Biology 1305
Modern Concepts in Bioscience (ICB Textbook)

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

This week is Week 8 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 9am8pm on class days at 254-710-4135).

KEYWORDS: Mutations, Errors, DNA Polymerase, Evolution

TOPIC OF THE WEEK

Genomic Changes

In previous chapters, we talked about genetic mutations and the role they play as a mechanism of evolution. We know that mutations are random and are a result of errors during DNA replication. In order to understand how mutations are introduced into DNA, scientists first had to study how DNA polymerase starts the process of replication and figure out how to polymerize DNA ***in vitro.***

In order to determine what DNA polymerase needs to start polymerizing, they added *E. coli* DNA polymerase, all four bases of deoxyribonucleotide triphosphates (dNTPs), template DNA, and a small amount of deoxyguanosine triphosphate (dGTP) which contained radioactive phosphorus (^{32}P-dGTP) to three test tubes. They also added different amounts of DNA primer to each test tube.

- A **primer** is a short single strand of DNA or RNA that is complementary to the template strand; (DNA polymerase can only attach new DNA nucleotides to an existing strand of nucleotides)

For both of the below sets of data, DNA polymerization was quantified by measuring the amount of radioactive dGMP incorporated into the growing DNA strand.

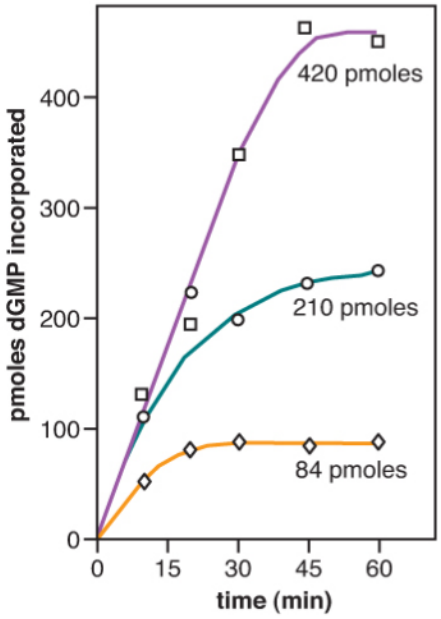
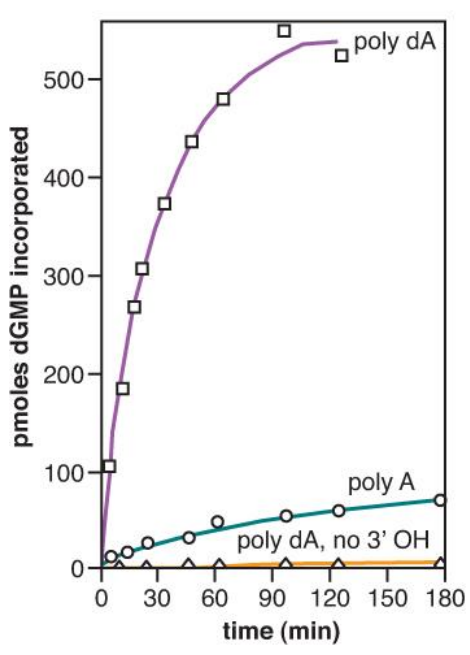


Figure A shows the results of the experiment described above. We can see that DNA polymerase requires primers to make new polymers from a DNA template and more radioactive dGMP was incorporated into new DNA strands when more primer was available. **This means that DNA polymerization increases when the primer is longer.**

Figure B shows the results of a similar experiment in which different types of DNA primers were added to the three different test tubes instead of primers of different length. Under these *in vitro* experimental conditions, we can see that *E. coli* DNA polymerase works better if the primer is a polymer of dAMP (poly dA) instead of AMP (poly A). Furthermore, the primer must have a 3' OH group in order for DNA polymerase to add the next nucleotide onto the primer.



Note: In living cells, the primer is made up of RNA instead of DNA; however, the important thing to know is that DNA Polymerase needs a primer with an OH group in order to start polymerizing.

After scientists learned how to conduct DNA polymerization studies like the one described above, they began to study the role that DNA polymerase and other factors play in the appearance of new mutations.

For example, they first looked at the role that **age of the DNA polymerase** plays on the rate of polymerase activity. In order to do this, scientists grew human skin cells in petri dishes and isolated DNA polymerase from samples of the cells right away and again later from cells that had grown for many days in the petri dish.

cell extracts	activity
young	982 units
old	58 units

The scientists then measured the speed of the young versus old polymerases and quantified the rate of replication as units of activity. As we can see, DNA polymerase from older cells, or "old" DNA polymerase has a much lower rate of polymerization than "newer" DNA.

Once they established that older DNA polymerases were less active, they compared old and new DNA polymerases in the presence of the two different metal ions (Mg^{2+} and Mn^{2+}).

DNA polymerase	ion	bases polymerized	error rate
young	Mg^{2+}	17,300	1 in 1821 bases
old	Mg^{2+}	5,400	1 in 474 bases
young	Mn^{2+}	26,800	1 in 1848 bases
old	Mn^{2+}	18,800	1 in 556 bases

We can see from these results that old DNA polymerases have a much higher rate of DNA replication errors than new DNA polymerases. We also see that DNA polymerase in the presence of Mg2+ ions has a higher error rate than DNA polymerase in the presence of Mn2+.

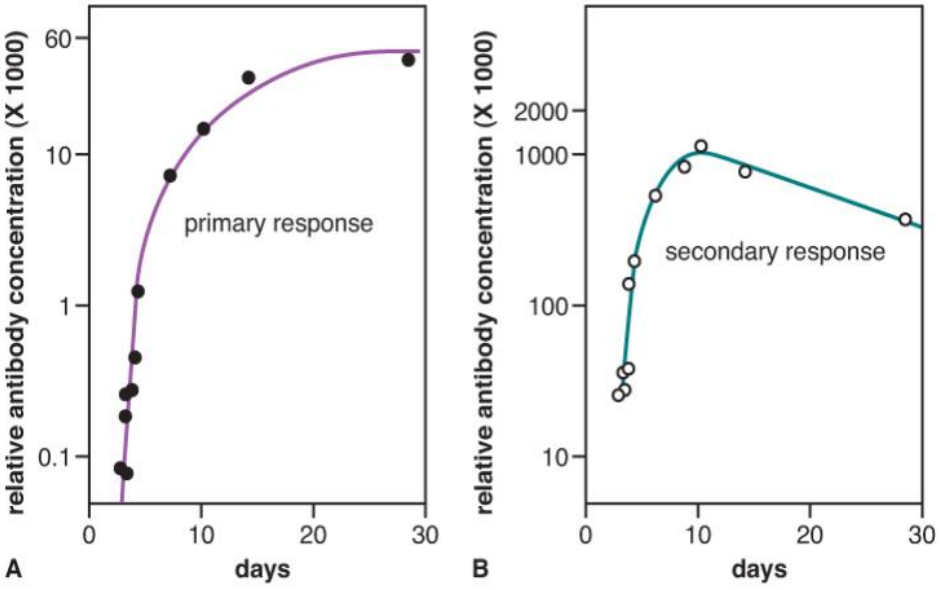
The figures and experiments in this section provide some examples of ways that mutations in DNA can randomly arise.

HIGHLIGHT #1: The Immune Response

Section 5.3 looks at evolution within a specific group of immune cells in our body called B cells. Our immune system protects us from toxins and pathogens by producing antibodies which recognize and bind to antigens and make it easier for the body to destroy them. These antibodies are produced by B cells.

Antibodies: proteins produced by body as a response to specific antigens; recognize and bind to antigens as part of immune response
Antigens: Toxic or foreign substances which trigger an immune response in the body, specifically the production of specific antibodies

In order to study how immune responses to antigens get stronger with each exposure, scientists injected guinea pigs with small amounts of a particular protein and measured the amount of antibody in the animals' blood that bound to the injected protein over time. When they did this, within a few days, the animals began to produce more antibodies until the amount leveled off later in the month. Three weeks later, the immunologists reinjected the same guinea pigs with more of the same protein antigen and measured and quantified the amount of antigen-specific antibody in their blood.



This is an example of a figure where it is very important for us to **study the x and y axis before we begin to look at the data!** At first glance, it may seem like the first figure is showing a greater response. However, when we look at the Y axis, we see that the **second figure,** or the results for the experiment done three weeks later, is showing much higher levels of antibody concentration in the blood.

These results show that **a secondary immune response to the same antigen produces at least ten times more antibodies than the primary response**. The antibodies produced by this

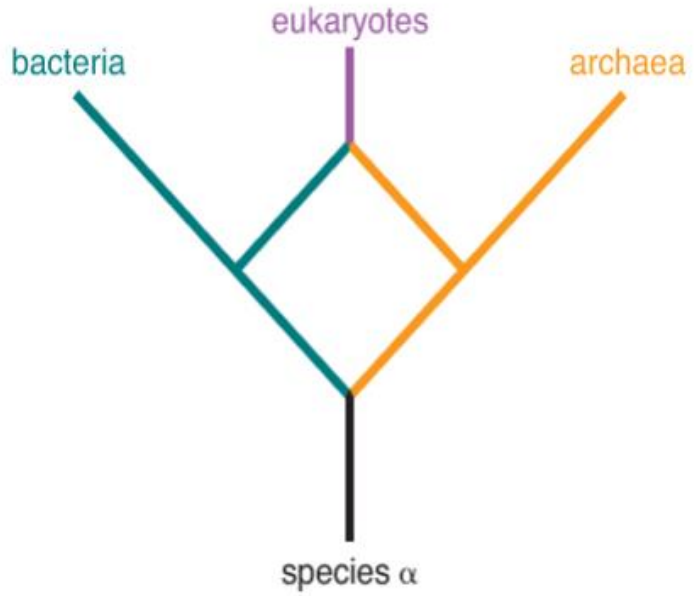
response clear your blood of the antigen faster, so the level of antibodies goes down faster as well, as we can see in the second figure.

HIGHLIGHT #2: Evolutionary Trees

Phylogenetic/Evolutionary tree: branching diagram or tree showing the evolutionary relationships between various biological species based on similarities and differences in their physical or genetic characteristics.

Remember to always look at the base of the tree to find the oldest group or species. The branches which come out from this base represent the passage of evolutionary time and the divergence of the original species into various descendents and new species

Section 6.1 shows various ways that evolutionary trees can be generated. The below tree was generated based on gene sequence alignments between species, and therefore is thought to be more accurate than a phylogenetic tree which is based only on one specific gene sequence.

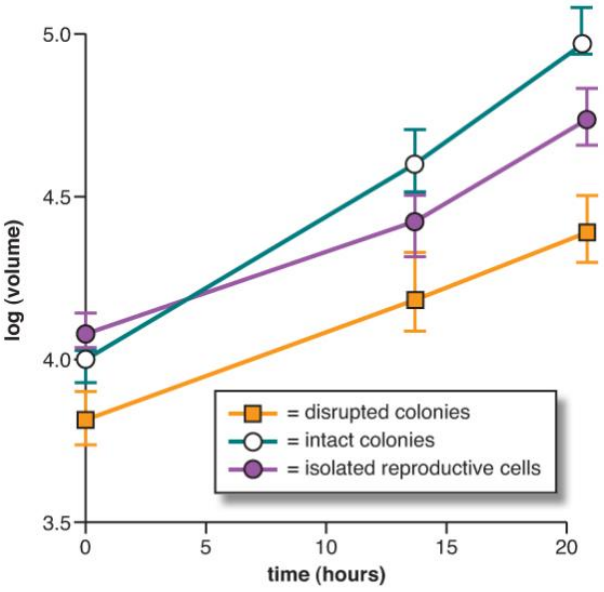


This diagram illustrates how a primitive species could diverge into two branches, which later merged genomes to produce a third branch. This data shows us that humans and all eukaryotes contain genes from both eubacteria and archaea which both diverged from a common ancestor, **species α,** long ago. This model explains why some human proteins are more closely related to eubacterial proteins, while others are more closely related to archaeal proteins.

HIGHLIGHT #3: Multicellular Organisms

Next, we will look at a different type of evolution. Section 6.4 studies the question of how multicellular organisms evolved. In order to do this, scientists compared growth rates of intact *Volvox carteri* (green algae) colonies to growth rates of isolated reproductive *V. carteri* cells that would have to conduct their own cellular metabolism and perform their own reproductive processes. The biologists predicted that reproductive cells would not grow as quickly on their own compared to reproductive cells within functional colonies. In other words, they hypothesized that multicellularity would give *Volvox carteri* colonies an advantage.

In order to test this prediction, investigators produced three types of *V. carteri* cell populations from colonies: **isolated reproductive cells, partially disrupted colonies, and intact colonies**. The algae were grown in constant light and temperature to promote maximum growth rates.



These results show us that in rich media, reproductive cells grew faster in intact colonies than in disrupted colonies or in isolation. It is also important to realize that the growth rates of isolated reproductive cells and reproductive cells growing in disrupted colonies were not different from each other (look at the slopes of the lines in order to compare rates). Therefore, Bell and his colleagues deduced that the **non-reproductive cells transferred nutrients to reproductive cells, which allowed for a higher rate of growth of reproductive cells in intact colonies.** This helps to explain how living in colonies gave *Volvox carteri* cells an advantage and why multicellularity may have evolved.

CHECK YOUR LEARNING

(Answers below)

1) Based on what we learned about the immune response in this section, why do immunizations and booster shots help prepare our bodies to fight specific foreign pathogens?
2) What does it mean for DNA polymerase to be "old?" What characteristics do older DNA polymerases have when compared to newer DNA polymerases?
3) What are dNTPs?
4) What is the difference between antibodies and antigens?

THINGS YOU MAY STRUGGLE WITH

- When studying the figure comparing growth rates of *V.carteri* cells, be sure to look at the **slope** of the line graph to compare growth rates. The endpoints do not give us the information we need because the starting points are all different
- Humans and all eukaryotes contain genes from both eubacteria and archaea. Based on evolutionary trees generated from **gene sequence alignment**, it is likely that both eubacteria and archaea evolved from a common ancestor, and at one point, these two domains merged genomes to create a third domain, eukarya.
- When comparing the primary and secondary immune responses, remember that in the secondary response, which produced more antibodies at a much faster rate, levels of antibodies decrease quicker because the antibodies bind to all of the antigens in the body at a faster rate

ANSWERS

1) Immunizations expose your body to the antigen for the first time and allow it to carry out the primary response, so your body is much better prepared to make the appropriate antibodies at a higher rate (secondary response) if it ever encounters that antigen again.
2) "Old" DNA polymerase was isolated from cells that were older, and therefore had been polymerizing for longer. Older DNA polymerase is slower and has a higher error rate than newer DNA polymerase.
3) dNTP stands for deoxyribonucleotide triphosphate. Each dNTP is made up of a phosphate group, a deoxyribose sugar and a nitrogenous base. There are four different dNTPs (because there are four different nitrogenous bases)

4) Antibodies are made by B cells in the body to specifically recognize and interact with antigens, which are foreign substances which enter the body and trigger an immune response. Antibodies bind to antigens and mark them for destruction.

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!