

Biology 1305

Modern Concepts in Bioscience (ICB Textbook)

Hello and welcome to the weekly resources for BIO-1305 - Biology 1

This week is Week 9 of class, and typically in this week of the semester, your professors are covering the topics below. If you do not see the topics your particular section of class is learning this week, please take a look at other weekly resources listed on our website for additional topics throughout the semester.

We also invite you **to look at the group tutoring chart on our website to see if this course has a group tutoring session offered this semester.**

If you have any questions about these study guides, group tutoring sessions, private 30 minute tutoring appointments, the Baylor Tutoring YouTube channel, or any tutoring services we offer, please visit our website www.baylor.edu/tutoring or call our drop in center during open business hours (M-Th 9am-8pm on class days at 254-710-4135).

KEYWORDS: Chromatin, Histones, Nucleosomes, DNA Organization

TOPIC OF THE WEEK

Organization of DNA

As we all know, a typical human nucleus is extremely small. However, if we stretched out all of the DNA in a typical nucleus, it would be much longer than the diameter of a nucleus. In this section, we will discuss how DNA in eukaryotes is organized in a way that allows it to fit into a much smaller space while still maintaining organization.

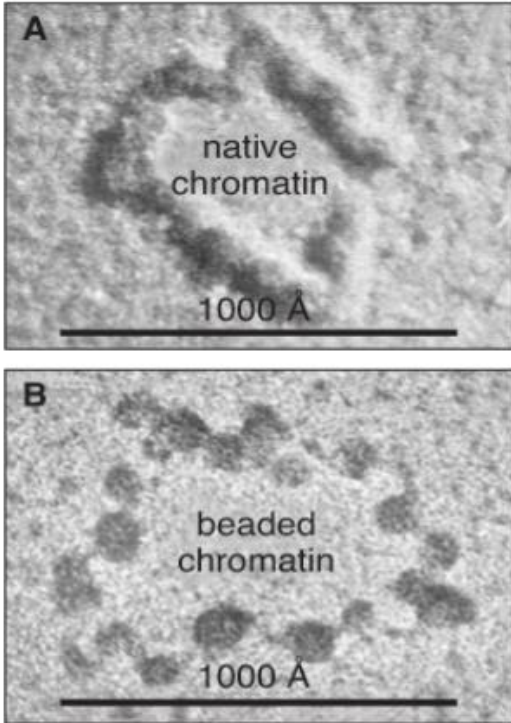
In its native state, our DNA is bound to many different proteins. We call this combination of DNA and proteins **chromatin**. The most abundant class of proteins which are associated with DNA are called **histones**.

Recall that DNA has a negative charge; what can we infer about the properties of histone proteins if we know that DNA is attracted to and binds to histones?

Many biologists used electron microscopes to view chromatin in the nucleus. When they did this, they saw that the DNA was wrapped around bead-like spheres, which they realized were

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histone proteins. The DNA looked like a string which connected the beads. Because of this, we use the **“beads on a string”** model to describe DNA organization in eukaryotes. A section of DNA which is wrapped around a histone is called a **nucleosome**.

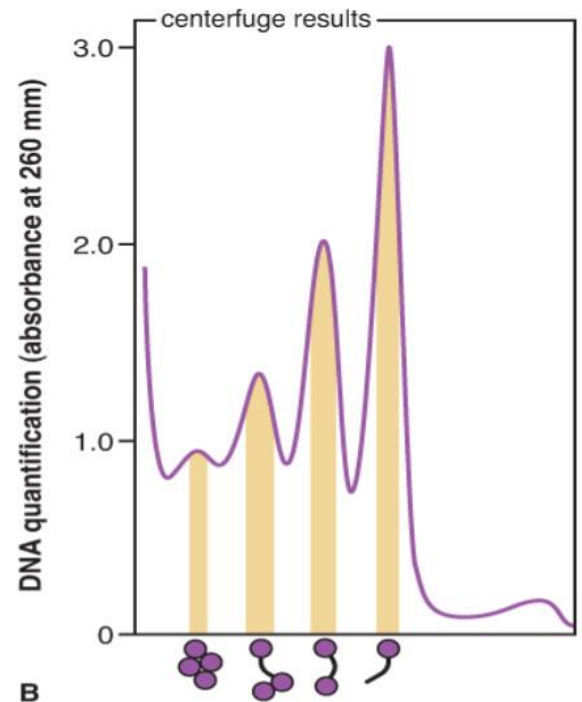


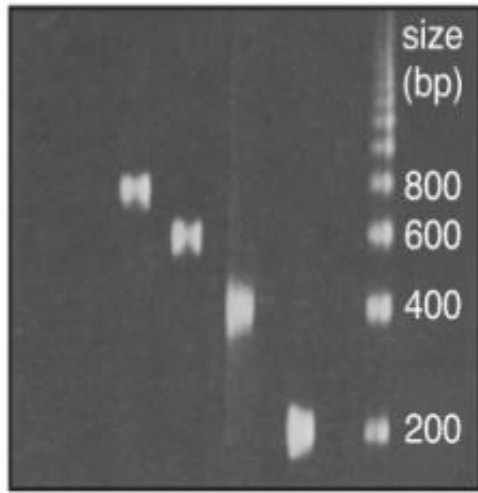
This image is an example of how DNA can be visualized using **electron micrographs**, which are generated through **electron microscopy**. Image A is a micrograph of SV40 viral DNA which is in its **native** chromatin state, while image B shows us what the same chromatin looks like after it has been treated in order to maximize the appearance of the “beads,” or histones.

When scientists measured the length of this viral DNA both with and without histones and compared them, they saw that in this particular virus, DNA with histones was compacted sevenfold!

In a different experiment, a biochemist used centrifugation to isolate chromatin fragments of DNA and histones in units of 1, 2, 3, or 4 beads. Remember that **centrifugation** is a technique that separates different components of a heterogenous mixture by size, shape, or density.

As we can see from the four peaks in this image, the **chromatin separated into four distinct sized fragments**. This helped to confirm that DNA was uniformly organized around distinct histone proteins.



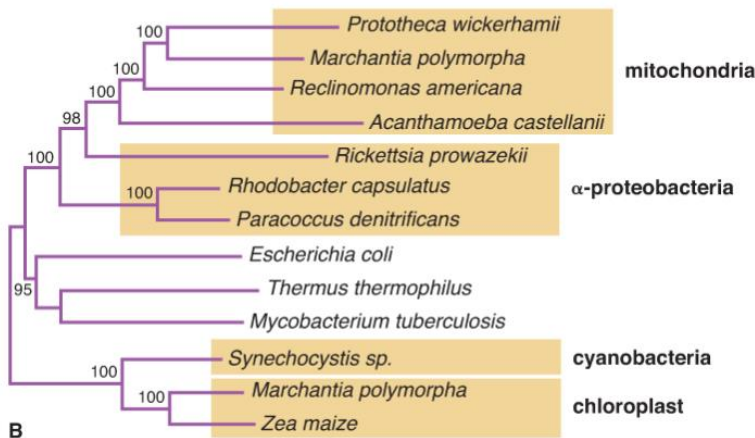


gel electrophoresis

The gel results from this experiment show that each of the smallest fragments had a size of 200 base pairs, and each of the other fragment sizes were multiples of 200. Based on this data, researchers confirmed that DNA is wrapped around each histone in multiples of 200 base pairs. Based on further study, biochemists determined that each histone complex has a **quaternary** structure and is composed of **two copies of four different histone protein subunits, for a total of eight histone subunits**. While histones are only one of many levels of DNA organization, these figures help us understand how our DNA can fit into such a small space and still remain organized and functional.

HIGHLIGHT #1: Endosymbiotic Theory

Endosymbiotic Theory: A theory explaining the origin of **eukaryotic** cells. It states that the mitochondria and chloroplast in eukaryotic cells were once bacteria which were ingested by a large anaerobic bacterium.

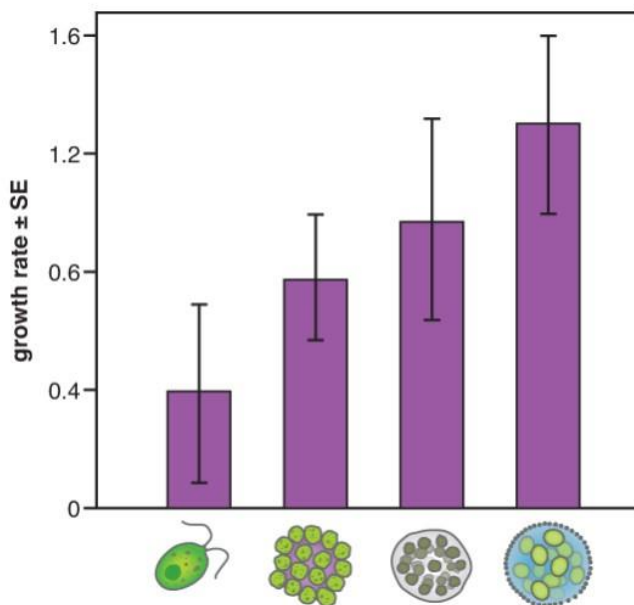


This evolutionary tree is based on **genome sequences** and shows the relationships between mitochondrial DNA from various eukaryotes, chloroplast DNA from two plants, three bacterial genomes, and a cyanobacteria genome.

We can see from the above tree that mitochondria evolved from a subtype of bacteria called **α -proteobacteria**, and the species *Rickettsia prowazekii* is its nearest living relative. Chloroplasts evolved from **photosynthetic** prokaryotes called **cyanobacteria**, and according to this figure, their nearest living relative comes from the genus *Synechocystis*. Currently, the most widely accepted model for this theory is that a primitive eukaryote engulfed a bacterium, and because the bacteria was useful, the two organisms had a **symbiotic relationship**. Over time, natural selection led to the evolution of mitochondria and chloroplasts from prokaryotic cells (because they provided their eukaryotic hosts with benefits that allowed them to out-compete organisms without engulfed bacteria).

HIGHLIGHT #2: Volvox Cells

Last week, we talked about how scientists compared growth rates of intact *Volvox carteri* colonies, intact colonies, and isolated reproductive cells. This week, we're looking at an experiment in which scientists compared **growth rates of different species of related green algae as a function of nutrient enrichment**. Biologists had noticed that Volvox were found more often in ponds containing a lot of organic matter, and they decided to quantify growth rates in ponds with different levels of nutrient enrichment.



They studied autonomous unicellular *Chlamydomonas* (first column), *Gonium*, which produces colonies that are flat (second), and *Eudorina*, which produces small spherical colonies (third). **Volvox was the only species studied that produces specialized reproductive cells (division of labor)**. The investigators determined the growth rates of all four species at different nutrient levels, and this figure shows the results for the richest nutrient level tested.

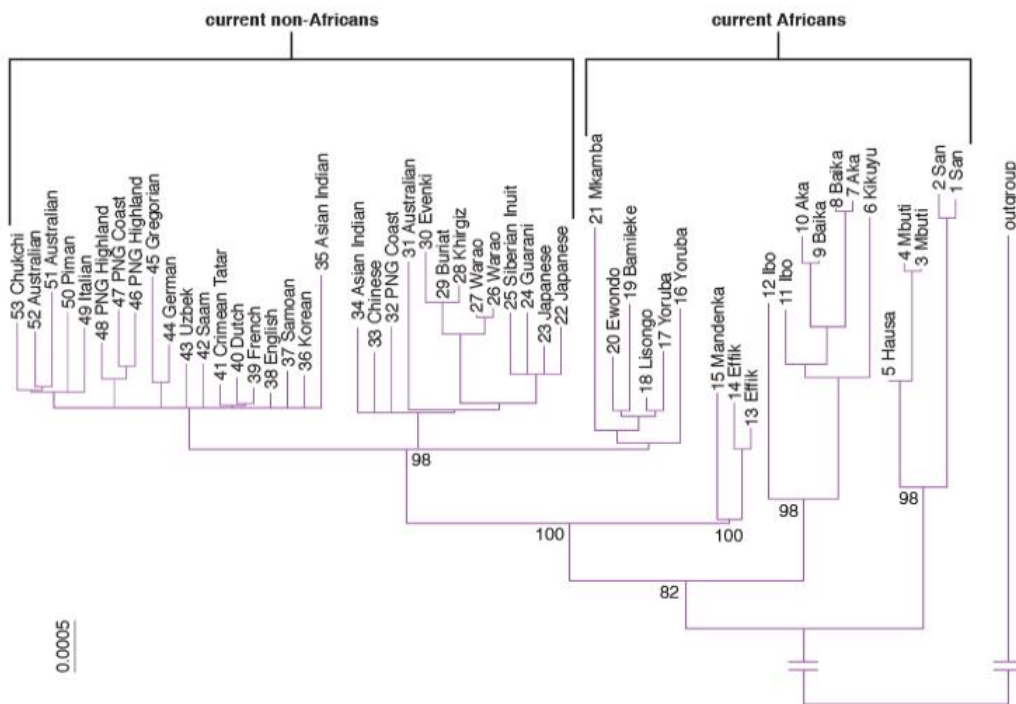
We can see from the above figure that ***V. carteri* grew the fastest** of the four species tested, suggesting that **multicellularity with division of labor is better adapted to growth in a rich environment**. The biologists also found that Volvox did not grow faster in nutrient-poor

water, which indicates that *Volvox probably did not evolve until some bodies of water were rich with organic molecules produced by other species*. The investigators speculated that the energetic cost of swimming was too high in low nutrient water for the large colonies compared to the smaller colonies and unicellular species.

HIGHLIGHT #3: Mitochondrial Genomes

“Out-of-Africa” Hypothesis: proposes that *Homo sapiens* evolved once in Africa and then migrated out to every other part of the earth

In order to provide evidence which definitively supported this hypothesis, investigators sequenced complete mitochondrial genomes from 53 people who lived in geographically distributed locations around the world. They chose to use mitochondrial genomes because **mitochondrial DNA is relatively stable due to its maternal inheritance pattern**. They used this information to construct an evolutionary tree from the 53 human mitochondrial genomes. They also included mitochondrial DNA from an outgroup so that all human sequences were compared to one very different genome.



This evolutionary tree shows the number of DNA base changes as a **vertical distance** relative to the length of the line under the key (*the key is provided in the bottom left corner: the length of the line segment shown corresponds to a base change frequency of 0.0005*). The numbers at each of the branch points represent the **bootstrap** value at that point, while the numbers at the ends of the tree are simply identifying the sample number of their data point.

MRCA=Most Recent Common Ancestor: The last individual in a lineage from which all the members in a group are directly descended (represented by branch points).

As you study the above figure, make sure you can identify which individuals have similar DNA and which have relatively different DNA. For example, the distance between individuals #2 (San) and #7 (Aka) is the greatest number of DNA differences among all the people on the entire evolutionary tree. The MRCA of two individuals is represented by the first branch point that connects them both.

CHECK YOUR LEARNING

(Answers below)

- 1) What is the bootstrap value for the MRCA of individuals 16 and 22 on the above figure?
- 2) If you had to find the base change frequency between two individuals, what process would you use to do this?
- 3) Why do you think *volvox* thrive in nutrient rich environments but not in nutrient poor environments compared to other smaller species of algae?
- 4) Over time, chloroplasts and mitochondria have lost many genes from their ancestral bacterial genomes. Why do you think this is?

THINGS YOU MAY STRUGGLE WITH

- For the mitochondrial DNA evolutionary tree (and any evolutionary tree), keep in mind that only the distance of the branches matters. The order of the branches does not give us any information, and changing this order would not make a difference in our interpretation of the data. For the above figure, this means that vertical distance is a measure of evolutionary distance, but the horizontal distance between two individuals does not mean anything.
- A symbiotic relationship is a close biological interaction between two organisms which benefits one or both of the organisms.
- Remember that organization of DNA around histones occurs only in eukaryotes! This form of organization does not apply to all living organisms.

ANSWERS

- 1) 98%
- 2) Measure the length of the line on the key, then measure the length of the branch that you are trying to find the base change frequency of. Divide the length of the branch by the length given in the key, then multiply this value by 0.0005.
- 3) Maintaining larger colonies requires much more energy, so in nutrient poor environments where it is difficult to access the required nutrients, volvox expend more energy than other smaller species but cannot benefit from their colony structure. However, in nutrient rich environments, volvox's colonies and division of labor give them an advantage.
- 4) Over time, genes which were present both in the mitochondrial or chloroplast DNA and the eukaryotic nuclear DNA were lost from the mitochondrial and chloroplast genomes because they were not needed.

Thanks for checking out these weekly resources! Don't forget to check out our website for group tutoring times, video tutorials and lots of other resources: www.baylor.edu/tutoring! Answers to Check your Learning questions are below!