Survival Skills

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Survival Skills

GENERAL STUDY HABITS

Since you are now enrolled in college, odds are that you were a pretty good student in high school. But no matter how successful a student you were, experience has shown that the learning skills you employed in high school will likely not be sufficient to guarantee success in your college courses.

College professors will routinely expect you to exceed the accomplishments of your high school coursework, and that means you must adjust your study habits appropriately to meet this challenge. A good way to begin this adjustment process is to consider the ways in which college coursework differs from high school.

Common differences between college and high school courses are that in college:

- Material is presented more rapidly and in larger quantities.
- Fewer exams are given and each exam covers more material.
- All assignments typically count toward the final grade.
- Keeping up with previous material is essential to understand new topics.
- Considerable out-of-class time investments are required to effectively learn course material.
- Critical thinking is more important than rote memorization.
- Students are expected not only to understand the specific examples given in class, but also to apply their knowledge broadly.
- Neither professors nor parents are “looking over your shoulder” to ensure that necessary coursework gets done on time.
- Help is available, but you must take the initiative to seek it out.

Now let’s consider some general keys to academic success in biology.

Take Studying Seriously

College is a time of many transitions, both social and intellectual. One of the keys to academic success in college is learning to balance these often conflicting pressures.

Making new friends, joining social organizations, and generally involving yourself in campus life are all important elements of your personal development.

You should never forget, however, that the primary reason you are in college is to get an education! Therefore, you should always make sure that the amount of time you spend in class and studying out of class exceeds the amount of time you spend socializing. In other words, take your studying seriously by devoting the necessary time to achieve academic success.

Always Attend Class

One of the first things freshmen hear when they come to campus is talk about how easy it is to "cut" classes compared to high school. This is because college professors assume that their students are mature enough to accept the responsibility of attending class without the need to use valuable class time calling roll. College work proceeds at a rapid pace, and missing class is a surefire way to quickly fall behind. Never assume that the professor considers lecture attendance unimportant simply because she/he does not take roll. Regular lecture attendance on your part is essential for success in biology!

Lecture is also a place where important scheduling information about review sessions, exams, and laboratories is conveyed to students. Missing lecture means that you miss out on this useful information.

Unlike lecture, laboratories in biology usually have a mandatory attendance policy, with absences allowed only for legitimate and verifiable excuses. Moreover, since labs typically meet only once per week, missing a lab means that you have missed a large amount of material, which puts you at a competitive disadvantage with other students.

If you need a more practical incentive to make yourself attend class, think about this. The average college graduate makes roughly $600,000 more in lifetime earnings than a person having only a high school diploma. That's $150,000 per year, $75,000 per 15-week semester, or $5,000 per week when factored over the four years of a college education. Thus, at a potential loss of $1,000 per day in additional lifetime income, the cost of missing classes really adds up!

Study Often and Early

The typical first-year student's schedule includes 4–6 classes totaling 12–16 credit hours. Usually one or more of these is an introductory-level course such as biology. As you may have already discovered, the coursework that accompanies this kind of class schedule is demanding. Moreover, due to the constraints of college schedules, there will be many weeks in a semester where more than one course will have exams, papers, or other assignments due at the same time.

It is therefore essential that you stay ahead of your classes by studying often and early. If possible, study ahead of the lecture schedule during the early part of the semester to ease the load on yourself during midterms and the final weeks of each term. Getting ahead of your studies and staying there is one of the biggest favors you can do for yourself in college!

Utilize Special Assignments and Extra Credit Opportunities

Many biology professors offer special assignments or extra credit as a way for you to expand your knowledge of the subject and supplement your exam or laboratory grades. The value of these assignments varies among professors, but can be as much as 5% of your total grade, or roughly half a letter grade.

Since these extra credit and special assignments are optional, many students elect not to do them because they don't have time or think they aren't important. These students lose out on the chance to accumulate valuable points that may well affect their final grade in the course. You should therefore get in the habit of treating extra credit as a regular course assignment, and make the time to get it done. You will not only gain extra points, but you may also be protecting yourself against a subpar performance on some other required assignment later in the course.

Recognize and Avoid Situations of Academic Dishonesty

Academic integrity is an extremely important issue in college. You should learn to recognize what constitutes academic dishonesty and avoid getting yourself into such situations. Your student handbook should discuss your school's policy on academic dishonesty in detail. The following excerpt, for example, is from the Clemson University Student Handbook:

"Academic dishonesty includes giving, receiving or using unauthorized aid on any academic work. Plagiarism, a form of academic dishonesty, includes the copying of language, structure or ideas of another and attributing the work to one's own efforts. All academic work submitted for grading contains an implicit pledge . . . by the student that no unauthorized aid has been received."

In college, academic dishonesty is treated as a serious offense. The penalty for first-time offenders of the academic dishonesty policy is usually a failing grade on the particular assignment for which the dishonest activity occurred. Second offenses result in a failing grade for the course and may lead to suspension from the college for one or more semesters. Permanent dismissal is also a possibility for repeat offenders.

The bottom line is simply that cheating, in biology or any other course, will not be tolerated. Besides, if you spend your time studying properly and keeping up with your work, there is no reason to be dishonest.

Here are some easy guidelines that will help you avoid violating the rules governing academic dishonesty . . .

- Carefully read and understand the instructions for every assignment before you begin working.
- Unless told otherwise by the instructor, always assume that course assignments are to be done individually.
- When in doubt about the rules governing an assignment, ask your instructor for clarification.
- Don't wait until the last moment to begin work on an assignment.
- Never knowingly pass off the work of another as your own.
- Use appropriate referencing when citing another's work.

Good Students Stay Healthy and Well-Rested

College is an exciting time in a young person's life. You will undoubtedly meet new friends and experience new activities, both of which will make demands on your time and energy.

With the newfound freedom to pick and choose your lifestyle also comes a personal responsibility to maintain your health. It is impossible to be a good student if you are constantly exhausted, whether it's from studying or socializing. Even one day of being too sick to attend classes can set you behind. Also, the less sleep you get, the harder it is to maintain your alertness in class, which means that you fail to gather information necessary for your academic success.

Don't Be Afraid to Ask for Help

Sometimes it's difficult for students to admit that they are having trouble with a class. Pride, embarrassment, or just the shock of realizing for the first time in your school career that you are unable to quickly master a topic can all contribute to this situation. Experience has shown that biology can be such a "problem" course for some students.

Unfortunately, many students wait too long before doing something constructive about their difficulties in class. Should you find yourself having problems with biology, you must not be afraid to ask for help as early in the semester as possible! Colleges offer many resources that can improve your lecture or laboratory performance. This study skills enhancement program is one of them; by taking the time to work through it, you are equipping yourself with some of the tools necessary to be a better student. There are also other ways that you can get help with problems in biology. Let's explore a few.

Resources to help you succeed in biology

Your professor or lab instructor's office hours are a great way to get help with problems. Office hours are notoriously underused by students. This is unfortunate, since the lecture professors and lab instructors know the material well and have a vested interest in helping you understand that material better. Taking advantage of office hours is also a good way to build a personal relationship with your instructors, which makes learning more fun.

More resources to help you study biology

Many professors provide lecture outlines, study objectives, problem sets, and practice exams online or as part of their course handouts. These materials are designed to help you organize and learn the material being presented in class. You should utilize them as much as possible.

Some introductory biology professors offer one or more review sessions prior to each exam. These sessions provide an excellent opportunity to ask questions about material that is not clear to you after studying your notes or other course materials.

Tutors are also available on campus, either through the biology department or learning center. Student athletes and members of selected minority programs can often take advantage of tutors sponsored by their supervisory offices. Others can hire private tutors, often graduate students specializing in some area of biology, by consulting posted notices on campus bulletin boards. Some fraternities, sororities, and other service organizations also offer academic tutoring as part of their outreach programs.

Congratulations! You've finished the section on how to improve your general study habits.

You can now return to the Table of Contents, or continue on to the next section.

Survival Skills

TIME MANAGEMENT

In college, as with life in general, there never seems to be enough time to go around. One of the most difficult challenges you will face as you make the transition from high school to college is to recognize and deal constructively with the fact that you, and you alone, are now in charge of determining how your valuable time is spent.

One of the reasons that high school seems so easy in comparison to college is that others manage time for you. In high school, both your teachers and your parents actively involved themselves in making sure your day was full, that you got where you needed to go, and that all your work was done on schedule.

In college, the responsibility for scheduling your time and making room for all you have to do rests squarely on your shoulders. One of the most serious mistakes you can make in college is to commit the error of thinking that you have "plenty of time" to get things done.

Because your high school workloads were generally lighter than those you will encounter in college, and also because more of the work in high school involved simple memorization as opposed to true understanding of a subject, it was probably easy for you to "cram" the night before a test and still get a good grade.

College is not like high school in this regard. You simply cannot get by in college with only last-minute efforts on assignments, and thus you must learn to manage your time wisely.
An important key to successful time management returns us to one of our general rules for good study habits:

You must take studying seriously and make a commitment to your work.

This means prioritizing your academic and social activities to ensure that there is adequate time in your schedule to complete all course assignments.

Many new students fail to realize that carrying a full load of college credits is essentially equivalent to having a full-time job. In other words, to understand the material in each of your courses at a level the professor considers adequate, you should plan on studying between 2 and 3 hours for every hour you spend in lecture. Thus, for a 3-hour lecture course, you should be spending 6 to 9 hours per week outside of class studying your notes, doing assigned readings, preparing for exams, and so forth. For a schedule with 12 credit hours, that means 24 to 36 additional hours of out-of-class effort to adequately understand the material.

A well-known theory of human learning also holds that people remember information best when they study in frequent, relatively short bouts of time, rather than in last-minute marathon study sessions. Thus, the trick is to balance the need for studying a total of 24 to 36 hours each week with the goal of studying in frequent, short sessions.

One effective way to make time for all your work is to create a weekly activity planner. You can print the weekly planner shown on the next page, purchase a similar planner at your local bookstore, or create your own using notebook paper.

The first step is to indicate all of your regular academic and social commitments for the entire week ahead. Doing this allows you to see where free time exists in your schedule.

The second step is to assign specific study tasks to the free time slots identified in Step 1. By doing this, you are ensuring that you study in shorter, more productive bouts and that nothing gets lost in the shuffle!

In summary, the following are keys to successful time management in college:

- You control the timing of your academic schedule; do it wisely.
- Studying properly is serious business; plan on devoting hours of out-of-class time per week to the task.
- You will study better if you study often and in relatively short sessions.
- Weekly planning is a good way to ensure that you have adequate time for studying. Remember, writing it down works!
- Get in the habit of making a weekly schedule of your study plans.
- Stick to your plan!

Congratulations! You've finished the section on time management.

You can now return to the Table of Contents, or continue on to the next section.∆

Study Calendar

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
7 am	7 am	7 am	7 am	7 am	7 am	7 am
8 am	8 am	8 am	8 am	8 am	8 am	8 am
9 am	9 am	9 am	9 am	9 am	9 am	9 am
10 am	10 am	10 am	10 am	10 am	10 am	10 am
11 am	11 am	11 am	11 am	11 am	11 am	11 am
12 pm	12 pm	12 pm	12 pm	12 pm	12 pm	12 pm
1 pm	1 pm	1 pm	1 pm	1 pm	1 pm	1 pm
2 pm	2 pm	2 pm	2 pm	2 pm	2 pm	2 pm
3 pm	3 pm	3 pm	3 pm	3 pm	3 pm	3 pm
4 pm	4 pm	4 pm	4 pm	4 pm	4 pm	4 pm
5 pm	5 pm	5 pm	5 pm	5 pm	5 pm	5 pm
6 pm	6 pm	6 pm	6 pm	6 pm	6 pm	6 pm
7 pm	7 pm	7 pm	7 pm	7 pm	7 pm	7 pm
8 pm	8 pm	8 pm	8 pm	8 pm	8 pm	8 pm
9 pm	9 pm	9 pm	9 pm	9 pm	9 pm	9 pm
10 pm	10 pm	10 pm	10 pm	10 pm	10 pm	10 pm
11 pm	11 pm	11 pm	11 pm	11 pm	11 pm	11 pm

Survival Skills

TAKING NOTES AND READING

I wish I'd learned to do this in high school.

Unlike many of your high school courses, where teachers routinely gave you study sheets containing virtually all of the important information from a lecture, college professors expect you to follow a rapidly developing train of thought and to capture those thoughts in your own notes. Biology lectures will be no exception, so it is in your best interest to develop good note-taking skills as quickly as possible.

The notes you take in biology lecture *should* . . .

- Capture the main points of a lecture, including relevant examples.
- Be organized in some coherent manner for later study.
- Leave room to include additional information learned after lecture.
- Use a personalized shorthand notation that makes sense to you.

Your biology lecture notes should *not* . . .

- Attempt to record every word the professor says during a lecture.
- Simply be what the professor writes on the blackboard or overhead.

Beginning college note takers often make some basic mistakes. Here are two easy ones to avoid that will greatly improve the quality of your notes:

1. Trying to write down every word the professor says is both pointless and impossible. You must learn to concentrate on what is being said and filter out the nonessential portions that connect important ideas and examples. Remember, by definition notes are supposed to be an abbreviated version of what the professor says.

2. There's probably more content in a lecture than what the professor actually writes on the overhead or blackboard. Although what the professor writes down is obviously important, in most lectures there will also be important spoken material that connects the ideas and terms that actually end up on the screen or board. Again, you must learn to recognize and record these connectors.

One way to make note taking easier is to prepare yourself *before* coming to lecture. You can do this in two ways:

1. Professors usually provide assigned readings in the course syllabus or other handouts. Spend 10 to 15 minutes before class and skim the assigned pages. Doing so will familiarize you with the basic concepts and terminology for that lecture and prepare you to take more organized notes.

2. If the professor provides individual lecture handouts or online materials that list key concepts, terminology, or specific study objectives, take the time to look over these items before lecture begins. Then when the professor uses these ideas and terms in lecture, you will already be somewhat familiar with them and have a better chance of accurately recording this information in your notes.

A Shorthand System

Another excellent technique for taking better notes is to develop a personalized shorthand notation system. This strategy allows you to quickly record words and ideas without taking the time to write them out in their entirety.

Since your shorthand notation system need only be understood by you, any symbols or abbreviations that make sense are okay.

To get you started, here are some common examples of shorthand notations and their meanings.

Symbol	Meaning
=	equal, same as
≠	not equal, different
w/	with
w/r/t	with respect to
→	leads to, gives rise to, etc.

You can also abbreviate long words after their first use (e.g., abbr.) and omit simple articles or prepositional phrases to further decrease the amount of writing in your notes. Remember, there are no hard and fast rules for developing a shorthand system, except that it must make sense to you.

College students often complain that their professors present lecture material too rapidly. While this criticism may, in part, be valid, it is also something that you as a student are unlikely to ever see change! You must therefore learn to take effective notes quickly, and like any worthwhile skill, this requires practice. You'll certainly get plenty of practice in biology lectures, but if you'd like to practice even more, try the following technique:

Each evening, grab a pen and notepad and take notes while watching one of the national news programs. These half-hour segments are delivered at a rapid pace not unlike classroom lectures, and are full of information. Try to capture the main ideas of each story in your notes, and train yourself to filter out unnecessary detail. If you want, record the program and then play it back to check the accuracy of your notes.

Formatting Your Notes

When taking notes in lecture, there is no perfect format to follow. Ways of taking notes are as varied as the people who take them.

There are, however, some general formatting rules to follow that will greatly improve the quality and usefulness of your notes, whatever style you choose.

Rule 1. Don't cram too much information into small spaces.

Paper is one of the cheapest things you will purchase in college, so don't be afraid to use lots of it. Your notes will be much easier to read and work with if you leave sufficient space between ideas.

Rule 2. Leave room in your notes for supplementary information.

When you study your notes after lecture and compare the professor's discussion of an idea with what's in the textbook, you will often find it useful to add diagrams or additional commentary. Be sure to leave room for this information while taking your notes in class.

Rule 3. Include questions about ideas you don't understand.

If something the professor says in class doesn't make sense as you take notes, be sure to include a question mark or partial sentence to remind yourself that this idea needs clarification. That way you will remember to look up this information in the textbook, or ask the professor directly.

Rule 4. Don't try to be a professional artist in class.

The diagrams and graphic images the professor uses in lecture were probably made by a professional artist. Indeed, many of these images can probably be found in your textbook. Don't waste time attempting detailed renditions of them during lecture. Rather, make simple versions and then refine those drawings as you study your notes.

Don't Be Afraid to Change

Many students believe that once their notes have been taken in class, they somehow become sacred and should not be altered. Nothing is further from the truth!

It is not only useful, but actually essential that you review your notes after each lecture and add to or modify the ideas captured on the page. Comparing your notes with those of a classmate, referencing the lecture to the relevant chapters in your textbook, or talking with the professor directly are all good ways to supplement your notes. Ideally, this review should be done within a few hours of class, but never more than 24 hours after the lecture. Following this strategy will maximize your chances of remembering important ideas.

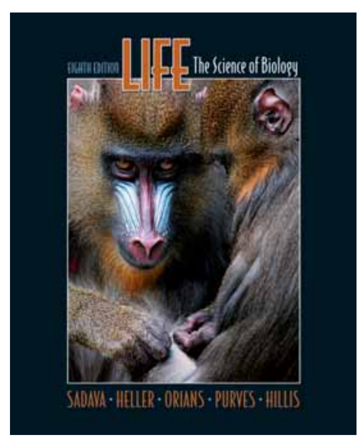
Remember, practice makes perfect with this skill, so practice taking notes whenever you can!

Getting the Most out of Your Textbook

Textbook use in biology courses will vary with the teaching style of the professor. Some professors will rely heavily on the textbook to fill in gaps of content information that they do not have time to cover in lecture. Others will use the textbook more as a reference source to supplement or reinforce your understanding of the main points covered in lecture. In addition, the degree to which you will be tested on specific information from the textbook will vary among professors.
At the beginning of a biology course, you should determine which textbook usage style your professor employs and adjust your reading strategy accordingly. If the professor's style is not obvious from information contained in the course syllabus or practice exams, don't hesitate to ask him/her directly about the role of the textbook in lectures.

To get the maximum effect from a textbook, you need to get in the habit of using it regularly. Moreover, you should consult the book both before and after a topic has been covered in lecture.

The best use of a textbook before lecture is to skim the assignment for that day, concentrating on the section headings, boldfaced words, figures, and figure captions. This will familiarize you with the main points of the topic to be covered in lecture that day, and facilitate your note-taking efforts.



After lecture, you should go back and carefully reread the assignment. This time you should look for details that reinforce the lecture discussion and supplement your notes with this information. You should also pay special attention to any figures from the textbook that the professor used during lecture, possibly recopying some form of these figures into your notes.

Read, Stop, and Ask

This simple rule can really help you in your efforts to assimilate textbook information. The sheer quantity and density of information in biology texts can sometimes be overwhelming, so one way to help transfer what you've read from your short-term memory into your long-term memory is to read a section no longer than one page, stop, and then quiz yourself on what you've just read and how it relates to what you already know about the subject.

This method plays on the human brain's ability to learn more easily when material is presented in short segments. It also forces you to make conceptual and factual connections between new and old ideas, which helps to organize complex information in your brain more meaningfully.

Highlighting

When highlighting, try to avoid the "Picasso effect": the habit of highlighting your textbook to death!

Poor use of highlighting:

Excessive highlighting is not a good way to emphasize important ideas in the text. In fact, many learning specialists believe that by highlighting too much, you simply are putting off learning as you "paint" the textbook with your favorite color. You will not learn anything by simply coloring sentences you have not read or thought about.

Instead, try using highlighting on key words or phrases only, or try highlighting only the parts of the text that don't make sense. That way you can come back later and quickly identify the section on which you need to place additional effort.

Better use of highlighting:

Excessive highlighting is not a good way to emphasize important ideas in the text. In fact, many learning specialists believe that by highlighting too much, you simply are putting off learning as you "paint" the textbook with your favorite color. You will not learn anything by simply coloring sentences you have not read or thought about.

Instead, try using highlighting on key words or phrases only, or try highlighting only the parts of the text that don't make sense. That way you can come back later and quickly identify the section on which you need to place additional effort.

Congratulations! You've finished the section on taking notes and reading.

To follow are two different versions of two samples pages from the textbook (they are pages 241–242 from Chapter 11). The first set of two pages are examples of excessive highlighting. The second set of two pages are examples of effective highlighting.

After reviewing these examples, you can now return to the Table of Contents, or continue on to the next section.

Example of excessive highlighting, 1:

Thus the surfaces of the AT and GC base pairs offer slightly different, chemically distinct surfaces that another molecule, such as a protein, could recognize and bind to. Access to the exposed base-pair sequences in the major and minor grooves is the key to protein–DNA interactions in the replication and expression of the genetic information in DNA.

The double-helical structure of DNA is essential to its function

The genetic material performs four important functions, and the DNA structure proposed by Watson and Crick was elegantly suited to three of them.

- *The genetic material stores an organism's genetic information.* With its millions of nucleotides, the base sequence of a DNA molecule could encode and store an enormous amount of information and could account for species and individual differences. DNA fits this role nicely.
- *The genetic material is susceptible to mutation,* or permanent changes in the information it encodes. For DNA, mutations might be simple changes in the linear sequence of base pairs.
- *The genetic material is precisely replicated* in the cell division cycle. Replication could be accomplished by complementary base pairing, A with T and G with C. In the original publication of their findings in the journal *Nature* in 1953, Watson and Crick coyly pointed out, "It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material."
- *The genetic material is expressed as the phenotype.* This function is not obvious in the structure of DNA. However, as we will see in the next chapter, the nucleotide sequence of DNA is copied into RNA, which is in turn converted into a linear sequence of amino acids—a protein. The folded forms of proteins provide much of the phenotype of an organism.

11.2 RECAP

DNA is a double helix made up of two antiparallel polynucleotide chains. The two chains are joined by hydrogen bonds between the nucleotide bases, which pair specifically, A with T and G with C. Chemical groups of the bases that are exposed in the grooves of the helix can be recognized by other molecules.

- Can you describe some of the evidence that Watson and Crick used to come up with the double helix model for DNA? See pp. 238–239
- Do you understand how the double-helical structure of DNA relates to its function?

Once the structure of DNA was understood, it was possible to discover how DNA replicates itself. Let's examine the experiments that taught us how this elegant process works.

11.3 How Is DNA Replicated?

The mechanism of DNA replication that had suggested itself to Watson and Crick was soon confirmed. First, experiments showed that single strands of DNA could be replicated in a test tube containing simple substrates and an enzyme. Then a truly classic experiment showed that each of the two strands of the double helix can serve as a template for a new strand of DNA.

Three modes of DNA replication appeared possible

The prediction that the DNA molecule contains the information needed for its own replication was confirmed by the work of Arthur Kornberg, then at Washington University in St. Louis. He showed that DNA with the same base composition as parental DNA can be synthesized in a test tube containing three substances:

- The substrates, deoxyribonucleoside triphosphates dATP, dCTP, dGTP, and dTTP
- A **DNA polymerase** enzyme
- DNA, which serves as a **template** to guide the incoming nucleotides

Recall that a nucleoside is a nitrogen base attached to a sugar. The four deoxyribonucleoside triphosphates each consist of a nitrogen base attached to deoxyribose, which in turn is attached to three phosphate groups.

The next question was which of three possible replication patterns was occurring:

- *Semiconservative replication,* in which each parent strand serves as a template for a new strand, and the two new DNA molecules each have one old and one new strand (**Figure 11.10A**)
- *Conservative replication,* in which the original double helix serves as a template for, but does not contribute to, a new double helix (**Figure 11.10B**)
- *Dispersive replication,* in which fragments of the original DNA molecule serve as templates for assembling two new molecules, each containing old and new parts, perhaps at random (**Figure 11.10C**)

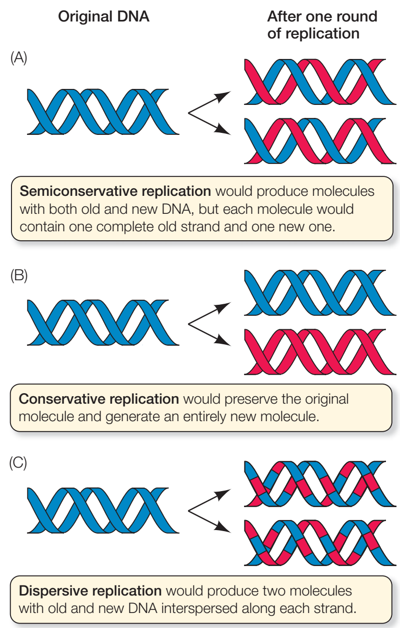
Watson and Crick's original paper suggested that DNA replication was semiconservative, but Kornberg's experiment did not provide a basis for choosing among these three models.

Meselson and Stahl demonstrated that DNA replication is semiconservative

The work of Matthew Meselson and Franklin Stahl convinced the scientific community that the pattern seen in DNA is **semiconservative replication**. Working at the California Institute of Technology, Meselson and Stahl devised a simple way to distinguish old parent strands of DNA from newly copied ones: *density labeling.*

The key to their experiment was the use of a "heavy" isotope of nitrogen. Heavy nitrogen (^{15}N) is a rare, nonradioactive isotope that makes molecules containing it more dense than chemically identical molecules containing the common isotope, ^{14}N. Meselson, Stahl, and Jerome Vinograd grew two cultures of the bacterium *Escherichia coli* for many generations:

Example of excessive highlighting, 2:



11.10 Three Models for DNA Replication In each model, original DNA is shown in blue and newly synthesized DNA in red.

- One culture was grown in a medium whose nitrogen source (ammonium chloride, NH_4Cl) was made with ^{15}N instead of ^{14}N. As a result, all the DNA in the bacteria was "heavy."
- Another culture was grown in a medium containing ^{14}N, and all the DNA in these bacteria was "light."

When extracts from the two cultures were combined and centrifuged, two separate DNA bands formed, showing that this method could distinguish DNA samples of slightly different densities.

Next, the researchers grew another *E. coli* culture on ^{15}N medium, then transferred it to normal ^{14}N medium and allowed the bacteria to continue growing (**Figure 11.11**). Under the conditions they used, *E. coli* cells divide, replicating their DNA every 20 minutes. Meselson and Stahl collected some of the bacteria after each division and extracted DNA from the samples. They found that the density gradient was different in each bacterial generation:

- At the time of the transfer to the ^{14}N medium, the DNA was uniformly labeled with ^{15}N, and hence was relatively dense.
- After one generation in the ^{14}N medium, when the DNA had been duplicated once, all the DNA was of an intermediate density.
- After two generations, there were two equally large DNA bands: one of low density and one of intermediate density.
- In samples from subsequent generations, the proportion of low-density DNA increased steadily.

The results of this experiment can be explained only by the semiconservative model of DNA replication. In the first round of DNA replication in the ^{14}N medium, the strands of the double helix—both heavy with ^{15}N—separated. Each strand then acted as the template for a second strand, which contained only ^{14}N and hence was less dense. Each double helix then consisted of one ^{15}N strand and one ^{14}N strand, and was of intermediate density. In the second replication, the ^{14}N-containing strands directed the synthesis of partners with ^{14}N, creating low-density DNA, and the ^{15}N strands formed new ^{14}N partners (see Figure 11.10).

The crucial observation demonstrating the semiconservative model was that intermediate-density DNA (^{15}N–^{14}N) appeared in the first generation and continued to appear in subsequent generations. With the other models, the results would have been quite different (see Figure 11.10):

- In conservative replication, the first generation would have had both high-density DNA (^{15}N–^{15}N) and low-density DNA (^{14}N–^{14}N), but no intermediate-density DNA.
- In dispersive replication, the density of the new DNA would have been half that of the parent DNA, but DNA of this density would not continue to appear in subsequent generations.

The Meselson–Stahl experiment, called by some scientists among the most elegant ever done by biologists, was an excellent example of the scientific method. It began with three hypotheses—the three models of DNA replication—and was designed so that the results could differentiate between them.

We all began life as a fertilized egg, with only one set of double-stranded DNA molecules from our parents. Given semiconservative replication, do we still have those original parental strands? There is some evidence that we may. During mitosis, stem cells in the adult body preferentially retain DNA with the "old" strands. A similar mechanism may operate during early development.

There are two steps in DNA replication

Semiconservative DNA replication in the cell involves a number of different enzymes and other proteins. It takes place in two steps:

- The DNA double helix is unwound to separate the two template strands and make them available for new base pairing.
- New nucleotides are joined by phosphodiester linkages to each growing new strand in a sequence determined by complementary base pairing with the bases on the template strand.

A key observation is that *nucleotides are added to the growing new strand at the 3′ end*—the end at which the DNA strand has a free

Example of effective highlighting, 1:

Thus the surfaces of the AT and GC base pairs offer slightly different, chemically distinct surfaces that another molecule, such as a protein, could recognize and bind to. Access to the exposed base-pair sequences in the major and minor grooves is the key to protein–DNA interactions in the replication and expression of the genetic information in DNA.

The double-helical structure of DNA is essential to its function

The genetic material performs four important functions, and the DNA structure proposed by Watson and Crick was elegantly suited to three of them.

- *The genetic material stores an organism's genetic information.* With its millions of nucleotides, the base sequence of a DNA molecule could encode and store an enormous amount of information and could account for species and individual differences. DNA fits this role nicely.
- *The genetic material is susceptible to mutation,* or permanent changes in the information it encodes. For DNA, mutations might be simple changes in the linear sequence of base pairs.
- *The genetic material is precisely replicated* in the cell division cycle. Replication could be accomplished by complementary base pairing, A with T and G with C. In the original publication of their findings in the journal *Nature* in 1953, Watson and Crick coyly pointed out, "It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material."
- *The genetic material is expressed as the phenotype.* This function is not obvious in the structure of DNA. However, as we will see in the next chapter, the nucleotide sequence of DNA is copied into RNA, which is in turn converted into a linear sequence of amino acids—a protein. The folded forms of proteins provide much of the phenotype of an organism.

11.2 RECAP

DNA is a double helix made up of two antiparallel polynucleotide chains. The two chains are joined by hydrogen bonds between the nucleotide bases, which pair specifically, A with T and G with C. Chemical groups of the bases that are exposed in the grooves of the helix can be recognized by other molecules.

- Can you describe some of the evidence that Watson and Crick used to come up with the double helix model for DNA? See pp. 238–239
- Do you understand how the double-helical structure of DNA relates to its function?

Once the structure of DNA was understood, it was possible to discover how DNA replicates itself. Let's examine the experiments that taught us how this elegant process works.

11.3 How Is DNA Replicated?

The mechanism of DNA replication that had suggested itself to Watson and Crick was soon confirmed. First, experiments showed that single strands of DNA could be replicated in a test tube containing simple substrates and an enzyme. Then a truly classic experiment showed that each of the two strands of the double helix can serve as a template for a new strand of DNA.

Three modes of DNA replication appeared possible

The prediction that the DNA molecule contains the information needed for its own replication was confirmed by the work of Arthur Kornberg, then at Washington University in St. Louis. He showed that DNA with the same base composition as parental DNA can be synthesized in a test tube containing three substances:

- The substrates, deoxyribonucleoside triphosphates dATP, dCTP, dGTP, and dTTP
- A **DNA polymerase** enzyme
- DNA, which serves as a **template** to guide the incoming nucleotides

Recall that a nucleoside is a nitrogen base attached to a sugar. The four deoxyribonucleoside triphosphates each consist of a nitrogen base attached to deoxyribose, which in turn is attached to three phosphate groups.

The next question was which of three possible replication patterns was occurring:

- *Semiconservative replication,* in which each parent strand serves as a template for a new strand, and the two new DNA molecules each have one old and one new strand (**Figure 11.10A**)
- *Conservative replication,* in which the original double helix serves as a template for, but does not contribute to, a new double helix (**Figure 11.10B**)
- *Dispersive replication,* in which fragments of the original DNA molecule serve as templates for assembling two new molecules, each containing old and new parts, perhaps at random (**Figure 11.10C**)

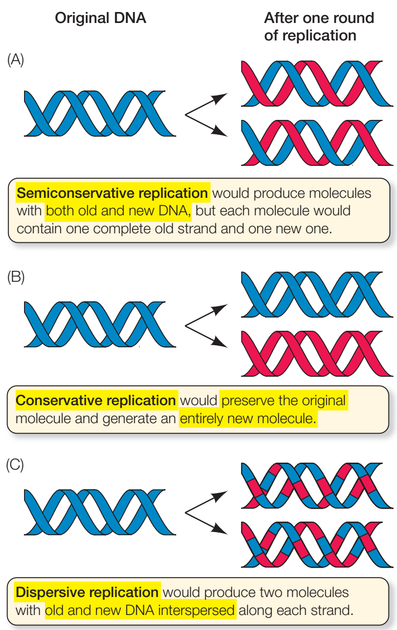
Watson and Crick's original paper suggested that DNA replication was semiconservative, but Kornberg's experiment did not provide a basis for choosing among these three models.

Meselson and Stahl demonstrated that DNA replication is semiconservative

The work of Matthew Meselson and Franklin Stahl convinced the scientific community that the pattern seen in DNA is **semiconservative replication.** Working at the California Institute of Technology, Meselson and Stahl devised a simple way to distinguish old parent strands of DNA from newly copied ones: *density labeling.*

The key to their experiment was the use of a "heavy" isotope of nitrogen. Heavy nitrogen (^{15}N) is a rare, nonradioactive isotope that makes molecules containing it more dense than chemically identical molecules containing the common isotope, ^{14}N. Meselson, Stahl, and Jerome Vinograd grew two cultures of the bacterium *Escherichia coli* for many generations:

Example of effective highlighting, 2:



11.10 Three Models for DNA Replication In each model, original DNA is shown in blue and newly synthesized DNA in red.

- One culture was grown in a medium whose nitrogen source (ammonium chloride, NH_4Cl) was made with ^{15}N instead of ^{14}N. As a result, all the DNA in the bacteria was "heavy."
- Another culture was grown in a medium containing ^{14}N, and all the DNA in these bacteria was "light."

When extracts from the two cultures were combined and centrifuged, two separate DNA bands formed, showing that this method could distinguish DNA samples of slightly different densities.

Next, the researchers grew another *E. coli* culture on ^{15}N medium, then transferred it to normal ^{14}N medium and allowed the bacteria to continue growing (**Figure 11.11**). Under the conditions they used, *E. coli* cells divide, replicating their DNA every 20 minutes. Meselson and Stahl collected some of the bacteria after each division and extracted DNA from the samples. They found that the density gradient was different in each bacterial generation:

- At the time of the transfer to the ^{14}N medium, the DNA was uniformly labeled with ^{15}N, and hence was relatively dense.
- After one generation in the ^{14}N medium, when the DNA had been duplicated once, all the DNA was of an intermediate density.
- After two generations, there were two equally large DNA bands: one of low density and one of intermediate density.
- In samples from subsequent generations, the proportion of low-density DNA increased steadily.

The results of this experiment can be explained only by the semiconservative model of DNA replication. In the first round of DNA replication in the ^{14}N medium, the strands of the double helix—both heavy with ^{15}N—separated. Each strand then acted as the template for a second strand, which contained only ^{14}N and hence was less dense. Each double helix then consisted of one ^{15}N strand and one ^{14}N strand, and was of intermediate density. In the second replication, the ^{14}N-containing strands directed the synthesis of partners with ^{14}N, creating low-density DNA, and the ^{15}N strands formed new ^{14}N partners (see Figure 11.10).

The crucial observation demonstrating the semiconservative model was that intermediate-density DNA (^{15}N–^{14}N) appeared in the first generation and continued to appear in subsequent generations. With the other models, the results would have been quite different (see Figure 11.10):

- In conservative replication, the first generation would have had both high-density DNA (^{15}N–^{15}N) and low-density DNA (^{14}N–^{14}N), but no intermediate-density DNA.
- In dispersive replication, the density of the new DNA would have been half that of the parent DNA, but DNA of this density would not continue to appear in subsequent generations.

The Meselson–Stahl experiment, called by some scientists among the most elegant ever done by biologists, was an excellent example of the scientific method. It began with three hypotheses—the three models of DNA replication—and was designed so that the results could differentiate between them.

We all began life as a fertilized egg, with only one set of double-stranded DNA molecules from our parents. Given semiconservative replication, do we still have those original parental strands? There is some evidence that we may. During mitosis, stem cells in the adult body preferentially retain DNA with the "old" strands. A similar mechanism may operate during early development.

There are two steps in DNA replication

Semiconservative DNA replication in the cell involves a number of different enzymes and other proteins. It takes place in two steps:

- The DNA double helix is unwound to separate the two template strands and make them available for new base pairing.
- New nucleotides are joined by phosphodiester linkages to each growing new strand in a sequence determined by complementary base pairing with the bases on the template strand.

A key observation is that *nucleotides are added to the growing new strand at the 3′ end*—the end at which the DNA strand has a free hydroxyl (—OH) group on the 3′ carbon of its terminal deoxyri-

Survival Skills

EXAMINATIONS

Success on biology exams is a two-step process. First, you must prepare properly so that information is in your head in a meaningful form and accessible during the exam. Second, you must discipline yourself to think carefully while reading and evaluating test questions.

Your exam preparation should begin well in advance of the exam itself. Ideally, you should be studying lecture material on a regular basis, i.e., 2 to 3 times weekly throughout the pre-exam period so that very little in the way of studying is actually necessary immediately prior to the exam itself. As part of this preparation process, you should . . .

- Do all the assigned readings and take good lecture notes.
- Learn material in accordance with lecture objectives and other guidelines.
- Practice applying your knowledge with sample exam questions.
- Write key concepts on note cards for frequent review.
- Be sure to have your questions about unclear topics answered.
- Attend any review sessions offered by the professor.
- Study enough in advance to avoid the need for all-night cram sessions.
- Get a good night's sleep and be well-rested for the examination.

Question Types and Examination Formats

Because of the large size of most biology lectures, exam questions tend to be predominantly multiple choice in format, although short answers and essays are also used in some cases. Despite what you may have heard about multiple choice questions being "picky" or "too specific," biology professors try very hard to avoid this problem. In fact, many of the multiple choice questions on biology exams can be thought provoking and thorough in their scope.
For this reason, you must learn to read and think very carefully while taking biology tests. There are a number of strategies for training yourself to be a careful thinker on exams, and you should feel free to use whatever method works best for you. One proven method is to employ this simple three-step technique:

1. Read the question completely and carefully.

2. Think about your answer before looking at the possible choices.

3. Evaluate each choice critically before selecting the best answer.

Let's consider a specific example of a typical biology exam question to see how this three-step method works.

Cell A is a roughly spherical animal cell with a radius of 10 microns. Cell B is also roughly spherical and has a radius of 20 microns. Which of the following statements about these two cells is *false*?

1. Cell A has a smaller volume than cell B.

2. Cell B has a larger surface area than cell A.

3. Cell A has a larger surface area-to-volume ratio than does cell B.

4. Cell B has a larger surface area-to-volume ratio than does cell A.

Step one: Read the question completely and carefully.

Cover up the answers—pretend they aren't there and read the question carefully. You can force yourself to read carefully by identifying key words in the question that provide important information.

[Cell A] is a roughly [spherical] animal cell with a [radius of 10 microns]. [Cell B] is also roughly [spherical] and has a [radius of 20 microns]. Which of the following statements about these two cells is [*false*]?

1. Cell A has a smaller volume than cell B.

2. Cell B has a larger surface area than cell A.

3. Cell A has a larger surface area–to-volume ratio than does cell B.

4. Cell B has a larger surface area–to-volume ratio than does cell A.

Step two: Think about your answer before looking at the possible choices.

Answer the question in your head, pretending it's an essay or short-answer question. The important ideas here are that surface area is determined by the square of the radius, and volume by the cube. Surface areas, volumes, and surface area–to-volume ratios for the two cells will thus be different.

[Cell A] is a roughly [spherical] animal cell with a [radius of 10 microns]. [Cell B] is also roughly [spherical] and has a [radius of 20 microns]. Which of the following statements about these two cells is [*false*]?

1. Cell A has a smaller volume than cell B.

2. Cell B has a larger surface area than cell A.

3. Cell A has a larger surface area–to-volume ratio than does cell B.

4. Cell B has a larger surface area–to-volume ratio than does cell A.

Step three: Evaluate each choice critically before selecting the best answer.

Uncover the answers and read each one carefully, evaluating the correctness of each as you go. It is useful to actually put a T or F next to each number to indicate whether the answer is true or false. Doing this shows us that answer 4 is false, and thus the correct choice.

[Cell A] is a roughly [spherical] animal cell with a [radius of 10 microns]. [Cell B] is also roughly [spherical] and has a [radius of 20 microns]. Which of the following statements about these two cells is [*false*]?

[T] 1. Cell A has a smaller volume than cell B.

[T] 2. Cell B has a larger surface area than cell A.

[T] 3. Cell A has a larger surface area–to-volume ratio than does cell B.

[F] 4. Cell B has a larger surface area–to-volume ratio than does cell A.

Summary

1. Cover up the answers and read the question carefully. Highlight, underline, or circle key words to make sure that you don't miss important information.
2. Think about the answer to the question as though you had to provide it to the professor. Consider only the subset of biological information you need to answer that particular question.

3. Uncover the answers provided, and carefully read each one to evaluate its correctness. Put marks indicating true or false by each answer, and then make the appropriate choice.

Sometimes you will find yourself initially unable to select between what appear to be two correct answers. In this case, repeat the three-step method but only consider the two remaining choices. Then ask yourself what evidence is there that one of the answers is *better* than the other—not perfect, not absolutely correct, but simply better.

If you discipline yourself to do this form of educated guessing, and if you have studied well, you will likely get more of these kinds of questions right than wrong.

It Takes Practice

Like any other worthwhile skill, becoming a good exam taker requires practice. Think of it as analogous to a dancer, who wouldn't consider performing without substantial amounts of practice doing the specific moves in his or her routine. Similarly, you should think of an exam as your "performance," and you should practice doing the maneuvers by thinking through questions that you will be expected to execute.

As a general rule, you should practice taking tests to the point that when the real examination comes around, the process of thinking carefully and clearly is second nature. Practice tests supplied by the professor and questions of your own design can all accomplish this goal. Furthermore, by practicing the test-taking process early and often in your studying, you will help yourself learn the subject matter in exactly the context that the professor wants.

Doing A Post-Exam Review

Just as an athlete analyzes the results of a game after the fact in an effort to improve his or her skills, you too should conduct a post-exam review to see why you got particular questions wrong. Specifically, you should try to determine if you got the wrong answer because you

1. Read the question incorrectly or carelessly.
2. Did not properly think your way through your answer before looking at the choices available.
3. Incorrectly read the possible choices offered.
4. Simply did not know this particular material.
5. Made a careless mistake such as writing down the wrong answer number on the test form.

By carefully assessing the nature of your incorrect responses on an exam, you can help prevent similar mistakes from occurring on subsequent tests, and thus become a better overall test taker.

Congratulations! You've finished the section on examinations.

This concludes the tutorial. Good luck in your study of biology!