

## Session 6: From Prokaryotes to Multicellular Organisms

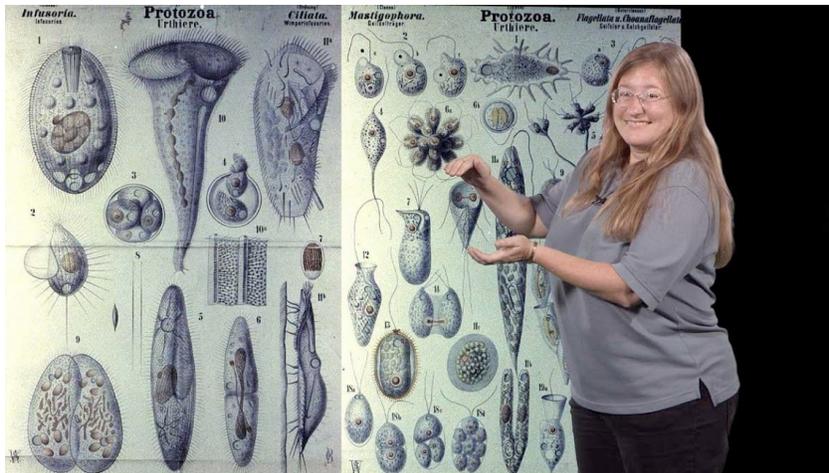
### Overview:

Once prokaryotic life emerged on earth, how did it evolve into larger, more complex eukaryotic organisms? Three scientists help us understand how this may have happened. Dr. Julie Theriot speculates about the important role that cytoskeleton-associated proteins may have played in that transition (and she challenges you to prove her speculation wrong!). Dr. Miller explains how endosymbionts such as mitochondria and chloroplasts came to be the power organelles of eukaryotes. And Dr. Nicole King addresses the fascinating question of how the first multicellular animals may have evolved from our unicellular ancestors.

### First video:

Title: Evolution of a dynamic cytoskeleton

Speaker: Julie Theriot



### Questions for Part 1:

1. Which of the following is a characteristic observed in eukaryotes but not in prokaryotes?
  - a. Motor proteins.
  - b. Cellular organization.
  - c. Compartmentalization.
  - d. Actin or actin-like proteins.
  - e. Cytoskeletal proteins.
2. Can bacteria form multicellular structures?
  - a. Only pre-metazoan bacteria have this property.
  - b. Any bacteria can form multicellular structures.
  - c. No bacteria can form multicellular structures.
  - d. Only post-metazoan bacteria have this property.
  - e. None of the above.

For questions 3-6, determine if the statement is true or false. If the statement is false, change one word to make it true.

3. Proteins that self-assemble are likely to form alpha helices.
4. The last common ancestor (LUCA) to all organisms living today contained both a tubulin- and an actin-like protein.
5. Similar to prokaryotes, eukaryotes contain cytoskeletal proteins.
6. Similar to prokaryotes, eukaryotes contain motor proteins that move on the cytoskeleton.
7. The last universal common ancestor (LUCA) is thought to be the predecessor of all organisms living today.
  - a. Provide examples of two features that scientists assume LUCA had.
  - b. Why do scientists think LUCA had these characteristics? Briefly explain.
8. Why do scientists believe that myosin and kinesin evolved from a common ancestor? Briefly explain.
9. Scientists hypothesize that molecular motor proteins arose from a common ancestor of eukaryotic lineage, and therefore molecular motor proteins are not present in prokaryotes. While studying the evolution of prokaryotes to eukaryotes, Elliott discovered bacteria that contain a molecular motor-like protein. Provide a hypothesis that explains this observation, but agrees with the current thinking about the origins of eukaryotic motor proteins.

10. Scientists have identified many differences in the structural complexity of prokaryotes and eukaryotes. Prior to the 1990s, they hypothesized that these differences were due to the presence of a cytoskeleton in eukaryotes but not prokaryotes.
- a. Explain how the presence of a cytoskeleton could be responsible for the following features in eukaryotes but not prokaryotes:
    - i. Membrane-enclosed nucleus and membrane-bound internal organelles
    - ii. Endosymbiosis (chloroplasts and mitochondria)
    - iii. Multicellularity and larger size
  - b. What happened in the 1990s that led scientists to rethink their ideas about the role of the eukaryotic cytoskeleton? Briefly explain.

**Second video:**

Title: Evolution - Why it Matters

Speaker: Kenneth Miller

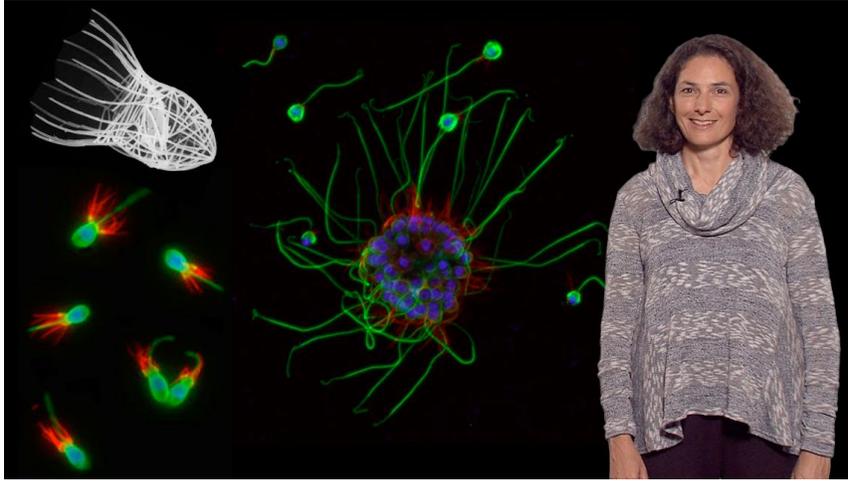
*Please watch this video from time 8:40 to 10:52.*



**Third video:**

Title: The origin of animal multicellularity

Speaker: Nicole King



**Questions for Part 2 and 3:**

1. The hypothesis which explains the evolution of endosymbionts in eukaryotic cells is supported by:
  - a. DNA-sequencing analysis comparing bacterial genomes, mitochondrial genomes, and eukaryotic nuclear genomes.
  - b. The presence of unique ribosomes in mitochondria and chloroplasts.
  - c. The presence of DNA in mitochondria and chloroplasts.
  - d. All of the above.
  - e. A and b only.
  
2. Which of the following are possible origins of multicellularity?
  - a. Endosymbiosis.
  - b. Aggregation of cells to form a colony.
  - c. Division of cells with the resulting cells sticking together.
  - d. Multiple cell types aggregating to form a complex organism.
  - e. b and c.
  
3. The first animals were capable of
  - a. Sexual reproduction.
  - b. Photosynthesis.
  - c. Gametogenesis.
  - d. A and B are correct.
  - e. A and C are correct.
  - f. B and C are correct.

4. Which of the following groups include organisms that are able to generate multicellular structures?
  - a. Eukaryotes.
  - b. Prokaryotes.
  - c. Fungi
  - d. All of the above.
  - e. None of the above.
  
5. Which of the following are examples of multicellular organisms? Choose all of the answers that apply.
  - a. **Yeast.**
  - b. E. Coli.
  - c. Lizards.
  - d. Amoeba.
  - e. Malaria.

For questions 6-9, determine if the statement is true or false. If the statement is false, change one word to make it true.

6. Multicellular organisms do not share a common multicellular ancestor.
  
7. When comparing multicellular organisms, the genes that are shared between species give a clue to the genes involved in multicellularity.
  
8. Although choanoflagellates can form multicellular structures, they can also exist in the single cell form.
  
9. According to the endosymbiotic theory, mitochondria used to be free-living cyanobacteria that were engulfed by early cells.
  
10. List two characteristics that may have been common to the first animals.
  
  
  
  
  
  
  
  
  
  
11. Shannon is studying the evolution of eukaryotic cells. What characteristics have scientists observed in mitochondria and/or chloroplasts that support the endosymbiotic theory?

12. Draw a possible phylogenetic tree that connects the following organisms:

plants, chimpanzees, cyanobacteria, choanoflagellates, yeast, humans, early prokaryotes

13. Eric is studying the evolution of species. After performing DNA analysis, he discovers a gene that is conserved from yeast to humans.

a. In which cellular processes is this gene most likely to be involved?

b. Could this gene have evolved to confer some of the complex traits that we observe in modern animals, like multicellularity? Briefly explain.

## Answers for Session 6:

### Questions for Part 1:

1. Which of the following is a characteristic observed in eukaryotes but not in prokaryotes?
  - a. Motor proteins.
  - b. Cellular organization.
  - c. **Compartmentalization.**
  - d. Actin or actin-like proteins.
  - e. Cytoskeletal proteins.

2. Can bacteria form multicellular structures?
  - a. Only pre-metazoan bacteria have this property.
  - b. Any bacteria can form multicellular structures.
  - c. No bacteria can form multicellular structures.
  - d. Only post-metazoan bacteria have this property.
  - e. **None of the above.**

For questions 3-6, determine if the statement is true or false. If the statement is false, change one word to make it true.

3. Proteins that self-assemble are likely to form alpha helices.  
**True.**
4. The last common ancestor (LUCA) to all organisms living today contained both a tubulin- and an actin-like protein.  
**True.**
5. Similar to prokaryotes, eukaryotes contain cytoskeletal proteins.  
**True.**
6. Similar to prokaryotes, eukaryotes contain motor proteins that move on the cytoskeleton.  
**False; Similar to Unlike OR different from**
7. The last universal common ancestor (LUCA) is thought to be the predecessor of all organisms living today.
  - a. Provide examples of two features that scientists assume LUCA had.  
**Ribosomes, DNA, metabolism and glycolysis, cytoskeletal components.**
  - b. Why do scientists think LUCA had these characteristics? Briefly explain.  
**As LUCA is the common ancestor, scientists presume that it had the processes and characteristics that are common to all living organisms.**
8. Why do scientists believe that myosin and kinesin evolved from a common ancestor? Briefly explain.  
**Structural analysis shows that the catalytic cores of myosin and kinesin are very similar, even though the amino acid sequence is different. This led to the hypothesis that the proteins must have come from a common ancestor (motor protein precursor). Gene duplication events and later specialization led to the evolution of two distinct motor proteins.**

9. Scientists hypothesize that molecular motor proteins arose from a common ancestor of eukaryotic lineage, and therefore molecular motor proteins are not present in prokaryotes. While studying the evolution of prokaryotes to eukaryotes, Elliott discovered bacteria that contain a molecular motor-like protein. Provide a hypothesis that explains this observation, but agrees with the current thinking about the origins of eukaryotic motor proteins.

**Convergent evolution. After the ancient divergence of prokaryotes and eukaryotes, both the eukaryotic ancestor and the bacteria that Elliot discovered could have independently evolved motor proteins.**

10. Scientists have identified many differences in the structural complexity of prokaryotes and eukaryotes. Prior to the 1990s, they hypothesized that these differences were due to the presence of a cytoskeleton in eukaryotes but not prokaryotes.

- a. Explain how the presence of a cytoskeleton could be responsible for the following features in eukaryotes but not prokaryotes:

- i. Membrane-enclosed nucleus and membrane-bound internal organelles

- 1. Intracellular membrane transport by motor proteins**
- 2. Nuclear lamins (intermediate filaments) stabilize the nuclear membrane**

- ii. Endosymbiosis (chloroplasts and mitochondria)

- 1. Actin cytoskeleton enables phagocytosis**

- iii. Multicellularity and larger size

- 1. Actin and intermediate filaments generate strong cell-cell junctions**
- 2. Cytoskeleton regulates cell wall and extracellular matrix deposition**

- b. What happened in the 1990s that led scientists to rethink their ideas about the role of the eukaryotic cytoskeleton? Briefly explain.

**Scientists discovered that bacteria have a cytoskeleton with proteins that are homologous to eukaryotic tubulin and actin. These proteins probably existed in the common ancestor and did not evolve independently in the eukaryotic lineage. Therefore these proteins are unlikely to explain all the differences in complexity between prokaryotes and eukaryotes.**

**Questions for Part 2 and 3:**

1. The hypothesis which explains the evolution of endosymbionts in eukaryotic cells is supported by:
  - a. DNA-sequencing analysis comparing bacterial genomes, mitochondrial genomes, and eukaryotic nuclear genomes.
  - b. The presence of unique ribosomes in mitochondria and chloroplasts.
  - c. The presence of DNA in mitochondria and chloroplasts.
  - d. **All of the above.**
  - e. A and b only.
  
2. Which of the following are possible origins of multicellularity?
  - a. Endosymbiosis.
  - b. Aggregation of cells to form a colony.
  - c. Division of cells with the resulting cells sticking together.
  - d. Multiple cell types aggregating to form a complex organism.
  - e. **b and c.**
  
3. The first animals were capable of
  - a. Sexual reproduction.
  - b. Photosynthesis.
  - c. Gametogenesis.
  - d. A and B are correct.
  - e. **A and C are correct.**
  - f. B and C are correct.
  
4. Which of the following groups include organisms that are able to generate multicellular structures?
  - a. Eukaryotes.
  - b. Prokaryotes.
  - c. Fungi
  - d. **All of the above.**
  - e. None of the above.
  
5. Which of the following are examples of multicellular organisms? Choose all of the answers that apply.
  - a. **Yeast.**
  - b. E. Coli.
  - c. **Lizards.**
  - d. Amoeba.
  - e. Malaria.

For questions 6-9, determine if the statement is true or false. If the statement is false, change one word to make it true.

6. Multicellular organisms do not share a common multicellular ancestor.  
**True.**

7. When comparing multicellular organisms, the genes that are shared between species give a clue to the genes involved in multicellularity.

**False; shared unique**

8. Although choanoflagellates can form multicellular structures, they can also exist in the single cell form.

**True.**

9. According to the endosymbiotic theory, mitochondria used to be free-living cyanobacteria that were engulfed by early cells.

**False; mitochondria chloroplasts**

10. List two characteristics that may have been common to the first animals.

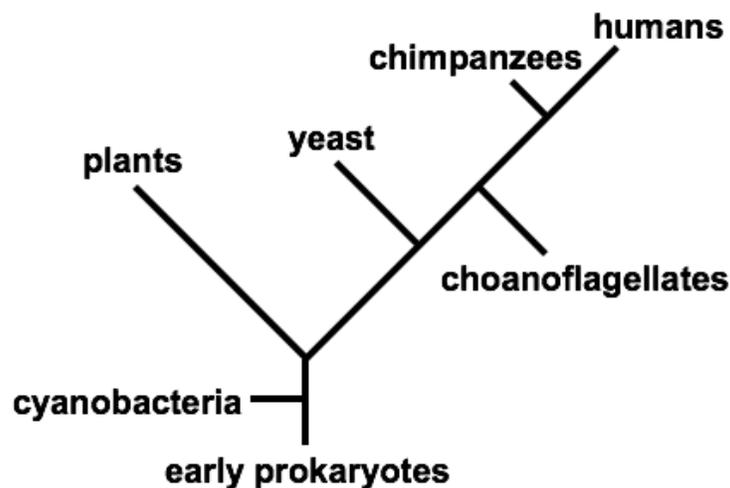
- a. **Ate bacteria.**
- b. **Collar cells.**
- c. **Apoptosis.**
- d. **Cell differentiation.**
- e. **Gametogenesis.**

11. Shannon is studying the evolution of eukaryotic cells. What characteristics have scientists observed in mitochondria and/or chloroplasts that support the endosymbiotic theory?

**They contain DNA that is different from, and replicates independently from, nuclear DNA. They are surrounded by two membranes (rather than one like other organelles). They have distinct ribosomes.**

12. Draw a possible phylogenetic tree that connects the following organisms:

plants, chimpanzees, cyanobacteria, choanoflagellates, yeast, humans, early prokaryotes



13. Eric is studying the evolution of species. After performing DNA analysis, he discovers a gene that is conserved from yeast to humans.

a. In which cellular processes is this gene most likely to be involved?

**This gene is probably involved in the basic housekeeping functions of the cell such as DNA replication, transcription, and translation.**

b. Could this gene have evolved to confer some of the complex traits that we observe in modern animals, like multicellularity? Briefly explain.

**Probably not. Fossil and DNA analysis suggest that certain traits, like multicellularity, evolved independently between different phyla. Therefore, the genes involved in complex traits are unlikely to be shared by the common ancestor.**