - a. Given the impressive list of scientists, why do you think Darwin defenders claim their theory has “no weaknesses”?

Session 7

Chapter 15: The Post-Darwinian World and Self-Organization; Chapter 16: Other Post-Neo-Darwinian Models; Chapter 17: The Possibility of Intelligent Design

Ch. 15 The Post-Darwinian World and Self-Organization

Challenges to the neo-Darwinian paradigm have caused some theorists to propose “post-Darwinian” models of evolution which invoke strictly unguided, material mechanisms, but reject one (or more) of the three pillars of neo-Darwinism: (1) random mutations cause variation, (2) natural selection preserves variations which enhance survival and reproduction, and (3) favored variations are inherited by offspring. Self-organization, a model advocated by Stuart Kauffman, de-emphasizes random mutation and natural selection by claiming natural laws can spontaneously produce biological form. However, the model presupposes the genetic and epigenetic information necessary for cell differentiation and organization. Stuart Newman proposes dynamical patterning modules to explain how cells self-organize into different patterns to build new body plans, but he presupposes a complex toolkit of mechanisms that allows cells to aggregate, and provides no explanation for how these aggregated cell clusters are arranged into functional tissues, organs, and body plans. Self-organization produces order, not information, and types of order it generates are biologically irrelevant. It cannot explain the specified and complex *information* which generates order in living organisms.

Ch. 16 Other Post-Neo- Darwinian Models

Evolutionary developmental biology (“evo-devo”) rejects the neo-Darwinian view that mutations are random and small-scale, and proposes regulatory mutations can radically reshape body plans. However, the effects cited by evo-devo advocates are small-scale, such as changes to coloration patterns on insect wings. Changes to regulatory *Hox* genes cannot generate new body parts, and are harmful. Proponents of neutral evolution diminish the importance of natural selection, and claim random mutations naturally accumulate to build new complex features. But this model provides no account of the cellular machinery needed for mutations to accumulate, and cannot explain why beneficial mutations should be retained. Neo-Lamarckism claims that heritable changes arise outside of genetic mutations, but the traits influenced by such mechanisms are limited and impermanent. Natural genetic engineering rejects the randomness of mutation for generating variation, and holds that organisms have a natural, preprogrammed capacity to “engineer” themselves. However, this model never accounts for those preprogrammed abilities. Like neo-Darwinism, post-Darwinian models fail to explain the origin of the biological information necessary to build animal body plans.

Ch. 17 The Possibility of Intelligent Design

Intelligent design is another post-Darwinian scientific model which holds that certain features of biology are best explained by the action of a conscious mind—an intelligent agent—as opposed to mindless, material processes like natural selection. ID does not reject “evolution” defined as “change over time” or universal common ancestry, but disputes the claim that life is the result of strictly blind and undirected processes. In claiming that life’s apparent design is *real* design, ID is not a religious theory, and has a longstanding tradition within biology. Design is inferred using the same abductive reasoning employed in other historical sciences, like geology or evolutionary biology, where one infers a prior cause by finding its known effects. If there are features of the Cambrian explosion which are known from experience to be produced by intelligence, and no other cause can explain those features, one may make an inference to the best explanation—intelligent design.

Discussion Questions

Session 7 (continued)

1. Why are some biologists claiming we now live in a “post-Darwinian” world?
2. Pillars of neo-Darwinian evolution:
 - a. What are the “three pillars” of neo-Darwinian evolution?
 - b. How do post-Darwinian models of evolution treat these three pillars?
3. In chapter 15, Meyer describes self-organization as one of the main post-Darwinian models of evolution.
 - a. Who is one of the most noteworthy advocates of self-organization?
 - b. How does this model claim new body plans arise?
 - c. What are some reasons why the self-organization model cannot explain the origin of new body plans?
4. Meyer uses the illustration of combining Lego bricks to evaluate the theory of dynamical patterning modules.
 - a. What are dynamical patterning modules?
 - b. What is Meyer’s point in using the Lego brick illustration?
 - c. Can dynamical patterning modules explain the origin of new body plans?
5. Evolutionary developmental biology (“evo-devo”) claims that new body plans evolved through mutations in regulatory genes and regulatory regions of DNA.
 - a. Which of the “three pillars” of neo-Darwinism does evo-devo reject?
 - b. What is some of the evidence offered by advocates of “evo-devo” in support of their model?

Discussion Questions

Session 7 (continued)

- c. Do you think this evidence can explain the origin of new body plans?
6. Neutral evolution:
 - a. Which of the three pillars of neo-Darwinism does neutral evolution reject?
 - b. How does neutral evolution propose complex new traits might arise?
 - c. By rejecting the importance of natural selection, can neutral evolution explain why beneficial mutations will be retained? Why or why not?
7. What did you think when you learned that some evolutionary theorists are postulating that living organisms have the ability to “naturally engineer” themselves?
8. Post-neo-Darwinian theories:
 - a. Had you heard of many of these post-neo-Darwinian theories prior to reading chapters 15 and 16?
 - b. Do you feel that any of these models will fulfill their promise to explain the origin of new body plans?
9. Intelligent design:
 - a. How would you define intelligent design?
 - b. How does Stephen Meyer define intelligent design?
 - c. Have you ever heard intelligent design depicted in the media?
 - d. Do you think those depictions are accurate?

Discussion Questions

Session 7
(continued)

10. Abductive reasoning:
 - a. What is abductive reasoning?
 - b. Can you think of an example from everyday life where abductive reasoning is used to make a valid inference?
11. Inference to the best explanation:
 - a. What is an inference to the best explanation?
 - b. What kind of evidence does Meyer suggest we need to find in order to infer intelligent design as the best explanation for the Cambrian explosion?

Session 8

Chapter 18: Signs of Design in the Cambrian Explosion; Chapter 19: The Rules of Science; Chapter 20: What's at Stake

Ch. 18 Signs of Design in the Cambrian Explosion	Evolutionary biologists recognize that whatever caused the Cambrian explosion was fundamentally different from evolutionary mechanisms we observe today. ID uses positive arguments, observing that intelligent agency is a cause now in operation that can generate functionally specified digital information, such as software code or written language. ID also uses negative arguments by observing that no known material causes can explain the Cambrian explosion. Neo-Darwinism predicts a bottom-up pattern of appearance, but ID explains the top-down trend in the fossil record where disparity (differences between higher-level taxonomic categories) precedes diversity (differences between lower-level taxonomic categories). Neo-Darwinism cannot explain why similar genes or parts exist in widely disparate organisms, but intelligent agents often reuse functional components in different designs. While neo-Darwinian mechanisms are blind and undirected, our uniform and repeated experience of cause and effect establishes ID as the only known cause capable of generating the complex integrated circuits and large amounts of functionally specified, and hierarchically organized digital (genetic) and structural (epigenetic) information, that rapidly appears in the Cambrian explosion.
Ch. 19 The Rules of Science	Critics often reject ID because they claim it is not science, but ID uses standard methods of historical sciences. ID is testable by comparing its explanatory power with that of competing theories. ID employs the principle of uniformitarianism—the idea that the present is the key to the past—and is based upon our knowledge of the cause and effect structure of the world. ID makes testable predictions that distinguish it from competing theories, such as the successful prediction, confirmed by the ENCODE project, that junk DNA is functional. We need not identify the precise mechanism or details of how a design was implemented to determine that a structure was designed. Philosophers of science lack a consensus definition of science, and generally reject demarcation criteria that distinguish exactly what is, and isn't science. No single demarcation criterion disqualifies ID from being science without also disqualifying other legitimate scientific theories. We should consider ID as science, and follow the evidence wherever it leads.
Ch. 20 What's at Stake	New atheists like Richard Dawkins claim neo-Darwinism shows there is no design in nature, and therefore no God exists. Theistic evolutionists like Francis Collins claim one can believe in God and Darwinism, but provide few details about how God influenced the evolutionary process, or how to reconcile tensions between Darwinian and Judeo-Christian accounts of origins. <i>Darwin's Doubt</i> challenges both atheistic and theistic evolutionists

Ch. 20
What's at Stake
(continued)

by showing that the neo-Darwinian mechanism fails. Specifically, neo-Darwinism: (1) cannot efficiently search combinatorial sequence space to find rare functional protein sequences, and (2) requires unrealistically long waiting times to generate the information needed for new genes. Neo-Darwinian mechanisms cannot produce new body plans because: (3) early acting developmental mutations are always harmful, and (4) genetic mutations cannot generate the epigenetic information necessary to build an animal. Collins has sought to refute ID by citing the now-defunct concept of junk DNA. But why should we follow his attempt to reconcile traditional Christian theology with Darwinism when Darwinian biology is wrong? As a science, ID does not address religious questions about the identity of the designer, but it opens the possibility that life was purposefully designed by an intelligent person that many would identify as God.

Discussion Questions

Session 8

1. Evidence of design:
 - a. Based upon your experience, what are some telltale signs that an intelligent agent has been at work?
 - b. What are some of the distinctive hallmarks of design that Meyer presents in Figure 18.7?
 - c. Do we find any of these hallmarks in the Cambrian explosion?
2. Positive vs. negative evidence:
 - a. What is the difference between positive evidence and negative evidence?
 - b. Describe the positive argument for intelligent design.
 - c. Describe the negative argument for intelligent design.
 - d. Critics claim intelligent design is based upon strictly negative arguments against evolution. Do you think this is a valid critique?
3. According to Meyer's arguments in chapter 18, as well as the arguments he cites from Douglas Erwin and Eric Davidson, what are some things that the cause of the Cambrian explosion must be capable of generating?
4. Is intelligent design a cause capable of accomplishing those things? Why or why not?
5. Can intelligent design help us understand why the same parts are found reused in widely different types of organisms?

Discussion Questions

Session 8 (continued)

6. Meyer writes: “The animal forms that arose in the Cambrian not only did so without any clear material antecedent; they came on the scene complete with digital code, dynamically expressed integrated circuitry, and multi-layered, hierarchically organized information storage and processing systems.” When comparing neo-Darwinian evolution and intelligent design, which do you think is the best explanation for this evidence?
7. What predictions has intelligent design made about junk DNA, and were the predictions successful?
8. Do you think it is possible to test intelligent design?
9. What was the uniformitarian method of Charles Lyell, and how does ID make use of this scientific method?
10. Demarcation criteria:
 - a. What are demarcation criteria?
 - b. Do philosophers of science believe that demarcation criteria are helpful in distinguishing science from non-science?
 - c. Can you think of any demarcation criteria which exclude ID from being science, but do not exclude other legitimate scientific theories? If so, are these criteria reasonable?
 - d. Sometimes critics dismiss ID because of its implications. Do you think that is a fair reason to reject ID?
 - e. Do you think ID is science? Why or why not?
11. Tension between faith and Darwinism:
 - a. What are some ways that belief in neo-Darwinian evolution is in tension with belief in traditional Judeo-Christian theology?

Discussion Questions

Session 8 (continued)

- b. Why do you think many people today are trying to reconcile belief in God with neo-Darwinian evolution?
- 12. Problems with neo-Darwinism:
 - a. What are the four main problems with neo-Darwinism that Meyer outlines in chapter 20?
 - b. Which problem do you think poses the greatest challenge to evolutionary explanations?
- 12. Meyer says that the ID research community likes to say, “follow the evidence wherever it leads.” Where do you feel the evidence is leading—to new atheism, theistic evolution, or intelligent design?
- 13. Naming the designer:
 - a. Why doesn’t intelligent design identify the designing intelligence responsible for life?
 - b. Is intelligent design compatible with traditional the Judeo-Christian belief that God is the designer?
 - c. If intelligent design is true, what might this say about the existence of God?

Additional Resources

darwinsdoubt.com	Explore a wealth of additional information about the issues raised by <i>Darwin's Doubt</i> at its official website. You can view lectures by Dr. Meyer, examine fossil photos, learn about the scientists who have endorsed the book, and read articles responding to critics.
Darwin's Dilemma	In this documentary, you can visit some of the amazing fossil sites in China and Canada described in <i>Darwin's Doubt</i> , meet leading scientists who are investigating the Cambrian explosion, and hear from Stephen Meyer and other experts about the growing challenges to modern Darwinian theory. Watching this documentary is a great way to begin or conclude your discussion of <i>Darwin's Doubt</i> . To view the trailer for the documentary and get more information, visit http://www.darwinsdilemma.org .
stephencmeyer.org	Learn about the author of <i>Darwin's Doubt</i> —his biography, his other writings, his media appearances, and more.
signatureinthecell.com	Explore the evidence for intelligent design in the origin of the first life in the companion book by Stephen Meyer, <i>Signature in the Cell</i> .
intelligentdesign.org	Learn more about the theory of intelligent design at this portal to additional resources, which includes a store where you can purchase videos and books relating to intelligent design.