Study Guide Zone

PCAT Test Study Guide

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PCAT Overview

The PCAT is indeed a difficult examination, and as such, it was required that media be chosen by which intellectual ability could be measured. In the case of the PCAT, math, reading, verbal, biology and chemistry were the selected media. While there is an ongoing, low-profile controversy about whether or not this test truly measure's your abilities with regards to what you'll need for pharmacy school, that is not the purpose of this book. The purpose is, however, to make sure that you're able to achieve the best possible state of preparation, allowing you to maximize your score potential - no matter if your actual aptitude has been measured.

As no test can measure all aspects of a person's intelligence, the PCAT measures those skills deemed most critical to a new pharmacy student. Then again, if any admission test, no matter how cleverly assembled, is inherently inadequate, why perform this type of testing at all? This is a question posed by every student who sees the PCAT looming ahead of him/her. Nevertheless, the answer to this question is quite simple, and quite reasonable; to make pharmacy school acceptance a more fair experience, by expanding the basis approval beyond your grades.

Your PCAT score is one of the most critical elements to your qualification for pharmacy school, so it is naturally much too important for you to take this test unprepared. The higher your PCAT score, the better your chances of admission will be for a respected, competitive pharmacy program.

While different pharmacy programs assign a different weight or importance to your PCAT scores, it is safe to assume that your PCAT will be a major determining factor when it comes to the final admission decision made by each pharmacy school to which you've applied.

Careful preparation, as described in this expert guide, along with hard work, will dramatically enhance your probability of success. In fact, it is wise to apply this philosophy not only to your pharmacy school applications, but to other elements of your life as well, to raise you above the competition. Your PCAT score is one of the areas in the pharmacy admission process over which you have a substantial amount of control; this opportunity should not be taken lightly. Hence, a rational, prepared approach to your PCAT test as well as the rest of the admission process will contribute considerably to the likelihood of acceptance.

Keep in mind, that although it is possible to take a PCAT test more than once, you should never take the test as an "experiment" just to see how well you do. It is of extreme importance that you always be prepared to do your best when taking the PCAT.

Testing and Analysis

It won't take you long to discover that the PCAT is unlike any test you've taken before, and it is probably unlike any test you will ever take again in your academic career. The typical high school or college test is a knowledge-based test. The PCAT, however, is skills-based.

What does this mean to you? It means that you'll have to prepare yourself in a completely different way! You won't simply be reciting memorized facts as they were phrased in some textbook.

The PCAT requires you to think in a thorough, quick and strategic manner…and still be accurate, logical and wise.

This test is designed to judge your writing, verbal and mathematical ability in the ways that pharmacy schools feel is vital to the success of first year pharmacy students.

To some extent, you have already gradually obtained these abilities over the length of your academic career. However, what you probably have not yet become familiar with is the capability to use these abilities for the purpose of maximizing performance within the complex and profound environment of a standardized, skills-based examination.

There are different strategies, mindsets and perspectives that you will be required to apply throughout the PCAT. You'll need to be prepared to use your whole brain as far as thinking and assessment is concerned, and you'll need to do this in a timely manner. This is not

something you can learn from taking a course or reading a book, but it is something you can develop through practice and concentration.

This guide provides you with the professional instruction you require for understanding the traditional PCAT test. Covered are all aspects of the test and preparation procedures that you will require throughout the process. Upon completion of this guide, you'll have the confidence and knowledge you need for maximizing your performance on your PCAT.

Introduction to the PCAT

The purpose of the PCAT is to establish a standard method of measurement for the skills that have been acquired by pharmacy school applicants. These skills are considered critical to pharmacy schools for a first-year student to be able to succeed. The principle behind the PCAT is similar to the SAT's that are required for application to American colleges. Although these tests are similar experiences, the PCAT is much more challenging and complex.

Fortunately, the PCAT does not change very dramatically from year to year. What this means to you, is that it has become possible for quality practice tests to be produced, and if you should take enough of these tests, in addition to learning the correct strategies, you will be able to prepare for the test in an effective manner.

The PCAT Scoring Scale

PCAT scoring is not hard to comprehend when it is properly explained.

There is no "passing" score to the PCAT, but you will need to know what the cut off average score is for the pharmacy schools to which you're looking to apply. For this information, check their website, or call, and they'll tell you the average score of students who are accepted.

Each pharmacy school has a different policy for weighing PCAT scores with your GPA. The majority of pharmacy schools will weigh your PCAT score more heavily than your GPA. In fact, some schools will weigh your PCAT at 70% and your GPA at 30%, which means that this one examination is worth more than your 4 years of undergraduate work.

It's up to you to look into the pharmacy schools to which you'll be applying, so that you'll have this information, and know the exact value of your PCAT. Many schools will make their calculation structure for the combination of PCAT and GPA available to the public.

Knowing this information before you enter the PCAT examination means that you know exactly what you're facing that day. You will have a realistic perception of the worth of the test, and you will have the proper motivation to fully apply yourself to reach your maximum potential.

You'll also be able to realistically judge the type of school to which you should be applying, and you can better set out your future plans in your mind.

Quantitative Test

The Quantitative Test will require you to:

-understand basic concepts of arithmetic, algebra, geometry, and data analysis
-reason quantitatively
-solve problems in a quantitative setting

To identify the skills that need extra work, complete a practice test that gives additional information, or, complete a practice test and look for yourself at the areas where you excelled, and the areas where struggle was apparent.

Your "critical" math skills will be in the areas where you have made the most wrong answers on your practice test. Those will be the math skills that will best help your score in the shortest period of time, if you manage to practice and better these skills. This is the area in which you can maximize your score increase potential.

To master your critical math skills, there are certain steps you may take:

- Read over the skill lesson in this book, very carefully
- Find some practice tests and work specifically on the questions that test your critical math skills, practicing the new skills that you have learned in through your review.
- Use textbooks for increased detail, assistance, and question examples for the areas in which you are struggling the most.

- Practice, practice, practice!

The best way to get to learn your math skills is to rehearse them with as many new sample questions as you can get your hands on. The questions you do, the more you will become familiar and comfortable with that type of question, so that you can move on and concentrate on other areas for perfection.

Question Types

The test is very consistent with the type of mathematics questions that it uses, year after year. The following are the types of mathematical questions that you are likely to encounter:

- Arithmetic
- Divisibility
- Multiplication
- Addition
- Subtraction
- Evens and Odds
- Prime Numbers
- Percents
- Square of a Number
- Exponents
- Roots
- Averages

Arithmetic

Arithmetic skills refer to the questions that can be solved by using addition, subtraction, multiplication and/or division.

Since calculators are permitted in the test, the questions will obviously not be purely arithmetic - they're not out to measure your ability with a calculator. So in this style of question, you'll need to recall your *order of operations*. A good trick to recall your order of operations is "**P**lease **E**xcuse **M**y **D**ear **A**unt **S**ally"…before you say "huh?" recognize the first letters in this phrase:

- Work within **P**arenthesis
- Simplify **E**xponents
- **M**ultiplication and **D**ivision
- **A**ddition and **S**ubtraction

The majority of arithmetic questions will require you to take multiple steps, and will likely test other skills as well, instead of being purely arithmetic. Often, the questions will be presented in the form of word problems, where you will need to decide when to add, subtract, multiply and divide.

For example:

How many egg cartons are needed to hold 300 eggs, if each carton can hold one dozen (1 dozen = 12)

A. 15
B. 18
C. 22

D. 25

E. 28

Note: the answer is 25

Divisibility

The factors of integer X are the integers by which X can be divided without leaving a remainder. Thus, X is divisible by its factors.

For example:

The number 10 is divisible by both 5 and 2. 10 can be divided by both of these integers without leaving a remainder.

To review the rules of divisibility, have a look at the following:

1. Numbers divisible by 2 end in even numbers.

2. Numbers divisible by 3 can be determined by adding the sum of their digits and checking if that number is divisible by 3 (for example the number 123: 1+2+3=6, 6 is divisible by 3 with no remainder).

3. Numbers divisible by 4 can be identified if their last two digits will divide by 4 without a remainder (for example, the number 624: the last two digits are 24, which are divisible by 4 with no remainder).

4. Numbers divisible by 5 end only in 5 or 0.

5. Numbers divisible by 9 occur when the sum of its their digits are divisible by 9 (for example, the number 639: 6+3+9 = 18, which is divisible by 9).

6. A number is only divisible by 10 if it ends in 0

The following is an example of a divisibility question:

Which of the following integers divides into both 200 and 150?

A. 3
B. 7
C. 30
D. 50
E. 300

Note: The correct answer is (D)

Multiplication

The following are a few simple rules to keep your multiplications on track:

Positive x Positive = Positive
Negative x Negative = Positive
Negative x Positive = Negative

Addition

Here are some rules to be certain that there are no slips while doing addition:

Positive + Positive = Positive
Negative + Negative = Negative
Negative + Positive = either positive or negative (you must use the absolute value of both: subtract the smaller from the larger and keep the sign of whichever absolute value was larger)

Subtraction

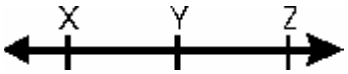
The definition of subtraction is: A - B = A + (-B)
A minus B is the same as A plus (the opposite of B)

X > 0, means that X is a positive number
X < 0, means that X is a negative number

-(A - B) = -A + B = B - A

$(-X)^2 = X^2$

If X - 0, $X^2 > 0$



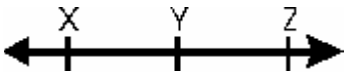
If, on the number line, one number occurs to the left of another number, the number on the left is the smallest number.

Therefore, when studying the line above, you will know that X < Y and Y < Z.

For example:

Use the number line to make conclusions with regards to whether each number is positive or negative.

In this situation, you will have an easier time if you implement specific numbers to fit the problem. For example, let X = -7, Y = -2, and Z = 3. Be certain to utilize some negative numbers while substituting.



The following is an example of a subtraction question:

Y - X

Solution: Positive Y is greater than X.
-2 - (-7) = -2 + 7 = 5

Evens and Odds

An even number is any word that is divisible by 2: numbers that are within the set {…-6, -4, -2, 0, 2, 4, 6,…}. Remember, though, that an

even number is divisible by 2 and not have any remainder. Keep in mind also that 0 is an even number. Consecutive even numbers are all located 2 units apart. For example, if x is an even number, then the next consecutive even number would be represented as X + 2.

Odd numbers, on the other hand, are numbers within the set {…-5, -3, -1, 1, 3, 5,…}.

The following charts demonstrate the properties of odd and even numbers. To check the property of a number, you can simply substitute the appropriate numbers.

Properties of odd and even numbers with Addition

Property	**Example**
Even + Even = Even	2 + 8 = 10
Odd + Odd = Even	3 + 9 = 12
Odd + Even = Odd	3 + 8 = 11

Properties of odd and even numbers with Addition

Property	**Example**
Even x Even = Even	4 x 6 = 24
Even x Odd = Even	4 x 5 = 20
Odd x Odd = Odd	3 x 9 = 27

Consider the following example:

If R is an odd integer, what are the next two consecutive odd integers?

A) T and V
B) R and R+1
C) R+1 and R+2
D) R+2 and R+4
E) R+1 and R+3
Note: the correct answer is (D)

Here's another example:

If x is an odd integer and y is an even integer, tell whether each expression is odd or even.

A. x^2
B. xy
C. y^2
D. x + y
E. 2x + y

Note (A) is odd. (B) is even. (C) is even. (D) is odd, and (E) is even.

Prime Numbers

A prime number is defined as an integer that is greater than 1, and has only two positive factors, 1 and itself.

For example, 7 is a prime number, as its only factors are 1 and 7. However, 6 is not a prime number, because its factors are 1, 2, 3, 6

The first ten prime numbers are: 2, 3, 5, 7, 11, 13, 17, 19, 23, 29

Note, though that 1 is not a prime number, and both the smallest and the only even prime number is 2.

Prime factorization is the process by which you express a number as a result of only prime numbers.

For example:

To create the prime factorization of 24, you'd represent it as:
$2 \times 2 \times 2 \times 3$ or $2^3 \times 3$

To create the prime factorization of 15, you'd represent it as:
5×3

An example of a factor question is:

If xy = 13 and both x and y are positive integers, then what is the sum of x + y?

A. 13
B. 14
C. 16
D. 20
E. 26

Note: the answer is B

Here is another example:

What is the sum of the first 5 prime numbers?

A. 18
B. 28
C. 30
D. 34
E. 38

Note: The first five prime numbers are 2, 3, 5, 7, 11 and their sum is 28. The answer is B.

Percents

The word percent means "hundredths" or a number which is divided by 100. Converting a number into a percentage involves multiplying the number by 100.

A percent can be determined by performing the division of the part by the total and multiplying it by 100:

$$\text{Percent} = \frac{\text{Part}}{\text{Total}} \times 100$$

For example, if Wendy missed 12 out of 80 examination questions, what is the percent of questions she missed?

Percent = missed questions / Total x 100 = 12/80 x 100 = 0.15 x 100 = 15%

The phrase "X is N percent of Y" can also be written mathematically as

$$X = \frac{N}{100} \times Y$$

The word "is" means equal (=), while the word "of" means "multiply" However, before multiplying, you must change a percent into a decimal or fractional format.

For example:

5 is 20% of 25, means 5 = 0.20 x 25

To change the fraction into the percent, you must first change the fraction into a decimal, and then multiply by 100 (or move the decimal point by 2 places to the right)

For example:

Change the fraction 1/5 into a percent.

First, change the fraction 1/5 into the decimal 0.2, and multiply by 100 (move the decimal 2 places to the right). Therefore:

1/5 x 100 = 20%

The following table provides the common percentages that you will use on a regular basis, and may wish to memorize.

Fraction	Decimal	Percent
1/100	0.01	1%
1/10	0.1	10%
1/7	0.1428571	14.3%
1/6	0.16666...	16.6% or 16.7%
1/5	0.2	20%
1/4	0.25	25%
1/3	0.33	33.3%
1/2	0.5	50%
3/5	0.6	60%
1	1.0	100%
3/2	1.5	150%

Please note that numbers over 1 achieve percentages that are greater than 100%

Consider the following example:

What is 20% of 50?

A. 5

B. 8
C. 10
D. 12
E. 15

Note: the answer is C

To solve this question, you must rewrite it as an algebraic question. Therefore, let x represent the unknown number.

X = 0.20 x 50

Keep in mind that to change the percent to a decimal, and that the word "of" means that you should multiply.

X = 10

Here is another example:

5 is what percent of 2?

A. 2.5%
B. 25%
C. 100%
D. 250%
E. 500%

Rewrite this as an algebraic equation. $5 = n \times 2$
Solve for n and remember to change the answer to a percent.

n = 5/2 = 2.5 = 250%

Therefore, the answer is (D)

Square of a Number

Squaring a number means to multiply that number by itself.

The notation for squaring a number (x) is as follows: x^2

When squaring an integer, the result obtained is called a perfect square.

When preparing for the test, make sure that you are fully capable of understanding and reproducing the following table, as well as recognizing the numbers that are perfect squares and perfect cubes.

n	n^2	$n^3 (n > 0)$	$n^3 (n < 0)$
1	1	1	-1
2	4	8	-8
3	9	27	-27
4	16	64	-64
5	25	125	-125
6	36	216	-216
7	49	You will not need to know any higher	You will not need to know any higher
8	64		

9	81		
10	100		
11	121		
12	144		

Squared numbers and special properties

- $x^2 > 0$ always, except for $x = 0$
- $x^2 > x$ for $x > 1$
- $x^2 < x$ for $0 < x < 1$

  *important
- $x^2 = x$ for $x = 1$ or 0
- The square root of x^2 equals the absolute value of x.

$$\sqrt{x^2} = |x|$$

- If $x^2 = y^2$, then either $x = y$, or $y = -x$, or $x = -y$.

The following is an example:

Of the following numbers, which is a both a perfect square and a perfect cube?

A. 4
B. 8
C. 9
D. 16
E. 64

Note: the answer is (E)

Exponents

The mathematical notations for numbers which are the result of a number that is multiplied by itself a number of times is called exponents.

Examples:

$x^3 = x \times x \times x$
$x^5 = x \times x \times x \times x \times x$

The expression of x^n is also called the n^{th} power of x. The x is the base, while the n is the exponent. Math questions will usually only utilize integral exponents. x^2 is read as x-squared, and x^3 is read as x-cubed. All others are read as a power of x. x^4 is read as the 4th power of x.

When it comes to the power of 10, there is a simple, quick rule that simplifies the powers of 10, by writing it as 1, followed by the number of zeros as specified by the power.

Examples: 10^5 = 1 followed by 5 zeros. 100000 = 100,000.

An example you may find is:

Represent 32,456 to the power of 10.

The solution would be as follows:

$32,456 = 3 \times 10^4 + 2 \times 10^3 + 4 \times 10^2 + 5 \times 10^1 + 6 \times 10^0$

Consider the following example:

Solve for x: $(x - 3)^2 = 49$.

You could use algebra and take the square root of both sides or since 49 is a perfect square you could guess integers for x. Just remember x -3 must be positive or negative.

If you try guessing, the integers 10 and -4 work. To get an algebra solution, do the following:

$(x - 3)^2 = 49$
$x - 3 = 7$ or $x - 3 = -7$
$x = 10$ or $x = -4$

It is your goal to get problems correct quickly. Sometimes guessing (Guessing in this case means substituting in numbers to see which satisfy the equation.) is faster than solving an equation, if you train yourself to use the technique. Of course, if you cannot "see" the answers fast enough, use other approaches to answer the problem.

Roots

The test will require you to manipulate both square roots and cube roots. Some of the questions will measure whether or not you understand these expressions.

You should remember that none of the following should ever occur:

1. No perfect square can be left underneath a radical (square root) sign.
2. No radical can be within the denominator.
3. No fractions may occur within the radical sign.

Averages

There are three basic components that comprise an average problem:

1. Total
2. Average (also known as a mean)
3. # of numbers

The average is the total of elements that are within the set.

To discover the average, simply divide the total by the # of numbers.

For example:

Jenna's last four test scores were 35, 56, 75, and 28. What is the average of Jenna's test scores?

A. 43

B. 48.5

C. 52.5

D. 54

E. 47

Note: the answer is (B).

35 + 56 + 75 + 28 = 194

194 / 4 = 48.5

Five things to remember when solving averages:

1. If a number that is the same as the average is added, the new average will not change.
2. If a number is added and it is less than the average, the average will decrease.
3. If a number is added and it is greater than the average, the average will increase.
4. If a pair of numbers are added, and they are "balanced" on both sides of the average, the arithmetic mean is the middle value.
5. To discover the average between two evenly spaced numbers, add the first and the last terms and divide them by 2.

Reading Comprehension Test

Flying Over the Passage

A topic that is hotly debated among test taking circles is whether or not you should read the reading passages before you read the question. One theory is that you can save time if you read the questions first and then go back and read over the passage. Another theory is that you should read the passage first and then go into the questions. Both theories have their own individual merit and due to the differences in ability and preferences among test takers, one method may work better than another for you.

Our recommended theory is the flyover. You want to spend some time on the passage, at a bare minimum so that you have a general idea about what the questions are going to ask and get your mind into the proper mindset for the series of questions. However, you don't want to waste too much time on reading the passage, because much of the detail will be forgotten by the time you get to the questions anyway. Therefore, you should fly over the passage. You should read it very quickly for a high-level overview (hence the flyover) understanding of what is contained in the passage.

In part, this is a compromise between the theories that gains most of the benefits of each. You won't waste time on the details and yet will have a general idea of what the passage is about and what to expect.

Creating a Tentative Summary

After you've finished your flyover of the passage, take a few seconds and compose a tentative mental summary of what you've just read. Try to sort out the details you picked up on and arrange them into a loose organizational pattern that describes the passage. Remember that your goal in the flyover is not to check it off of a test-taking list of things to do. You want there to be some purpose behind the flyover and having the definite goal of being able to put together a brief mental summary will allow you to maintain some focus and gain benefit from the flyover – as opposed to just skimming it for the sake of skimming it without actually picking up on anything.

As you begin going through the questions and answer choices, if you get good enough at putting together your mental summaries from practice, you should be able to eliminate a number of answer choices that are immediately contrary to your summary. Note, however that if you find yourself without any good answer choices remaining (because you've eliminated them all) you obviously had to have eliminated the right answer choice. Don't hesitate to reopen an answer choice that you've already "eliminated" from consideration and reconsider it as a possibility. If you think an answer choice contradicts your initial summary, you're probably right, but are not infallible.

Openings and Endings

A main focus of this flyover will be the opening and ending sentences in each paragraph. These are likely to contain the main ideas of the paragraphs and should be mentally tagged for future reference. Try to remember a vague idea of what the different paragraphs are about, because this will save you time when answering questions later.

For the most part, make sure you never try to just answer the questions from this first flyover. Always try to go back and confirm the answer, as your memory will play tricks on you and the writers of the test questions may deliberately have planted a trap for you – remember that they don't exactly have your best interests at heart.

Extraneous Information

Some answer choices will seem to fit in and answer the question being asked. They might even be factually correct. Everything seems to check out, so what could possibly be wrong?

Does the answer choice actually match the passage, or is it based on extraneous information not even contained in the passage. Just because an answer choice seems right, don't assume that you overlooked information while reading the passage. Always try to go back and find the support for the answer choice in the passage. Your mind can easily play tricks on you and make you think that you read something or that you overlooked a phrase.

Unless you are behind on time, always go back to the passage and make sure that the answer choice "checks out."

Using Kitchen Logic

When a question asks the test taker to identify a main idea, you should first focus on the opening and ending sentences of the passage

and each individual paragraph. If you can't find the main idea from these key sentences, then ask yourself how you would describe the passage to someone who had never read it. Which words and phrases would you use to explain the principle ideas of the passage?

This is called "Kitchen Logic" - when you explain something the way you would if you were talking to your friends and family, while sitting at your kitchen table. So, when faced with identifying the main idea of a difficult passage, make it easier on yourself by backing away from the passage and thinking about it in terms of using easy "kitchen logic".

Getting into the Author's Mind

A number of questions become much easier when you place yourself into the mind of the author of the passage. Ask yourself a few different questions:

"Why did the author write this passage?"
"What was the author trying to say?"
What angle is the author taking?"
"What is the single most important point the author is trying to make?"

Put yourself in the shoes of the author and imagine that you wrote the passage and try to identify what you were trying to describe and how you were trying to describe it. If you take on the opinions and ideas expressed by the author as your own, then it becomes easier to answer questions that would be easy for the author to answer.

Emotional Words

Each question will be about a different angle of the passage. For questions asking about the author's emotions, find words in the passage that are adjectives describing emotions.

So, if a question asks what sort of attitude an author had towards the passage or subject, then look throughout the passage for attitude words that might convey a positive or negative attitude. Are words such as brilliant, excited, delightful used, or are words such as depressive, gloomy, disappointing used?

A lot of questions could be answered correctly simply by going through and circling all the adjectives in a passage. Without looking at anything else except for the adjectives in a passage, most questions about attitude or emotion could be answered correctly.

Another way of handling these situations is to arrange all of the answer choices in a list going from most negative to most positive.

Example:
Question: The author's attitude on this topic is best described as:

A. indignation
B. eagerness
C. fear
D. consent

Now arrange these in order from negative to positive:

(-) indignation, fear, consent, eagerness (+)

This will help sort out the different choices and keep you from overlooking an answer choice and making an easy mistake.

Finding the Key Words

The strategy of finding certain "give-away" words does not only apply to adjectives in questions about emotions or attitude. Many questions about specific details will have key words that hold the "key" to finding the right part of the passage to look in for the answer.

Rather than answering based on your memory of the passage, you always want to have support for your answer choice rooted in a specific part of the passage. To gain that support, it follows that you have to identify which part of the passage to look in. While reading back over the entire passage may be the most foolproof method of finding that important part of the passage, it definitely is not the most time economical method of finding that part of the passage.

A better route is to find key words in the question or answer choices that are likely to stand out in the passage and will enable you to quickly narrow your search down. These key words will be nouns or verbs in the question or answer choices. Once you've identified possible key words, then you should scan through the passage quickly looking for either those key words to be repeated in the passage, or their synonyms to appear in the passage. Once you find a particular part of the passage that either has the exact key word repeated or a synonym of the key word, you have probably identified the particular

part of the passage that will contain the support or justification that you need to correctly answer the question and will allow you to be confident in your answer choice selection.

One warning that should be made here is that often question writers may use the exact same word or wording in their answer choices that are used in the passage, but have done so in such a way as to mislead you. So, simply because a particular word or phrase appears in an answer choice and also appears exactly the same in a passage does not make that answer choice correct. Be sure that you reread the answer choice and consider the context that it is in, to ensure that you are not misled by a cheap trick.

In conclusion, always try to connect the question to the right words in the passage that will allow you to save time in finding the right part of the passage to look in for the answer and will give you the key to the correct answer choice.

Making Proper Inferences

Questions that ask you to make an inference from the passage will require you to use your own personal judgment. Anything directly stated by the author is not an inference. You will need to understand the main idea of the passage in order to make a proper inference about the author's intent and mindset.

The obvious will not be enough to answer an inference question. You must logically deduce what follows from what the author has stated in

the passage. You are looking for what can be inferred by the passage, not what is directly stated in the passage.

Applying Ideas for Generalizations

Generalization questions are similar to inference questions in that you have to go beyond what is directly stated in the passage by the author. It helps to put yourself again in the author's shoes. If you were the author and believed in what you had just written, how would you feel about another similar situation? What would either strengthen or weaken your argument. How would you apply the information you have just expressed to a completely different situation?

Using Context Clues

Context clues are a valuable aide in helping you understand difficult phrases or words in the passage. A number of questions will ask you about the meaning of words as they are used in a given passage.

If you already know the definition of the word, or have some familiarity with it, a common mistake is to go with your first impulse and choose the answer that you immediately recognize. However, the reason the test writers may have chosen that particular vocabulary word is because it is used in an unusual context. Therefore, return to the passage and find where the word is used and make sure that you understand how it is being used in the passage.

Once you've made your choice of a good definition go back again to the passage and reread that particular section, but mentally replace the answer choice you've chosen for the word being asked about.

Example:
A passage states: "He was notorious for making decisions on the spur of the moment…"

Question: Which of the following words, if substituted for the word "notorious" would introduce the LEAST change in the meaning of the sentence?

A. evil
B. disturbed
C. famous
D. despised

If you knew that the most common definition for "notorious" meant being known in an unfavorable sense, then you might be tempted to choose choice A, "evil."

But once you review back over the passage, choice C, "famous" fits in better into the context of the sentence of passage. Read the sentence again and substitute your chosen answer choice for the word it replaces. This gives you:

""He was famous for making decisions on the spur of the moment…," which makes sense and is correct.

Breaking Down Passage Organization

In trying to understand the author's perspective, you will sometimes be asked about how the passage is organized. Many times, the simplest way to find the answer is to note how the opening sentence in a passage or paragraph relates to the rest of the passage. How does the author's main idea get developed and broken down into supporting ideas and statements?

As you go through the answer choices for these organization problems, quiz yourself on each answer choice.

Example:
Question: Which of the following best describes the organization of the author's discussion of this topic?

A. He provides an example – Ask yourself, is there an example in the question? Don't work exclusively from your memory. Make sure you can go back and actually find the example in the passage.
B. He makes a comparison – Ask yourself, is there a comparison in the question? Again, go back to the passage and actually find the comparison being made and verify that it exists.
C. He makes an acknowledgement – Ask yourself, where is the acknowledgement made and to whom?
D. He discusses a theory – Ask yourself, which theory is being discussed?

After each of these initial questions, remember that it is not enough for them simply to be true, they have to answer the question. Simply

because the author provided an example, doesn't make choice A correct. The example provided may have been to support a comparison that he was making and the comparison may be the main method of organization, which in this case would make answer choice B correct. So always read all the answer choices and only choose the one that is the best, not just the first one you read that is factually correct.

First Word Analysis

When asked for main ideas that best summarize the passage, an easy strategy is to look at the first words in each answer choice and without looking at the rest of the answer choice, see if you could make a decision based on those first words alone.

Example:
Question: Which of the following best explains the author's primary purpose?

A. dispute…
B. describe…
C. condemn…
D. convince…

If you know that the passage is fairly neutral about the subject, then even if you know nothing else, you can probably eliminate the stronger verbs used in answer choices A, C, and D, leaving you with "describe" or answer choice B as being correct.

Understanding the Intimidation

The test writers will generally choose passages that will be completely foreign to most test takers. You can't expect the passages to be on a topic with which you have any familiarity. If you do happen to come across a passage that you are familiar with, consider yourself lucky, but don't plan on that happening.

The passages will also frequently be drawn from longer passages in books, articles, journals, etc. Therefore, the passage that you will face on the test may almost seem out of context and as though it begins in the middle of a thought process. You won't have a nice title overhead explaining the general topic being covered but will immediately be thrown into the middle of a strange format that you don't recognize.

Also, while the topics chosen may have originally been interesting reading in their original state, after a particular section is pulled and used for the test passage, it will likely be dry and boring.

Getting hit by strange reading topics that you don't recognize, of which you may only have a small part of the original selection, and that are dry and boring can be a bit intimidating if you're not adequately prepared. Just remember that the passages themselves will contain all the information necessary to answer the questions and you don't need any prior knowledge of the topic in order to succeed and do well on the test.

Finding your Optimal Pace

Everyone reads at a different rate. It will take practice to determine what is the optimal rate at which you can read fast and yet absorb and comprehend the information. This is true for both the flyover that you should initially conduct and then the subsequent reading you will have to do as you go through and begin answering the questions. However, on the flyover, you are looking for only a surface level knowledge and are not trying to comprehend the minutia of details that will be contained in the passages.

You can practice with any form of reading material. Read an article at your normal pace and then after you're finished, ask yourself some questions about what you just read and see how well you can comprehend. Experiment with reading articles faster and slower and always gauge how well you comprehended what you read at the end. Train your brain to remember the details and absorb the facts.

With practice, you will find the pace that you should maintain on the test while going back through passages. It should be a comfortable rate. This is not a speed reading exercise. If you have a good pace, and don't spend too much time on any question, you should have a sufficient amount of time to read the different sections of the passages at a comfortable rate. The two extremes you want to avoid are the dumbfounded mode, in which you are lip reading every word individually and mouthing each word as though in a stupor, and the overwhelmed mode, where you are panicked and are buzzing back and forth through the passage in a frenzy and not comprehending anything.

You must find your own pace that is relaxed and focused, allowing you to have time for every question and give you optimal comprehension. Note that you are looking for optimal comprehension, not maximum comprehension. If you spent hours on each word and memorized the passage, you would have maximum comprehension. That isn't the goal though, you want to optimize how much you comprehend with how much time you spend reading. Practice will allow you to determine that optimal rate.

Don't be a Perfectionist

If you're a perfectionist, this may be one of the hardest strategies, and yet one of the most important. The test you are taking is timed, and you cannot afford to spend too much time on any one question.

If you are working on a problem and you've got your answer split between two possible answer choices, and you're going back through the passage and reading it over and over again in order to decide between the two, you can be in one of the most frustrating situations possible. You feel that if you just spent one more minute on the problem, that you would be able to figure the right answer out and decide between the two. Watch out! You can easily get so absorbed in that problem that you loose track of time, get off track and end up spending the rest of the test playing catch up because of all the wasted time, which may leave you rattled and cause you to miss even more questions that you would have otherwise.

Therefore, unless you will only be satisfied with a perfect score and your abilities are in the top .1% strata of test takers, you should not

go into the test with the mindset that you've got to get every question right. It is far better to accept that you will have to guess on some questions and possibly get them wrong and still have time for every question, than to work on every problem until you're absolutely confident in your answer and then run out of time on the last few problems.

Factually Correct, but Actually Wrong

A favorite ploy of question writers is to write answer choices that are factually correct on their own, but fail to answer the question, and so are actually wrong.

When you are going through the answer choices and one jumps out for being factually correct, watch out. Before you mark it as your answer choice, first make sure that you go back to the question and confirm that the answer choice answers the question being asked.

Different Viewpoints

Some passages will express the author's viewpoint on a topic, along with the viewpoint of other experts or other individuals. This can lead to trouble in answering questions though. If asked for the viewpoint of the author, you might go back to the passage, find where a certain viewpoint is expressed, answer the question based on what you read and move on.

For most passages, that would be fine, but when other viewpoints besides the author's are expressed, you have to discern who is

expressing their opinion in the passage. Make sure that if multiple individuals are giving their viewpoint on a topic, that you sort them out for any questions and associate the right viewpoint with the right individual.

Verbal Test

Characteristic

Some characteristic analogies will focus on a characteristic of something else.

Dog: Paw – The foot of a dog is its paw.

Lady: Lovely – A lady has a lovely personality.

Some characteristic analogies will focus on something that is NOT a characteristic of something else.

Desert: Humidity – A desert does not have humidity.

Job: Unemployed – A person without a job is unemployed.

Quick: Considered – A quick decision is often not very considered.

Source

Casting: Metal – A casting is made from metal.

Forest: Trees – A forest is composed of trees.

Slogans: Banners – A slogan is printed on banners.

Location

Eiffel Tower: Paris – The Eiffel Tower is a structure in Paris.

Welsh: Wales – The Welsh are the inhabitants of Wales.

Pound: England – The pound is the monetary unit of England.

Sequential

One: Two – These are consecutive numbers.

Birth: Death – These are the first and last events of a life or project.

Spring: Summer – The season of Spring immediately precedes Summer.

Reciprocal

Parent: Child – A parent cannot exist without a child.

Power: Work – Power is a function of work.

Owner: Possession – For possession to occur, there must be an owner.

Cause/Effect

Storm: Hail – Hail can be caused by a storm.

Heat: Fire – Heat results from a fire.

Monotony: Boredom – Boredom is a consequence of monotony.

Creator/Creation

Carpenter: House – A carpenter builds a house.

Painter: Portrait – A painter makes a portrait.

Burroughs: Tarzan – Edgar Rice Burroughs wrote the novel Tarzan.

Provider/Provision

Job: Salary – A job provides a salary.

Therapist: Treatment – A therapist treats patients.

Army: Defense – An army enables national defense.

Object/Function

Pencil: Write – A pencil is used to write.

Pressure: Barometer – A barometer measures pressure.

Frown: Unhappy – A frown shows unhappiness.

User/Tool

Carpenter: Hammer – A carpenter uses a hammer.

Teacher: Chalk – A teacher uses chalk.

Farmer: Tractor – A farmer drives a tractor.

Whole/Part

Door: House – A door is part of a house.

State: Country – A country is made up of states.

Day: Month – A month consists of many days.

Category

Door: Window – Both a door and a window are parts of a house.

Thigh: Shin – Both a thigh and a shin are parts of a leg.

Measles: Mumps – Both measles and mumps are types of diseases.

Synonym or Definition

These are analogies in which both terms have a similar meaning.

Chase: Pursue – Both of these terms mean to "go after".

Achieve: Accomplish – Both of these terms refer to the successful attainment of a goal.

Satiate: Satisfy – Both of these terms mean to gratify a desire.

Antonym or Contrast

These are analogies in which both terms have an opposite meaning.

Disguise: Reveal – To disguise something is not to reveal it, but to conceal it.

Peace: War – Peace is a state in which there is no war.

Forget: Remember – The word "remember" means not to forget something.

Intensity

These are analogies in which either one term expresses a higher degree of something than the other term.

Exuberant: Happy – To be exuberant is to be extremely happy.

Break: Shatter – To shatter is to strongly break.

Deluge: Rain – A deluge is a heavy rain.

Word Part / Meaning

These are analogies in which one term explains what the other term means.

Pre-: Before – The prefix "pre-" means before; for example, predetermine means to determine before understanding or seeing all of the facts.

Excessiveness: -ard – The suffix "-ard" means to do something excessively; for example, a drunkard is someone that drinks excessively

Mis-: Poorly – The prefix "mis-" means to do something poorly; for example, to misspell a word is to spell it poorly.

Using Sentences

The most commonly used strategy for solving analogy problems is still the best. You should try to put the word pairs into sentences that make it easier to understand the meaning of the relationship. The sentence doesn't have to be complicated, but it needs to explain the relationship between the two words.

Example: joey: kangaroo ::

You wouldn't want to create the sentence "A joey and a kangaroo are both mammals."

A sentence that explains the relationship would be "A joey is a baby kangaroo".

To solve the problem you would want to plug in the other answer choices into the sentence that you've created. A _____ is a baby _____ . This sentence with its blanks is the template that you will use. By inserting each analogous pair answer choice into those blanks, you should determine which is correct.

Focus on What You Know

Many test takers are panicked when they realize they don't know what a word means. The key is to use what you do know. Does the unknown word have any prefixes or suffixes that you recognize? Do you know of any familiar words that have the same root word? You'll be surprised what you can determine about a word when you dissect it appropriately.

If you aren't able to dissect the word, there are still lots of other words in the other answer choices that you do know and can work with. Since there are only four choices to choose from, if you are able to eliminate the other three, then even if you don't know all the words in the fourth answer choice – it must be right. Also, if you are confident that another answer choice is correct, you can immediately move on, without worrying about a word that you don't know.

Sentence Completions

The sentence completion section will offer you a sentence that has a blank that must be filled in. The word(s) that best complete(s) the sentence will be correct. The sentences may either have one or two missing words and blanks.

Try Every Choice

Just because you think that one of the answer choices sounds best, go ahead and try all of them by plugging each of them into the blank(s) and seeing which one sounds the best. The test writers will be sure to put in additional choices that may sound "close enough," but you want to make sure that you pick the one that is the absolute best possible answer choice.

Read Carefully

Don't make the mistake of reading through the sentences carelessly. A prepositional phrase or a tiny word can alter the entire meaning of the sentence.

This is particularly true for transition/hedge words like if, then, therefore, also, sometimes, never, not, and always. These words are particularly critical to watch for, as a word such as "not" can make an answer choice directly opposite of the correct answer choice sound correct.

Multiple Blanks

Instead of being intimidated by the sentences that have multiple blanks, you should be excited, because they give you more data points to use to determine which answer is correct. The additional information required to answer the question actually helps, as if you aren't sure about one of the words in an answer choice word pair, you can still check the other word and see if it is right or wrong.

Elimination

Clearly, the best way to get the right answer to a question is to know how to solve it. If you have studied, it is likely that at least some of the questions you encounter will be a cinch. The right formula will just pop into your head, you'll do a quick calculation, and bingo! You'll see the results of your calculation listed there among the answer choices. You should count your blessings when this occurs, because most questions will involve a tad bit more of a struggle.

One way to reduce the amount of struggle is by eliminating some of the answer choices. Consider the following example:

Water is pumped from the bottom of a petroleum storage tank with a centrifugal pump at a volumetric flow rate of 50 gallons per minute (GPM) to ensure an accurate inventory reading. After all the water is removed from the tank, the pump continues to run for one minute. Calculate the mass of the oil that is pumped out of the tank. (Note: The API gravity of the oil is 30; water density is 8.3 lbs/gallon)

API = 141.5/SPGR - 131.5
SPGR=Specific Gravity

A. 350 lbs
B. 400 lbs
C. 45 gallons

D. 50 gallons

Imagine for a moment that you are not real sure how to answer this question. By following some simple rules of logic, you may be able to discern the correct answer.

First, it is always good practice to underline what you are looking for. In this case, you should underline "mass of oil." Immediately, that should enable you to eliminate two of the answers.

Think "units." Units of measure should always be considered when dealing with a physical science question. Sometimes, this can give you the answer immediately. In this case, it at least narrows down your field of choices.

What are the units of measure for mass? Well, you probably know that answer, but imagine for a minute that you don't. What can you do? First look for clues in the question. Are there any units presented there?

Yes, there are: gallons per minute (GPM) and lbs/gallon. In fact, GPM is specifically stated to be a unit of volumetric flow rate; a fine reminder that "gallons" is a unit of volume.

Now look at the choice of answers. You can choose from lbs or gallons. We know the answer can't be in gallons, because we're not looking for volume. But what if you don't know what a "lbs" is (of course you know it means "pounds", but just pretend for a moment.)

Your only choice now is to start looking at relationships between numbers you are given in the question and the numbers in our two remaining answers. Dealing with round number first, it's easy to see that if we multiply 50 GPM by 8 lbs/gallon, then you get 400 lbs/min. Compare that with the two answers we have left. It looks a lot like answer B, doesn't it? You must be on the right track.

How can you change that lbs/min to lbs? Look at the question one more time for clues.

Aha! "One minute" is the clue you are looking for. If it flows for one minute, then at a rate of 400 lbs/min, the mass of water that flowed must be 400 lbs.

CAUTION: This is the point at which you could make a costly mistake. You found an answer that works, but is it the answer to the question? What did you underline at the beginning?

You calculated the mass of water that would flow in one

Alternative Solution:

1.) Assume standard temperature conditions so that specific gravity does not need to be compensated.

2.) Understand that specific gravity is the ratio of a substances density compared to water at standard temperature conditions

3.) Solve the given equation for SPGR

$$SPGR=\frac{141.5}{API+131.5}$$

SPGR=0.876

4.) Calculate the mass of water pumped after 1 minute of flow. (400 lbs.)

5.) Assuming the volumetric flow rate of oil will be the same as water, use specific gravity to calculate mass: 400 lbs x 0.876=350.4 lbs.

minute, but you need the mass of oil. Time for a reality check: what is our only other choice?

That's right. Letter A is your answer. Does it make sense? Well, what weighs more: oil or water? (Hint: Oil floats on water.) Given the same volume of flow, you would expect the mass of oil to be lower, so the answer makes sense.

This has been a simple illustration of how you may work your way through a problem fairly quickly, even when you don't know the "right" way to do it (see alternative solution).

GENERAL TIPS

1) Underline or circle the information you need to find to answer the question.
2) Pay attention to notes given after the question. They generally hold information that is vital to finding an answer.
3) Perform unit analysis whenever possible. Evaluate the units in the answer choices to see if they make sense.
4) Use common sense knowledge to eliminate answers (oil weighs less than water, etc.)
5) Don't jump on an answer without thinking. There will sometimes be an answer listed that is really a "halfway point." Be careful.

Easy? No!

Please do not be fooled into thinking that you will be able to obtain the right answer every time by following the preceding tips. You still need to study your science.

Answering Questions

It is important that you read each question and its corresponding answers very carefully. You must understand what the question is asking. Reading the answers before doing your calculation can be helpful in focusing your attention. For instance, if all of the answers are numerical, that's a good clue that a calculation is involved. If the answers are all textual, then you may save time by not having to perform a calculation.

Consult the earlier passage on magnetic flow meters, and consider the following question:

Assuming an initial velocity of v=6 ft/sec and a constant volumetric flow rate, what happens to velocity if the diameter of the pipe is cut in half?

A. v=4 ft/sec
B. v=9 ft/sec
C. v=12 ft/sec
D. v=16 ft/sec

The choices of answers to this question reflect that you will have to calculate the change in velocity, testing your knowledge of the equations necessary to do so. But what if the answers are presented as follows?

Assuming an initial velocity of v=6 ft/sec and a constant volumetric flow rate, what happens to velocity if the diameter of the pipe is cut in half?

A. It is ¼ as fast
B. It is ½ as fast
C. It is 2 times as fast
D. It is 4 times as fast

You can see the relationship between the new diameter and the old diameter, and you know that velocity will increase as D decreases. This tests your conceptual knowledge without having to know an exact formula. It also saves you time, so read the answers first.

Time to Study

The primary purpose of this book has been to prepare for what you will face on exam day and give you an edge that will help you to excel. Now it's time to make sure your science skills are honed and ready.

If you are like most aspiring pharmacy students, you have a fairly recent history of using basic chemistry concepts in your undergraduate coursework. This is not always the case, of course. Maybe you decided to take a lengthy hiatus from school before making an attempt

to get into pharmacy school. In either case, it would be very wise to study the material before attempting the exam. The question is: what is the best approach?

There are a large number of facts and concepts required of you on the PCAT. To do a comprehensive review of every single subject would basically require you to read several textbooks cover to cover. Who has the time for such inefficiency? You may as well go back to school for a year. If you are taking this exam, then you have knowledge you require in that brain of yours. What you need is a review.

In the next section of this book, you will find a list of all the topics that may be included on the chemistry portion of the PCAT. As you look over the topics, you will have a gut feel for what you know and what you don't. Concentrate on what you don't know. You can use your old textbooks to find information on the topic, or better yet, you can use the world's best information resource for study materials: Google. If you've never used Google before, here are some tips for finding what you need.

First, point your web browser to http://www.google.com.

Next, type a word or phrase describing the topic you'd like to research and push the "Google Search" button. You will be given a list of results that contain more information than any single book could ever give you. There is more information than you need, and best of all: it's free!

When studying, remember to focus on just the basics. Fill your mind with the essentials, and nothing more. The following list covers everything you need to know. Please note that some of the topics are presented as formulas. These are formulas that should be committed to memory. Don't assume that they will be given to you.

Now get to Googling! And good luck!

Knowledge Requirements

Electronic Structure

- Orbital Structure of H, electrons/orbit
- Electron states (ground, excited)
- Absorption and emission spectra
- Quantum numbers & states
- Common names & shapes for s, p, & d orbitals
- Conventional notation
- Bohr model
- Effective nuclear charge

Periodic Table: Group Classification

- Alkali metals: chemical characteristics
- Alkaline earth metals: chemical characteristics
- Halogens: chemical characteristics
- Noble gases: physical and chemical characteristics
- Transition metals
- Representative elements
- Metals and non-metals
- Oxygen grouping

Periodic Table: Groups and Rows

- Electronic Structures
- Valence electrons
- Ionization energies
- Electron affinities
- Electronegativity
- Atom sizes / Electron Shells

Ionic Bonding

- E=kQ1Q2/d
- E=lattice energy
- R(n+e)(n-e)/d2=Force attraction

Covalent Bonding

- σ and π bonds
- Lewis electron dot formulas
- Partial ionic character

Phases of gases

- Absolute temperature (Kelvin scale)
- Pressure / simple mercury barometer
- Molar volume (0o C and 1 atm=22.4 mol/L)
- Ideal gas laws
- Kinetic molecular theory
- Real gas behavior vs. ideal gas law
- Partial pressure, mole fraction
- Dalton's law (partial pressure vs. composition)

Intermolecular forces of liquid phases

- Hydrogen bonding
- Dipole interactions
- Van der Waals' forces

Phase equilibria

- Phase diagrams / phase changes
- Boiling, melting, and freezing points
- Molality
- Colligative properties
- Colloids
- Henry's law

Stoichiometry

- Molecular weight
- Molecular formula vs. empirical formula
- Common metric units
- Composition by % mass
- Avogadro's number/mole concept
- Density

- Oxidation number
- Chemical equations/reactions

Thermochemistry

- State function of thermodynamic system
- Conservation of energy
- Endothermic/exothermic reactions
- Heats of formation/Bond dissociation energy
- Calorimetry/heat capacity/specific heat
- Entropy; relative entropy for gas, liquid & crystal states
- Free energy G
- Spontaneous reactions and ΔGo

Thermodynamics

- Zeroth law: concept of temperature
- First law (conservation of energy)
- Equivalence of mechanical, chemical, electrical, and thermal energy units
- Second law (concept of entropy)
- Temperature conversions, scales
- Conduction, convection, radiation heat transfer
- Specific heat, specific heat of water (1 cal/ o Cg)
- Heat of fusion and vaporization
- PV diagram

Kinetics and Equilibrium

- Reaction rates
- Effect of concentration of reactants on reaction rate; rate law
- Rate determining step
- Thermodynamic control vs. kinetic control of a reaction
- Catalysts; enzyme catalysis
- Equilibrium in reversible chemical reactions
- LeChatelier's principle
- Relationship of the equilibrium constant and ΔGo

Ions in solution

- Anions, cations; formulas, common names and charges for familiar ions
- Hydration, hydronium ion

Solubility

- Units of concentration
- Equilibrium expressions; solubility product constant
- Common-ion effect in laboratory separations
- Complex ion formation
- Solubility and pH

Acid/Base Equilibria

- Bronsted definition of acids & bases
- Ionization of water
- Approximate value of Kw
- Conjugate acids and bases (amino acids)
- Strong acids and bases & common examples
- Weak acids and bases & common examples
- Dissociation of weak acids and bases
- Hydrolysis of salts of weak acids and bases
- pH calculations for solutions of weak acids and bases
- Equilibrium constants Ka and Kb: p Ka, p Kb
- Buffers

Titration

- Indicators
- Neutralization
- Interpretation of titration curves
- Redox titration

Electrochemistry

- Electrolysis
- Electrolytic cell anode & cathode
- Electrolyte

- Faraday’s law relating to electrolysis
- Electron flow, oxidation and reduction
- Galvanic or voltaic cells

Biology Test

Molecular Biology

Molecular genetics. DNA: double-helix structure, its roles as template in nucleic acid synthesis.
Nucleotides:
Types and three structural components of DNA and RNA; base-pairing.

Protein Synthesis. Sequence of events from transcription to translation; the roles of mRNA, tRNA, amino acid and growing peptide chain, and the ribosome. Diversity and protein functions.

Enzymes. Catalytic function and universality of. General principles of enzyme action: active site:, specificity. Regulatory enzymes and feedback inhibition. Knowledge of Michaelis-Menten kinetics (e.g., K_m) is *not* required

Metabolism. ATP as universal energy source. Glycolysis, Krebs cycle, and electron-transport chain: important steps, intracellular location, sites and amounts of ATP and CO^2 production, O^2 consumption.

Cellular Biology

Prokaryotes. Defining characteristics. Viruses: protein-DNA structure; life cycle (lytic and lysogenic); as obligate intracellular parasites; bacteriophage. Bacteria: classification by shape (e.g., cocci, bacilli, spirochetes, rickettsians). Importance of mutation, transformation, transduction.

Eucaryotes. Defining characteristics. Function and essential structure of important organelles and inclusions, such as mitochondria, ribosomes, nucleus, nuclear and cell membranes. Mitosis: stages of, principles of, associates structures. The only thing that should be known about fungi is their characteristic life cycle.

Organismal Biology

Embryology and Reproduction. Meiosis and principles of sexual reproduction. Crude understanding of male and female sexual anatomy and physiology. Fertilization of egg and subsequent developmental stages (zygote, morula, blastula, gastula, neurula). The three primary germ layers and the organs each gives rise to. Basic anatomy of the early embryo. Induction and differentiation: prototypical example – development of the vertebrate eye.

Respiration and Renal Function. Lungs as gas exchangers (of O^2, CO^2). The kidneys as excretory organs (of urea, bicarbonate, drugs, etc.) and as reabsorbing organs (e.g., of glucose, water, sodium). The glomerulus, nephron, loop of Henle.

Circulation. Basic anatomy of the heart and great vessels. Functions of arteries, arterioles, capillaries, venules, and veins. Lymphatic system: function; drainage. Thermoregulation: counter-current heat exchange mechanism; importance of increased or decreased blood flow to the skin.

Muscle and Bone. Principles of muscle action: actinmyosin contraction, role of O^2 and lactic acid production, utilization of glucose and creatine

phosphate. Characteristics of smooth, striated (voluntary), and cardiac muscle. Bone: cellular components and inorganic matrix; cartilage and organic matrix. Haversian canals. Tendons and ligaments.

Nervous System. The neuron: dendrites, cell body, axon, resting potential, impulse propagation, sodium potassium transfers. Autonomic nervous system, central vs. peripheral nervous systems, afferent vs. efferent nerves vs. interneurons. The reflex arc. Basic functions of the medulla, cerebellum, and cerebrum. The neuromuscular junction.

Endocrine System. The major glands and their hormones. The feedback loop. Special emphasis is on the sex hormones, insulin, epinephrine, antidiuretic hormone (ADH), thyroid hormone. Connection between the hypothalamus and the pituitary gland.

Digestion. Major digestive events occurring in the mouth, stomach, small intestine, and large intestine. The portal vein, liver, bile, and gall bladder. Pancreatic digestive enzymes. Villi and microvilli.

Genetics, behavior, Evolution (Supraorganismal) Biology

The Gene, Alleles, and Mandelian Principles. Genetic crosses, pedigree analysis. Dominance, co-dominance, sex-linkage, heterozygosity, pleitropy. Mechanism and significance of crossovers. Assumptions necessary for the Hardy-Weinberg equilibrium
(but not the Hardy-Weinberg formula)

Animal and Human behavior. Imprinting, reflex, ritual, conditioned behavior, learning, habit, insight, etc. Territoriality, competition, dominance, aggression, courtship. Predation, symbiosis, mutualism, commensalisms, parasitism, saprophytism.

Evolution. Darwinian principles (survival of the fittest); definition of fitness. Lamarckian inheritance. Evolutionary mechanisms such as speciation, radiation, extinction, convergence, divergence. Nomenclature of taxonomy (kingdom, phylum, class, order, family, genus, species) and Linnaean nomenclature. Basic comparative anatomy and general evolutionary trends in body structure. Homology and analogy (with regard to organs).

REVIEW OUTLINE

The Cell- Its Structures and Function

The cell is the basic unit of structure and function and basis of all life; all cells come from preexisting cells.

Size

Most cell are between 10 and 100μ (microns) in diameter.
Measurements are made utilizing the following units:
1 cm= 10mm
1 mm= 1000μ
1μ= 10,000Å (angstrom units)

Average sizes of structures may be listed as follows:

Cells about 10μ	(100,000 Å)
MITOCHONDRIA ABOUT 1μ	**(10,000 Å)**
Bacteria about 1μ	(10,000 Å)
Viruses about 0. 1μ	(1,000 Å)
Macromolecules about 0.01μ	(100 Å)
Molecules about 0.001μ	(10Å)
Hydrogen ion about 0.0001μ	(1 Å)

Resolution is commonly defined as the ability to discriminate two points and visualize them as two points, even though they are extremely close together. With the unaided eye these two points might appear as one point. The resolution is dependent on the wavelength of the light source and can be calculated to be about one-half the wavelength.

Examples of resolving power are:
Human eye about 0.1 mm (100μ)
Light microscope about 0.2μ (2000 Å)
Electron microscope about 2-5 Å

Composition of Protoplasm

Protoplasm is made up mainly of proteins, carbohydrates, fats, salts and water; its average elemental composition is:

Oxygen 75 + %	Sulfur about 0.2%
Carbon 10+%	Phosphorus about 0.3%
Hydrogen 10+%	Potassium 0.3%
Nitrogen 2+%	Chlorine about 0.1%

Less than 0.1% - Sodium, calcium, magnesium, iron, etc.

Properties of the Cell and Protoplasm

IRRITABILITY

1. Conductivity
2. Respiration
3. Absorption
4. Secretion
5. Excretion
6. Growth
7. Reproduction
8. Metabolism

Components of a typical Cell

Cells are commonly recognized as having two major compartments: ***Cytoplasm*** which includes all components within the cell membrane but outside of the nucleus and ***nucleoplasm*** which includes everything within the nuclear membrane.

Cell Membrane: The cell membrane, or unit membrane, usually is about 75-100 Å thick; it is a trilaminar structure. As described by Danielli and Davson (1935), two protein layers sandwich a bimolecular lipid layer.
The cell membrane:
Provides for a boundary resulting in a controlled environment.
It is a relatively watertight barrier.
Maintains a constant composition and environment resulting in homeostasis.
Is semipermiable; only certain types of molecules are allowed to pass.
Is composed mainly of proteins, lipids, and carbohydrates; the major types of lipids found in nature are fats, phospholipids, and steroids.

Structure. Electron microscopy suggests that the central region of the membrane consists of two layers of lipid molecules, mainly phospholipids and steroids. Each layer is thought to be one molecule thick. The phospholipids molecules are fairly long and have two functional poles: one exhibits lipid properties (it exhibits hydrophobic properties, repelling water); the other exhibits polar properties(it has a tendency to dissolve water, and exhibits hydrophilic properties). The hydrophobic ends of both layers of lipid molecules associate with each other since they have affinity for one another. The hydrophilic portions

face toward the protein layers; parts of proteins associate readily with water.
Electron microscopy substantiates that there is a light central layer surrounded by two denser layers. The two denser layers are thought to represent the proteins and hydrophilic portions of the lipid molecules.

Activities. The plasma membrane is semi-permeable. It controls the passage of materials into and out of the cell. The movement of materials into and out of the cell is called *transport.*

There are two types of transport—passive, or transport that does not require the cells energy, and active, which does require the energy expenditure.
There are two types of passive transport—diffusion and osmosis.
In *diffusion* molecules pass from an area of higher concentration to that of lower concentration until the concentrations are equal on both sides of the membrane. Diffusion, in other words, follows the concentration gradient.

Osmosis is the movement of water across the semi-permeable membrane. Water will pass into a more concentrated solution and this passage of water will equalize the concentration of dissolved substances on each side of the membrane so that equilibrium is theoretically achieved.
Equilibrium implies an equal number of molecules of all dissolved material per unit volume on each side of the membrane compartment; the same applies to the concentration of each individual diffusible component.

Gases pass through the cell membrane with ease. Water and small molecules pass more readily than large molecules and lipid soluble materials enter the cell easier than non lipid soluble substances. Active transport requires the cell to expand energy to allow materials to pass through the membrane. (Also called uphill transport, energy dependant transport can operate against concentration gradients.) Electrical charge has also to be considered. The inside of the cell is usually electrically negative in comparison to the outside environment. In active transport, materials enter the cell in membrane-bound vesicles, formed by the membrane. This process is known collectively as *endocytosis.* When it involves solid material we speak of *phagocytosis;* liquid materials enters via *pinocytosis.* The process of expulsion of material is known as *exocytosis.*

Special Sites*.* To amplify the complexities of the cell membrane some general statements are in order at this point.
Cells must be held together and specialized structures are required. Adjacent cell membranes interdigitate and intercellular cement is utilized.
A *desmosome* is a specialized area of connection between adjacent cellular membranes (macula adherens).

A terminal bar is a dense area surrounding the apical cellular surface. It includes the tight junction (zona occludens) and the loose junction (zona adherens).
Layers of material (probably mucopolysaccharide) secreted by the cell are found on the surface of the cell. The most prominent layer is the *basement membrane,* or *basal lamina.*

The thick cellulose cell wall of plants falls within the above category. These structures are boundaries and must be traversed by material entering and leaving the cell.

Intercellular Space

Cells are usually separated by a space of about 100-200 Å. Only at specialized contact points do cells appose each other. The space is filled mainly by a matrix of proteins and polysaccharides which function in cementing cells to one another.
Some cells possess special extracellular polysaccharide substances: cartilage is rich in chrondroitin sulfate; joints have large amounts of hyaluronic acid; and cell walls of plants are composed largely of cellulose.

Cytoplasmic matrix

The cytoplasm of a cell appears homogeneous, translucent, and structureless; the homogeneous mass, which is also called cell-sap or hyaloplasm, contains inorganic substances and organic compounds of varying molecular sizes. The more peripheral layer of this matrix is also known as ectoplasm (plasmagel). It appears more rigid and seems to lack granules completely.

Cellular Inclusions

These may be composed of proteins, fats, carbohydrates, granules, pigments, and crystals.

a) *Secretion granules (products of cell activity)*. These are usually membrane-bound products that await extrusion by the cell (exocrine secretion into ducts or endocrine secretion into the extracellular space and capillaries).Release of secretory product from the cells is via exocytosis. Under the general term endocytosis (taking into the cell), are the more specific terms, pinocytosis (taking in of fluid) and phagocytosis (taking in of solids).
b) *Lipid droplets*. These are globular accumulations synthesized by the cell. During periods of need they may serve as a source of energy.
c) *Glycogen granules*. These are small spherical units synthesized by the cell. They serve as storage reservoirs of carbohydrates.
d) *Pigment granules*. These may be of two types: endogenous pigments derived from cell metabolismor exogenous pigments taken in by the cell. Hemosiderin, is an example of an exogenous pigment, while the lipochromes and the melanins are endogenous in nature.
e) *Vacuoles*. Under this general term may be classified any membrane-bound globular structure.
f) *Plastids*. The plastids are composed of leucoplasts, chromoplasts and chloroplasts. Leucoplasts resemble chloroplasts but have no chlorophyll; they manufacture starch, oil and protein. Chromoplasts possess pigments and are responsible for the color of flower petals. Chloroplastspossess chlorophyll, which is capable of capturing light energy to produce Glucose from CO^2 and H^2O.

Mitochondria

Mitochondria are the best known of the cellular organelles. They had been described during the 19th century, notably by Kollicker and Fleming. Altman, using Janus green, was able to stain them in 1890. Structually, the mitochondrion is composed of an outer trilaminar membrane and an inner trilaminar membrane; the inner one forms folds which are known as *cristae*. The space between the two membranes is about 6-10 nm wide.

Mitochondria as a whole and specifically the cristae vary in size, shape and number not only in different cells but also in the same cell depending on its functional state. Mitochondria are present in greater numbers in cells exhibiting high levels of activity and having more energy requirements. Muscle and grandular tissues fall in the above category.

DNA has been found in the mitochondria of animals and the chloroplasts of plants. Mitochondria are capable of division and are not generated *de novo.*
Granules have been observed in the mitochondria Matrix. Their identity is in question, however; some believe they might be reservoirs of calcium and other divalent ions. Phosphate is taken up with Ca^{2+} and calcium phosphate deposit may be the end result.

Mitochondria are the biochemical power plants of the cell. They recover energy from food stuffs (via krebs cycle, or citric acid cycle; tricarboxylic acid cycle and the respiratory chain) and convert it via

phosphorylation into adenosine triphosphate (ATP). In this manner they produce the energy necessary for the metabolic processes.

Enzymes. The organization of enzymes and coenzymes(especially enzymes involved in odidative phosphorylation) in the cristae appears to be highly specific facilitating an orderly and proper sequence of reactions.

Enzymes concerned with the Krebs cycle are presumed to be either free in the mitochondrial matrix (internal medium) or loosely bound to the membranes since they are readily recovered when mitochondria are disrupted. The electron transport and oxidative phosphorylation seem to be coupled.

Enzymes then are associated with the outer membrane, the inner membrane, the space between the outer and inner membranes, and the matrix.

DNA and protein Synthesis. Most extranuclear DNA, if not all, can be found in mitochondria (and in plants in the chloroplast). Thereis evidence that proteins are synthesized in mitochondria under direction of mitochondrial DNA. In biochemical preparations of mitochondria the synthesizing enzymes necessary for RNA and proteins have been isolated. However, there is also considerable documentation that the code for the enzymes involved in oxidative phosphorylation originates in nuclear DNA. Therefore, it must be assumed that mitochondrial DNA is involved only in the partial coding of the proteins manufactured in the organelle.

Krebs Cycle. Mitochondria are involved in the Krebs citric acid cycle in which organic acids are oxidized to CO^2. In each successive step oxidation of a single carbon of the chain takes place and each reaction requires a different enzyme.
The ATP produced is a small molecule and can diffuse out of the mitochondrion into the cytoplasm and participate in the endothermic reactions of the cell.

Chloroplast

For completeness sake, let us examine the homologue of the mitochondria in plants namely, the chloroplasts. Joseph Priestley discovered photosynthesis in 1771. In 1888 Haberlandt associated chloroplasts directly with oxygen production. Just as cellular respiration takes place in the mitochondria, photosynthesis occurs in chloroplasts.

Composition of chloroplasts: 56% protein, 35% lipid, 8% chrophyll. Chloroplasts are somewhat larger and exhibit more variability than mitochondria. They are bound by two membranes and possess an amorphous ground substance, or *stroma,*

Throughout which rows of parallel membranes called grana are distributed. These membranes house the photosynthetic machinery.

Photosynthesis

In photosynthesis light energy(photons) is absorbed by chlorophyll in the chloroplasts and utilized in the production of sugars from the water and atmospheric carbon dioxide.

The process (light dependent reaction) may be outlined as follows:

$$CO^2 + H^2O \xrightarrow[\text{radiant energy}]{\text{green plants}} (CH^2O)_n + O^2 + H^2O$$

sugars & **STARCHES**

OR

$$6CO^2 + 12H^2O + \text{light} \xrightarrow[\text{chlorophyll}]{} 6O^2 + C_6H_{12}O_6 + 6H^2O$$

The oxygen produced is returned to the air. The sugars are used by the mitochondria and the energy produced joins the high energy bonds of ATP. Chloroplasts can also produce ATP independently. Broadly speaking the photosynthetic process, due to its production of water, carbohydrates and oxygen, sustains all higher forms of life. Once the sugar has been produced no distinction can be made in the biochemical processes of plants and animals.
As implied before, photosynthesis is a two reaction process: one is dependent on light, while the other is known as the dark reaction. They may be summarized as follows:

Light- dependent reaction

Results in production of ATP from ADP via phosphorylation, results in formation of reduced NADP from NADP, which results in release of oxygen from water which results in ATP production.

Dark reaction

Results in carbohydrates from carbon dioxide, utilizes the ATP and reduced NADP from light reaction.

The sequence of reactions dictates the high degree of molecular organization. During fractionation studies most of the enzymes of the dark reaction can be isolated in the supernatant. The enzymes from the light reaction can be associated with the membranous structures. IN general terms, one can speculate that while carbohydrate synthesis occurs in the stroma, the production of ATP, is reduced NADP and O^2 is associated with membranes.

Endoplasmic Reticulum (ER)

This cellular organelle was first described using phase microscopy by Porter, Claude and Fallam in 1945. It is an extensive network of interconnecting channels. The endoplasmic reticular membranes are unit membranes (triminar). When ribosomes line the outer surface it is designated as *rough endoplasmic reticulum* (RER). The primary form of this organelle is the rough variety. The smooth is derived from the rough due to loss of ribosomes. The amount of each depends on the cell type and the cellular activity.

The RER is the synthetic machinery of the cell. It is mainly concerned with protein synthesis.

The Golgi Complex

This structure was discovered by Camillo Golgi in 1898. All eukaryotic cells, except for the red blood cell, possess a Golgi apparatus. Generally speaking the Golgi complex is prominent in glandular cells and is thought to function in the production, concentration packaging, and transportation of secretory material. IN summary one can link the

Golgi complex to: secretion, membrane biogenesis, lysosome formation, membrane recycling, hormone modulation.

Lysosome

Lysosomes are described as containing proteolytic enzymes (hydrolases). Lysosomes contain acid phosphatase and other hydrolytic enzymes.. These enzymes are enclosed by a membrane and are released when needed into the cell or into phagocytic vesicles.

Lysosomal enzymes have the capacity to hydrolyze all classes of macromolecules. A generalized list of substrates acted upon by respective enzymes is given bellow:

Lipids by lipases and phospholipases;
Proteins by proteases;
Polysaccharides by glycosidases;
Nucleic acids by nucleases;
Phosphates (organic-linked) by phosphatases;
Sulphates (organic-linked) by sulfatases.

Peroxisomes

Peroxisomes are found in virtually all mammalian cell types and probably arise from swellings of the endoplasmic Reticulum. These structures are often smaller than lysosomes. These enzymes they possess are active in the production of hydrogen peroxide (urate oxidase, D-amino acid oxidase, α-hydroxyacid oxidase), and one

functions in destroying hydrogen peroxide (catalase). The peroxisomes function in purine catabolism and in the degradation of nucleic acids.

Nucleus

The nucleus was first described by Robert Brown in 1831. The nucleus is surrounded by a double layer of the typical trilaminar membrane which is pierced by small pores. The pores measure about 50-80 nm in diameter.The pores allow and serve in the interchange of nuclear and cytoplasmic material.
Aproximate composition of the nucleus:
80% protein, 15% DNA, 5% RNA, 3% lipid.

Functions: Simply speaking, the nucleus controls the metabolic aspects of the cell and is responsible for its structural integrity, function, survival and passage of the hereditary material to the next generation.

DNA Structure, *DNA*-deoxyribonucleic acid – is a nucleic acid. A nucleic acid is a polymer of nucleotides. The combination of *purine* or *pyrimidine* base, a sugar, and phosphoric acid is called a *nucleotide. Deoxyrobose* is the sugar in DNA; ribose is the other nucleic acid, ribonucleic acid, or RNA.

DNA molecules are composed of two nucleotide strands coiled together in a double helix. Watson and Crick (1953) proposed a double helix model of DNA. The two strands consist of sugar-phosphate backbones which are connected by pairs of bases.All DNA nucleotides consist of a 5-carbon sugar (deoxyribose) with a phosphate group attached at one end and a nitrogen-containing ring compound (the base) at the other. The nitrogenous bases are: adenine and guanine (*purines*) and

thymine, cytosine, and uracil (*pyrimidines).* In DNA they pair specifically in the following manner:
Adenine and Thymine …….Guanine and Cytosine.

RNA pair as follows:
Adenine and Uracil ……Guanine and Cyrosine.
The paired bases are held together by hydrogen bonds.

CHARACTERISTICS OF DNA AND RNA

DNA	RNA
Double stranded	Single stranded (mainly)
Sugar-deoxyribose	Sugar- ribose
Base- thymine	Base- uracil

DNA determines and acts as a template for RNA synthesis. With the help of a transcription enzyme (RNA polymerase) a complementary RNA strand is produced. The base pairings are as follows:
DNA T-thymine, C-cytosine
RNA A-adenine, G-guanine.

Once RNA has been manufactured in the nucleus it moves fairly quickly into the cytoplasm.

Messenger RNA (mRNA) from the nucleus brings the coded message for protein synthesis to ribosomal RNA (rRNA). Ribosomal RNA imparts the message to *transfer RNA* (Trna), which carries the specific amino acids coded for to the ribosomes, where protein synthesis is carried out.

Chromatin. The survivor of the cell, organism, and species depends upon the chromatin material in the nucleus. Chromatin is DNA combined with protein, and stains with basic dyes. During the interphase of the cell cycle some chromosomes are visualized as tight coils and are referred to as *heterochromatin*.

Ribosomes and Polysomes: Ribosomes may be free or attached to the membranes of the endoplasmic Reticulum, which is then designated as rough ER. Ribosomes are the sites of protein synthesis in the cell. If ribosomes appear in clusters (rosettes) in the cytoplasm, they are commonly termed *polyribosomes* or *polysomes*.

Ribosomes possess RNA known as ribosomal RNA (rRNA) and both rRNA and messenger RNA (mRNA) are produced on DNA templates in the nucleus.

Microtubules: These structures are usually associated with centrioles and basal bodies. They are also present in the cytoplasm of various cells, in particular the axons of neurons. Microtubules apparently function in the maintenance of the structural integrity (shape and rigidity) of the cell. Transport of material and movement of cilia and flagella are also ascribed to these organelles.

Microfilaments: These structures are prominent in the microvilli of the absorptive cells of the intestines. They have been shown to be associated with the regions of the terminal web and the desmosome.

Centrioles, Cilia and Flagella: The centrioles are self-reproducing organelles that play an important role in the separation of the

chromosomes during mitosis. Before division of the cell the centriole splits into two and the daughter centrioles migrate to opposite sides of the nucleus. The form the center of the *spindle* and *aster* configuration during cell division.

Organelles almost identical in structure to the centriole are the basal bodies of cilia and flagella. The structure and function of cilia and flagella are similar. They, like the centriole, have nine (9) sets of tubules arranged in a peripheral cylinder; the sets, however, are doublets, not triplets. And unlike centrioles, cilia and flagella have an additional pair of central tubules. Therefore, we can summarize the arrangement in centrioles as 9 + 0-, and in cilia and flagella as 9 + 2.

Cell Division – Mitosis

For purposes of convenience, mitosis is divided into prophase, metaphase, anaphase, and telophase; the process, however, is a continuous one. The major events during the phases are:

1. *Prophase:* Chromosomes become distinct and nucleolus (nucleoli) disappear(s); centriole(s) and asters and spindle appear; nuclear membrane disappears.

2. *Metaphase*: Chromosomes move to the equator of the cell and duplicate.

3. Anaphase: The two chromatids split apart and start migration toward the poles of the spindle; the spindle loses its definition.

4. *Telophase:* Chromosomes lengthen and become less distinct; nucleoli reappear. The next period of growth and rest is known as *interphase*.

5. *Interphase:* Cell growth; protein synthesis; DNA synthesis; chromosome duplication.

Methods of Examining the Cell

1. Histological Methods:

a. *Microscopy*
b. *Stains*

2. Histochemical Methods: Tissues are composed of various chemicals such as proteins, carbohydrates, lipids, inorganic salts and miscellaneous substances, and various tests are used to detect these chemicals.

Examples:

PROTEINS (WITH TYROSINE) – YELLOW COLOR;

1) Enzymes – various tests for phosphatases, lipases, oxidases, exterases, and dehydrogenases;
2) Carbohydrates – glycogen by periodic acid Schiff (PAS) test results in a magenta or purple color; glycolproteins give a positive PAS magenta color. Basal laminae and reticular fibers are strongly PAS positive;
3) Lipids – Sudan dyes or osmic acid;

4) Nucleic acids – Feulgen reaction is specific for DNA, but not for RNA, which can be detected by ribonuclease. Both DNA and RNA are basophilic (because they are both acids).

3. Fixation: The fixative must modify the cell to resist further treatments and also to make further treatments possible. Fixatives may be classified as either coagulant or non-coagulant. Examples of each are:

1) *coagulant:* methanol, ethanol, acetone, nitric acid, hydrochloric acid, picric acid, trichloroacetic acid and mercuric chloride.
2) *non*-coagulant: formaldehyde, glutaraldehyde, osmium tetroxide, potassium dichromate, acetic acid, and potassium permanganate.

Fixatives can also be sub classified into two categories. The following are examples:

1) *additive:* osmium tetroxide, formaldehyde, and glutaraldehyde.
2) *Non-additive:* methanol, ethanol, and acetone.

4. Method of Preparation

1) *Fixation*
2) *Dehydration*
3) *Embedding*
4) *Sectioning*
5) *Staining*

Eukaryotic vs. prokaryotic Cell Structure

Eukaryotes: All higher animals and plants, as well as protozoa, are eukaryotes, and their cells possess the following characteristics:

1. A nucleus surrounded by a nuclear membrane (nucleolemma)
2. Discrete chromosomes that are present in the nucleus and undergo reduplication.
3. DNA, and DNA synthesis as a mode of duplication.
4. Cellular metabolites such as protein, RNA, vacuoles, ribosomes, and mitochondria in the cytoplasm.
5. Cilia and flagella that possess the basic structure of two inner fibrils surrounded by nine outer ones. (flagella of eukaryotic and prokaryotic organisms are structurally different.)

In addition, most eukaryotic cells are surrounded by a lipoprotein cell membrane; some also possess a cell wall (plants).

Prokaryotes: Bacteria (and blue-green algae) are the organisms which make up this important category. They possess the following characteristics:

1. The nucleus or nucleoid consists mostly of DNA and is never enveloped by a nuclear membrane.
2. In the cytoplasm vacuoles and mitochondria are absent. Many of the reactions that take place in the mitochondrion of the eukaryotic cell are carried out by the prokaryotic cell membrane.
3. Cytoplasmic granules which store carbohydrates, lipids, or volutin, (polymetaphosphate) are present.
4. Ribosomes are present.

5. A cell membrane surrounds the cytoplasm; however, unlike the eukaryotic cell membrane, it lacks sterols and is made up only of phospholipids and protein.
6. A ell wall giving integrity to the organism is present.
7. A polysaccharide-polypeptide capsule is also laid down outside the cell wall.
8. Flagella, if present are different than that of eukaryotes. Each flagellum consists of a single fi9bril (not the typical 11 axial fibrils) which originates from a basal granule of the Cytoplasmic membrane.
9. They may produce spores (endospores) which are thick and may protect them during unfavorable conditions.

Reproduction and Genetics in Eukaryotes and Prokaryotes:

Genetic stability in eukaryotes and prokaryotes is compatible. Frequency of mutations is the same. Eukaryotes introduce changes via sexual reproduction (combination of gametes). Sexual reproduction *per* se does not occur in prokaryotes. However, three very effective processes do result in the mixing of genetic material, they are:

Transformation. DNA released from a donor cell into a medium is taken up and incorporated by a recipient cell; it results in the replacement of part of the cell's genetic material.
Conjugation. Genetic material is transferred from one bacterium to another via a conjugation bridge.
Transduction. Genetic material is transferred from one bacterium to another via a bacteriophage (a bacterial virus).

Classification of Living Organisms

Taxonomy is the classification of living organisms based on characteristics and ancestry. Two *kingdoms*—animal and plant—are easily distinguished. In general, members of the former consume food and are mobile while those of the latter are stationary and produce their own nutrients.

Below is one of many ways to classify living things. They are classified into five kingdoms based on (1) the presence (eukaryotic) or absence (prokaryotic) of membrane-bound nuclei in the cells; (2) the number of cells forming the organism, and (3) the mechanism for nutrition.

FIVE-KINGDOM CLASSIFICATION SYSTEM		
Kingdom	**Characteristics**	**Examples**
Monera	Unicellular without organized nuclei; absorb or produce their own nutrients	Bacteria, blue-green algae
Protista	Unicellular with membrane-bound nuclei; ingest, absorb or produce nutrients via photosynthesis	Protozoans, algae
Fungi	Multicellular with membrane-bound nuclei; absorb nutrients	Mushrooms, molds
Plants	Multicellular with membrane-bound nuclei and a cell wall; possess chlorophyll and undergo photosynthesis	Flowering plants and

Animals	Multicellular with membrane-bound nuclei; ingest nutrients	trees; evergreens Mammals, birds, amphibians, fish, reptiles, insects, crustaceans, etc.

These kingdoms can be divided into three main groups based on the mode of nutrition-photosynthetic organisms (plants and algae), organisms which absorb their nutrients (bacteria and fungi), and organisms which engulf or ingest their nutrients (protozoa and animals).

Each kingdom is further divided into phyla → classes → families → genera → species. A human being is classified below:

CLASSIFICATION OF THE HUMAN

Classification Group		Distinguishing Features
Kingdom	Animalia	Consume food and are mobile
Phylum	Chordata	Notochord, hollow nervous system (neural tube) dorsally positioned, gill slits in pharyngeal wall, heart ventral to digestive

		system
Subphylum	Mammalia	
		Segmental vertebral column
Class	Vertebrata	
		Mammary glands for nourishment of young; hair or fur; warm-blooded; diaphragm
Order	Primates	
		Large cerebral hemispheres; opposable digits; nails; highly developed sense of sight—eyes directed forward; teeth
Family	Hominidae	specialized for different functions
		Walk with two limbs (bipedal locomotion);
Genus	Homo	binocular color vision
		Ability to speak and most highly developed
Species	sapiens	and largest brain
		Large skull, high forehead, reduced size of brow (supraorbital) ridges, prominent chin; decreased amount of body hair

Organization of the Human Body

A multicellular organism is composed of millions of cells organized into functional units (organs and systems) which are formed by various groups of similar cells (tissues) working together. These cells are embedded in intercellular substances and tissue fluids. A *tissue*

consists of a group of cells performing a similar function. Four basic tissues compose the human (mammalian) body; epithelium, connective tissue, muscle and nerve tissues. The four basic tissues may be organized to form functional units known as *organs*. Several organs which function together as a unit for a specified purpose make up an organ *system*.

Organ Systems

The human body is composed of the systems listed in the following table.

ORGAN SYSTEMS IN THE HUMAN

System	Functions
Muscular	Produces motion of body parts and viscera
Skeletal	Supports the body, protects organs and produces blood cells
Circulatory	Transports nutrients, wastes, gases (oxygen and carbon dioxide), hormones, blood cells throughout body; also protects body against foreign organisms
Nervous	Responds to internal and external stimuli; regulates and coordinates body activities and movements
Integumentary	Limits and protects the body as a whole; prevents excess loss of water and functions in regulating body temperature
Digestive	

Respiratory	Enzymatically breaks down food materials into usable and absorbable nutrients
Urinary	Functions in the exchange of gases (oxygen and carbon dioxide)
Reproductive	Removes body wastes from blood stream and helps regulate homeostasis of internal environment
Endocrine	Perpetuates the living organism by the production of sex cells (gametes) and future offsprings
	Regulates body growth and function via hormones

Four Basic Tissues

1. **Muscle Tissue:** Muscle tissue is contractile in nature and functions to move the skeletal system and body viscera.

TYPES OF MUSCLE

Type	Characteristics	Location
Skeletal	Striated, voluntary	Skeletal muscles of the body
Smooth	Non-striated, involuntary	Walls of digestive tract and blood vessels, uterus, urinary bladder
Cardiac	Striated, involuntary	heart

2. **Nervous Tissue:** Nervous tissue is composed of cells (*neurons*) that respond to external and internal stimuli and have the capability to transmit a message (*impulse*) from one area of the body to another. This tissue thus induces a response of distant muscles or glands, as well as regulating body processes such as respiration, circulation, and digestion.

3. **Epithelial Tissue:** Epithelial tissue covers the external surfaces of the body and lines the internal tubes and cavities. It also forms the glands of the body. Characteristics of epithelial tissue (epithelium) are that it

   (1) has compactly aggregated cells;
   (2) has limited intercellular spaces and substance;
   (3) is avascular (no blood vessels);
   (4) lies on a connective tissue layer—the basal lamina;
   (5) has cells that form sheets and are polarized;
   (6) is derived from all three germ layers.

TYPES OF EPITHELIUM

Classification	Location(s)	Function(s)
Simple squamous epithelium	Endothelium of blood and lymphatic vessels; Bowman's capsule and thin loop of Henle in kidney; mesothelium lining pericardial, peritoneal and pleural body cavities; lung alveoli; smallest excretory ducts of glands	Lubrication of body cavities (permits free movement of organs); pinocytotic transports across cells
Stratified squamous keratinized epithelium	Epidermis of skin	Prevents loss of water and protection
Stratified squamous nonkeratinized epithelium (moist)	Mucosa of oral cavity, esophagus, anal canal; vagina; cornea of eye and part of conjunctiva	Secretion; protection; prevents loss of water
Simple cuboidal epithelium	Kidney tubules; choroids plexus; thyroid gland; rete testis; surface of ovary	Secretion; absorption; lines surface
Stratified cuboidal epithelium		Secretion; protection

Simple columnar epithelium	Ducts of sweat glands; developing follicles of ovary	Secretion; absorption; protection; lubrication
Pseudostratified columnar epithelium	Cells lining lumen of digestive tract (stomach to rectum); gall bladder; many glands (secretory units and ducts); uterus; uterine tube (ciliated)	Secretion; protection; facilitates transport of substances on surface of cells
Stratified columnar epithelium	Lines lumen of respiratory tract (nasal cavity, trachea and bronchi) (cliliated); ducts of epididymis (stereocilia); ductus deferens; male urethra	Protection
Transitional epithelium	Male urethra; conjunctiva	Protection

	Urinary tract (renal calyces and pelvis, ureter and urinary bladder)	

Epithelial cells may also have specializations at the cell surface. For example,

Microvilli—fingerlike projections of plasma membranes.
Cilia—motile organelles extending into the luman consisting of specifically arranged microtubules.
Flagella—similar to cilia. Primary examples are human spermatozoa.
Stereocilia—are actually very elongated Microvilli.

4. **Connective Tissue:** Connective tissue is the packing and supporting material of the body tissues and organs. It develops from mesoderm (mesenchyme). All connective tissues consist of three distinct components: ground substance, cells and fibers.

a) *Ground substance*. Ground substance is located between the cells and fibers, both of which are embedded in it. It forms an amorphous intercellar material. In the fresh state, it appears as a transparent and homogenous gel. It acts as a route for the passage of nutrients and wastes to and from the cells within or adjacent to the connective tissue.

b) *Fibers.* The fiber components of connective tissue add support and strength. Three types of fibers are present: *collagenous*, *elastic* and *reticular.*

Collagen fibers (white fibers) are the most numerous fiber type and are present in all types of connective tissue in varying amounts. Collagen bundles are strong and resist stretching. They are found in structures such as tendons, ligaments, aponeuroses and fascia, which are subjected to pull or stretching activities.

Elastic fibers (yellow fibers) are refractile fibers which are thinner (0.2 to 1 μm diameter) than collagen fibers. They are extremely elastic and are located in structures with a degree of elasticity, such as the walls of blood vessels (elastic arteries), true vocal cords and trachea.

Reticular fibers are thinner (0.2 to 1 μm diameter) than collagenous fibers. They are arranged in an intermeshing network (reticulum) which supports the organ. Reticular fibers are inelastic. They are found in the walls of blood vessels, lymphoid tissues (spleen and lymph nodes), red bone marrow, basal laminae and glands (liver and kidney).

c) *Cells*. The *cells* of connective tissue are primarily attached and non-motile (*fixed cells*), but some have the ability to move (*wandering or free cells*). The typical cells found in connective tissue are:

Fibroblasts constitute the largest number of cells present in connective tissue. In an actively secreting state, they are flattened stellate-shaped cells with an oval nucleus and basophilic cytoplasm due to the

numerous rough endoplasmic reticulum. In the inactive state, they are referred to as *fibrocytes*.

Mesenchymal cells are undifferentiated connective tissue cells which have the potential to differentiate into other types of connective tissue cells. They are primarily found in embryonic and fetal tissues; some are thought to be present in the adult abutting the walls of capillaries. They are smaller than fibroblasts and are stellate in shape.

Macrophages (histiocytes) may be fixed or free. Free macrophages may wander through the connective tissue by extending their cell processes. Fixed mcrophages are very numerous in loose connective tissue.

Adipocytes (fat cells) are found in most connective tissue, either singly or in groups. If the connective tissue layer is primarily composed of fat cells, it is referred to as adipose tissue. An adipocyte is a round, large cell with a distinct, dense nucleus usually located at the periphery of the cytoplasm.

Mast cells are ovoid cells with small round nuclei. The cytoplasm contains numerous coarse basophilic granules which also stain metachromatically and are soluble in water. The mast cell granules are composed of *histamine* and an anticoagulant known as *heparin*.

Plasma cells have a characteristic eccentric nucleus which contains chromatin arranged in a definite pattern near the nuclear envelope. This pattern gives a "cartwheel or spoke wheel" appearance. The

juxtanuclear cytoplasm appears clear and less basophilic due to the Golgi complex located in this area.

Reticular cells are star-shaped cells which join via their processes to form a cellular network. They are found abutting reticular fibers in certain glands and lymphoid tissues.

Pericytes are located in the adventitia of blood vessels. They are believed to be tipotential cells which may differentiate into various connective tissue cells as well as into smooth muscle cells.

White blood cells or leukocytes. Certain white blood cells migrate out of the blood into the extracellular ground substance. The main leukocytes found in the connective tissue are lymphocytes, monocytes, eosinophils, basophils and neutrophils. The leukocytes in connective tissue are similar in structure and function to those in the blood.

Skeletal System

The skeletal system of vertebrates is an *endoskeleton*—that is, it is within the body—as compared to an *exoskeleton* characteristic of arthropods. The human skeletal system provides:

(1) support
(2) protection of vital organs
(3) sites for muscle attachment
(4) storage site of body calcium and phosphates
(5) sites for blood cell formation

The *human skeleton* consists of bone and cartilage. The bones form the main rigid structure of the skeleton. The human skeleton consists of about 206 bones, some of which are fused while others are joined together at sites which permit various degrees of movement. The sites of junction, or articulation, whether movable or immovable, are known as *joints*.

The human skeleton is divided into an *axial skeleton* and an *appendicular skeleton*.

Axial Skeleton

The axial skeleton consists of 80 bones forming the trunk (spine and thorax) and skull.

Vertebral Column: The main trunk of the body is supported by the spine, or vertebral column, which is composed of 26 bones, some of

which are formed by the fusion of a few bones. The vertebral column from superior to inferior consists of 7 cervical (neck), 12 thoracic and 5 lumbar vertebrae, as well as a sacrum, formed by fusion of 5 sacral vertebrae, and a coccyx, formed by fusion of 4 coccygeal vertebrae.

Ribs and Sternum: The axial skeleton also contains 12 pairs of *ribs* attached posteriorly to the thoracic vertebrae and anteriorly either directly or via cartilage to the *sternum* (breastbone). The ribs and sternum form the *thoracic cage*, which protects the heart and lungs. Seven pairs of ribs articulate with the sternum (*fixed ribs*) directly, and three do so via cartilage; the two most inferior pairs do not attach anteriorly and are referred to as *floating ribs*.

Skull: The skull consists of 22 bones fused together to form a rigid structure which houses and protects organs such as the brain, auditory apparatus and eyes. The bones of the skull form the *face* and *cranium* (brain case) and consist of 6 single bones (*occipital, frontal, ethmoid, sphenoid, vomer* and *mandible*) and 8 paired bones (*parietal, temporal, maxillary, palatine, zygomatic, lacrimal, inferior concha* and *nasal*). The *lower jaw* or *mandible* is the only movable bone of the skull (head); it articulates with the temporal bones.

Other Parts: Other bones considered part of the axial skeleton are the *middle ear bones* (*ossicles*) and the small U-shaped *hyoid bone* that is suspended in a portion of the neck by muscles and ligaments.

Appendicular Skeleton

The *appendicular skeleton* forms the major internal support of the appendages—the *upper* and *lower extremities* (limbs).

Pectoral Girdle and Upper Extremities: The arms are attached to and suspended from the axial skeleton via the *shoulder* (*pectoral*) *girdle*. The latter is composed of two *clavicles* (*collarbones)* and two *scapulae* (*shoulder blades*). The clavicles articulate with the sternum; the two *sternoclavicular joints* are the only sites of articulation between the trunk and upper extremity.

Each upper limb from distal to proximal (closest to the body) consists

Each upper limb from distal to proximal (closest to the body) consists of hand, wrist, forearm and arm (upper arm). The *hand* consists of 5 *digits* (fingers) and 5 *metacarpal* bones. Each digit is composed of three bones called *phalanges*, except the thumb which has only two bones.

Pelvic Girdle and Lower Extremities: The lower *extremities*, or legs, are attached to the axial skeleton via the *pelvic* or *hip girdle*. Each of the two coxal, or *hip bones* comprising the pelvic girdle is formed by the fusion of three bones—*illium*, *pubis*, and *ischium*. The coxal bones attach the lower limbs to the trunk by articulating with the sacrum.

THE HUMAN SKELETAL SYSTEM	
Part of the Skeleton	**Number of Bones**
Axial Skeleton	80
Skull	22
Ossicles (malleus, incus and stapes)	6
Vertebral column	26
Ribs	24
Sternum	1
Hyoid	1
Appendicular Skeleton	126
Upper extremities	64
Lower extremities	62

Characteristics of Bone

Bone is a specialized type of connective tissue consisting of cells (*osteocytes*) embedded in a calcified matrix which gives bone its characteristic hard and rigid nature. Bones are encased by a *periosteum*, a connective tissue sheath. All bone has a central marrow cavity. *Bone marrow* fills the marrow cavity or smaller marrow spaces, depending on the type of bone.

Types of Bone: There are two types of bone in the skeleton: *compact bone* and *spongy* (cancellous) bone.

Compact Bone. Compact bone lies within the periosteum, forms the outer region of bones, and appears dense due to its compact organization. The living osteocytes and calcified matrix are arranged in

layers, or *lamellae*. Lamellae may be circularly arranged surrounding a central canal, the *Haversian canal*, which contains small blood vessels.

Spongy Bone. Spongy bone consists of *bars, spicules* or *trabeculae*, which forms a lattice meshwork. Spongy bone is found at the ends of long bones and the inner layer of flat, irregular and short bones. The trabeculae consist of osteocytes embedded in calcified matrix, which in definitive bone has a lamellar nature. The spaces between the trabeculae contain bone marrow.

Bone Cells: The cells of bone are osteocytes, osteoblasts, and osteoclasts. *Osteocytes* are found singly in *lacunae* (spaces) within the calcified matrix and communicate with each other via small canals in the bone known as *canaliculi*. The latter contain osteocyte cell processes. The osteocytes in compact and spongy bone are similar in structure and function.

Osteoblasts are cells which form bone matrix, surrounding themselves with it, and thus are transformed into osteocytes. They arise from undifferentiated cells, such as mesenchymal cells. They are cuboidal cells which line the trabeculae of immature or developing spongy bone.

Osteoclasts are cells found during bone development and remodeling. They are multinucleated cells lying in cavities, *Howship's lacunae*, on the surface of the bone tissue being resorbed. Osteoclasts remove the existing calcified matrix releasing the inorganic or organic components.

Bone Matrix: *Matrix* of compact and spongy bone consists of collagenous fibers and ground substance which constitute the organic

component of bone. Matrix also consists of inorganic material which is about 65% of the dry weight of bone. Approximately 85% of the inorganic component consists of calcium phosphate in a crystalline form (hydroxyapatite crystals). Glycoproteins are the main components of the ground substance.

MAJOR TYPES OF HUMAN BONES

Type of Bone	Characteristics	Examples
Long bones	Width less than length	Humerus, radius, ulna, femur, tibia
Short bones	Length and width close to equal in size	Carpal and tarsal bones
Flat bones	Thin flat shape	Scapulae, ribs, sternum, bones of cranium (occipital,
Irregular bones	Multifaceted shape	frontal, parietal) Vertebrae, sphenoid,
Sesamoid	Small bones located in tendons of muscles	ethmoid ---

Joints

The bones of the skeoeton articulate with each other at *joints*, which are variable in structure and function. Some joints are immovable, such as the *sutures* between the bones of the cranium. Others are *slightly movable joints*; examples are the *intervertebral joints* and the *pubic symphysis* (joint between the two pubic bones of the coxal bones).

TYPES OF JOINTS

Joint Type	Characteristic	Example
Ball and socket	Permits all types of movement (abduction, adduction, flexion, extension, circumduction); it is considered a universal joint.	Hips and shoulder joints
Hinge (ginglymus)	Permits motion in one plane only	Elbow and knee, interphalangeal joints
Rotating or pivot	Rotation is only motion permitted	Radius and ulna, atlas and axis (first and second cervical vertebrae)
Plane or gliding	Permits sliding motion	Between tarsal bones and carpal bones
Condylar (condyloid)		

	Permits motion in two planes which are at right angles to each other (rotation is not possible)	Metacarop-phalangeal joints, temporomandibular

Adjacent bones at a joint are connected by fibrous connective tissue bands known as *ligaments*. They are strong bands which support the joint and may also act to limit the degree of motion occurring at a joint.

Muscular System

Classification

A muscle cell not only has the ability to propagate an action potential along its cell membrane, as does a nerve cell, but also has the internal machinery to give it the unique ability to contract.

Most muscles in the body can be classified as striated muscles in reference to the fact that when observed under a light microscope the muscular tissue has light and dark bands or striations running across it. Although both skeletal and cardiac muscles are striated and therefore have similar structural organizations, they do possess some characteristic functional differences.

In contrast to skeletal muscle, cardiac muscle is a functional syncytium. This means that although anatomically it consists of individual cells the entire mass normally responds as a unit and all of the cells contract together. In addition, cardiac muscle has the property of automaticity which means that the heart initiates its own contraction without the need for motor nerves.

Non-striated muscle consists of multi-unit and unitary (visceral) smooth muscle. Visceral smooth muscle has many of the properties of cardiac muscle. To some extent it acts as a functional syncytium (e.g., areas of intestinal smooth muscle will contract as a unit. Smooth muscle is part of the urinary bladder, uterus, spleen, gallbladder, and numerous other internal organs. It is also the muscle of blood vessels, respiratory tracts, and the iris of the eye.

Skeletal Muscles

In order for the human being to carry out the many intricate movements that must be performed, approximately 650 skeletal muscles of various lengths, shapes, and strength play a part. Each muscle consists of many muscle cells or fibers held together and surrounded by connective tissue that gives functional integrity to the system. Three definite units are commonly referred to:

(1) endomysium—connective tissue layer enveloping a single fiber;
(2) perimysium—connective tissue layer enveloping a bundle of fibers;
(3) epimysium—connective tissue layer enveloping the entire muscle

Muscle Attachment and Function

For coordinated movement to take place, the muscle must attach to either bone or cartilage or, as in the case of the muscles of facial expression, to skin. The portion of a muscle attaching to bone is the tendon. A muscle has two extremities, its origin and its insertion.

Terms to Describe Movement

Flexion is bending, most often ventrally to decrease the angle between two parts of the body; it is usually an action at an articulation or joint.

Extension is straightening, or increasing the angle between two parts of the body; a stretching out or making the flexed part straight.

Abduction is a movement away from the midsagittal plane (midline); to adduct is to move medially and bring a part back to the mid-axis.

Circumduction is a circular movement at a ball and socket (shoulder or hip) joint, utilizing the movements of flexion, extension, abduction, and adduction.

Rotation is a movement of a part of the body around its long axis.

Supination refers only to the movement of the radius around the ulna. In supination the palm of the hand is oriented anteriorly; turning the palm dorsally puts it into pronation. The body on its back is in the supine position.

Pronation refers to the palm of the hand being oriented posteriorly. The body on its belly is the prone position.

Inversion refers only to the lower extremity, specifically the ankle joint. When the foot (plantar surface) is turned inward, so that the sole is pointing and directed toward the midline of the body and is parallel with the median plane, we speak of inversion. Its opposite is eversion.

Eversion refers to the foot (plantar surface) being turned outward so that the sole is pointing laterally.

Opposition is one of the most critical movements in humans; it allows us to have pulp-to-pulp opposition, which gives us the great dexterity of our hands. In this movement the thumb pad is brought to a finger pad. A median nerve injury negates this action.

Muscle Names

1. Position and Location

a. Pectoralis major and minor…….pectoral region of thorax; major is larger
b. Temporalis……..temporal region of head
c. Infra-and supraspinatus……..below and above spine of scapula
d. External and internal intercostals……intercostals spaces

2. Principal Action:

a. pronators (e.g., pronator quadratus) refers to palm down and supinator to palm up; quadratus refers to the shape
b. Flexors and extensors (e.g., flexor……..flexors and extensors of digits and extensor digitorum)
c. Levator scapulae…….elevator of the scapula (shoulder)

3. *Shape:*

a. Trapezius……trapezoid in shape
b. Rhomboid major and minor……rhomboid in shape

4. *Number of Divisions (Heads) and Position:*

a. Biceps brachii…….two-headed muscle in anterior brachium
b. Triceps brachii……three-headed muscle in posterior brachium

5. *Size, Length, and Shape:*

a. Flexor pollicis longus and brevis……long and short flexors of the thumb
b. Rhomboid major and minor……major is larger in size; rhomboid in shape

6. Attachment Sites:

a. Sternocleidomastoid …… …extends from sternum and clavicle to
Mastoid process

b. Sternohyoid……extends from sternum to hyoid bone

Structural Organization of a Muscle Fiber

A muscle fiber is a single muscle cell. If we look at a section of a fiber we see that it is complete with a cell membrane called the sarcolemma and has several nuclei located just under the sarcolemma—it is multinucleated. Each fiber is composed of numerous cylindrical fibrils running the entire length of the fiber.

Myofilaments

The thick and thin myofilaments form the contractile machinery of muscle and are made up of proteins. Approximately 54% of all the contractile proteins (by weight) is myosin. The thick myofilament is composed of many myosin molecules oriented tail-end to tail-end at the center with myosin molecules staggered from the center to the myofilament tip. The second major contractile protein is actin. Actin is a globular protein.

Sarcoplasm

The sarcoplasm (cytoplasm of the muscle cell) contains Golgi complexes near the nuclei. Mitochondria are found between the myogibrils and just below the sarcolemma. The myofibrils are surrounded by smooth endoplasmic reticulum (*sarcoplasmic reticulum*) composed of a longitudinally arranged tubular network (*sarcotubules*).

The complex (terminal cistern-T tubule-terminal cistern) formed at this position is known as a *triad*. The T tubules function to bring a wave of depolarization of the sarcolemma into the fiber and thus into intimate relationship with the terminal cisternae.

Excitation

Contraction in a skeletal muscle is triggered by the generation of an action potential in the muscle membrane. Each motor neuron upon entering a skeletal muscle loses its myelin sheath and divides into branches with each branch innervating a single muscle fiber, forming a *neuromuscular junction*. Each fiber normally has one neuromuscular junction which is located near the center of the fiber. A *motor unit* consists of a single motor neuron and all the muscle fibers innervated by it. The *motor end plate* is the specialized part of the muscle fiber's membrane lying under the neuron.

Contraction

According to the sliding filament theory (Huxley) the sacromere response to excitation involves the sliding of thin and thick myofilaments past one another making and breaking chemical bonds with each other as they go. Neither the thick nor thin myofilaments change in length. If we could imagine observing this contraction under a light microscope we would see the narrowing of the "H" and "I" bands during contraction while the width of the "A" band would remain constant.

Muscle Twitch

A muscle's response to a single maximal stimulus is a *muscle twitch*. The beginning of muscular activity is signaled by the record of the *electrical activity* in the sarcolemma. The *latent period* is the delay between imposition of the stimulus and the development of tension.

Tetanus

When a volley of stimuli is applied to a muscle, each succeeding stimulus may arrive before the muscle can completely relax from the contraction caused by the preceding stimulus. The result is *summation*, an increased strength of contraction. If the frequency of stimulation is very fast, individual contractions fuse and the muscle smoothly and fully contracts. This is a *tetanus*.

Energy Sources

In any phenomenon including muscular contraction the energy input to the system and the energy output from the system are equal. Let us consider first the energy sources for muscular contraction. The immediate energy source for contraction is ATP which can be hydrolyzed by actomyosin to give ADP, P_i , and the energy which is in some way associated with cross-bridge motion.

Types of Muscle Fibers

Skeletal muscle fibers can be described, on the bases of structure and function, as follows:

1. *White (fast) fibers* – contract rapidly; fatigue quickly; energy production is mainly via anaerobic glycolysis; contain relatively few mitochondria; examples are the muscles of the eye.
2. *Red (slow) fibers* – contract slowly; fatigue slowly; energy production is mainly via oxidative phosphorylation (aerobic); contain relatively many mitochondria; examples are postural muscles.
3. *Intermediate fibers* – have structural and functional qualities between those of white and of red fibers.

Circulatory System

Functions

The circulatory system serves:

(1) to conduct nutrients and oxygen to the tissues;
(2) to remove waste materials by transporting nitrogenous compounds to the kidneys and carbon dioxide to the lungs;
(3) to transport chemical messengers (hormones) to target organs and modulate and integrate the internal milieu of the body;
(4) to transport agents which serve the body in allergic, immune, and infectious responses;
(5) to initiate clotting and thereby prevent blood loss;
(6) to maintain body temperature;
(7) to produce, carry and contain blood;
(8) to transfer body reserves, specifically mineral salts, to areas of need.

General Components and Structure

The circulatory system consists of the heart, blood vessels, blood and lymphatics. It is a network of tubular structures through which blood travels to and from all the parts of the body. In vertebrates this is a completely closed circuit system, as William Harvey (1628) once demonstrated. The heart is a modified, specialized, powerful pumping blood vessel. Arteries, eventually becoming arterioles, conduct blood

to capillaries (essentially endothelial tubes), and venules, eventually becoming veins, return blood from the capillary bed to the heart.

Course of Circulation

Systemic Route:

a. *Arterial system*. Blood is delivered by the pulmonary veins (two from each lung) to the left atrium, passes through the bicuspid (mitral) valve into the left ventricle and then is pumped into the ascending aorta; backflow here is prevented by the aortic semilunar valves. The aortic arch toward the right side gives rise to the brachiocephalic (innominate) artery which divides into the right subclavian and right common carotid arteries. Next, arising from the arch is the common carotid artery, then the left subclavian artery.

The subclavians supply the upper limbs. As the subclavian arteries leave the axilla (armpit) and enter the arm (brachium), they are called brachial arteries. Below the elbow these main trunk lines divide into ulnar and radial arteries, which supply the forearm and eventually form a set of arterial arches in the hand which give rise to common and proper digital arteries. The descending (dorsal) aorta continues along the posterior aspect of the thorax giving rise to the segmental intercostals arteries. After passage "through" (behind) the diaphragm it is called the abdominal aorta.

At the pelvic rim the abdominal aorta divides into the right and left common iliac arteries. These divide into the internal iliacs, which

supply the pelvic organs, and the external iliacs, which supply the lower limb.

b. *Venous system*. Veins are frequently multiple and variations are common. They return blood originating in the capillaries of peripheral and distal body parts to the heart.

Hepatic Portal System: Blood draining the alimentary tract (intestines), pancreas, spleen and gall bladder does not return directly to the systemic circulation, but is relayed by the hepatic portal system of veins to and through the liver. In the liver, absorbed foodstuffs and wastes are processed. After processing, the liver returns the blood via hepatic veins to the inferior vena cava and from there to the heart.

Pulmonary Circuit: Blood is oxygenated and depleted of metabolic products such as carbon dioxide in the lungs.

Lymphatic Drainage: A network of lymphatic capillaries permeates the body tissues. Lymph is a fluid similar in composition to blood plasma, and tissue fluids not reabsorbed into blood capillaries are transported via the lymphatic system eventually to join the venous system at the junction of the left internal jugular and subclavian veins.

The Heart

The heart is a highly specialized blood vessel which pumps 72 times per minute and propels about 4,000 gallons (about 15,000 liters) of blood daily to the tissues. It is composed of:

Endocardium (lining coat; epithelium)

Myocardium (middle coat; cardiac muscle)
Epicardium (external coat or visceral layer of pericardium; epithelium and mostly connective tissue)
Impulse conducting system

Cardiac Nerves: Modification of the intrinsic rhythmicity of the heart muscle is produced by cardiac nerves of the sympathetic and parasympathetic nervous system. Stimulation of the sympathetic system increases the rate and force of the heartbeat and dilates the coronary arteries. Stimulation of the parasympathetic (vagus nerve) reduces the rate and force of the heartbeat and constricts the coronary circulation. Visceral afferent (sensory) fibers from the heart end almost wholly in the first four segments of the thoracic spinal cord.

Cardiac Cycle: Alternating contraction and relaxation is repeated about 75 times per minute; the duration of one cycle is about 0.8 second. Three phases succeed one another during the cycle:

a) atrial systole: 0.1 second,
b) ventricular systole: 0.3 second,
c) diastole: 0.4 second

The actual period of rest for each chamber is 0.7 second for the atria and 0.5 second for the ventricles, so in spite of its activity, the heart is at rest longer than at work.

Blood

Blood is composed of cells (corpuscles) and a liquid intercellular ground substance called plasma. The average blood volume is 5 or 6

liters (7% of body weight). Plasma constitutes about 55% of blood volume, cellular elements about 45%.

Plasma: Over 90% of plasma is water; the balance is made up of plasma proteins and dissolved electrolytes, hormones, antibodies, nutrients, and waste products. Plasma is isotonic (0.85% sodium chloride). Plasma plays a vital role in respiration, circulation, coagulation, temperature regulation, buffer activities and overall fluid balance.

Blood Cells: There are two types of blood cells: red blood cells (RBC), or erythrocytes, and white blood cells (WBC), or leukocytes. Cell fragments called blood platelets are also present in mammalian blood.

a) *Erythrocytes – RBC.* These cells are biconcave discs about 7.7 microns in diameter. Mature cells lack a nucleus.
b) *Leukocytes—WBC.* These cells differ from red blood cells by having nuclei and by exhibiting ameboid movement.

Non- or Agranular Leukocytes

1. *Lymphocytes* make up between 20 and 25% of total leukocytes and are seldom phagocytic.

2. *Monocytes* make up between 3 and 8% of total WBC. They are sometimes phagocytic and help in debridement.

Granular (possess abundant, specific granules) Leukocytes

1. *Neutrophilis* make up about 65-75% of leukocytes.

2. *Eosinophils* make up about 2-5% WBC.

3. *Basophils* make up 0.5% or less of the total white blood cell count.

c) *Blood platelets.* These Cytoplasmic structures are not true cells but are cell fragments characteristic of mammalian blood.

Blood clotting: Platelets contribute thromboplastin (thrombokinase), an enzymatically active substance. Thromboplastin interacts with calcium ions and prothrombin (a plasma protein).

Anticoagulants. An anticoagulant is a substance that prevents or retards coagulation of blood.

Blood Pressure: Blood pressure is usually measured by placing a sphygmomanometer cuff around the arm compressing the brachial artery and vein. Maximum blood pressure is obtained during ventricular contraction (systole) and minimum blood pressure indicated ventricular rest (diastole).

Respiratory System

The respiratory system is composed of a conduit for air and an air-blood interface for gaseous exchange in the alveoli of the lungs.

Removal of Inhaled Products

Large particles are filtered by hairs and mucous material in the nose and respiratory tract. Air is also warmed and humidified.

Pulmonary Ventilation

Respiration refers to the gaseous exchanges which occur between the body as a while and the environment.

Inspiration and Expiration

During inspiration the thoracic cavity expands, its volume increases and air rushes into the respiratory tract due to the creation of negative pressure; the musculature involved is the diaphragm. Normal expiration is passive and involves no great muscular contraction.

Positive and negative Pressure Breathing

Gases flow from regions of higher pressure to those of lower pressure. For inspiration to occur, the alveolar gas pressure must be less than the atmospheric pressure. Normal breathing is a form of negative pressure breathing.

Neuronal Control and Integration of Breathing

Normal spontaneous breathing is under control of motor neurons (primarily the phrenic nerves) which innervate the respiratory muscles. Brain impulses regulate and modulate the process. Voluntary activity originates in the cerebral cortex, automatic (autonomic) control rests in the pons and medulla of the brain.

Gas Exchange in the Alveoli

Gas exchange takes place only in the alveoli and not in the tracheobronchial tree. The diffusion pathway for alveolar gas may be listed as:

1) surfactant (lowers surface tension)
2) alveolar epithelium
3) interstitium (fused basement membranes)
4) capillary endothelium (epithelium)
5) plasma
6) red blood cells

Oxygen Transport

Oxygen is transported mainly in the form of oxyhemoglobin. Fully oxygenated blood can be calculated thus:

$$(15 \text{ g Hb}/100 \text{ ml blood}) \times (1.39 \text{ ml } O_2/\text{g Hb})$$

Four factors affect the affinity of hemoglobin for oxygen:

1) pH
2) temperature
3) concentration of 2,3-diphosphoglycerate (DPG)
4) carbon dioxide

Carbon Dioxide Transport

While some carbon dioxide remains in plasma, most diffuses into red blood cells. Bicarbonate ions produced in the red blood cells diffuse into the plasma because of the concentration gradient.

Chemical Regulation of Respiration

Chemical stimulants of physiological importance that affect respiration are:

1) increased arterial PCO_2 (hypercapnia),
2) decreased arterial PO_2 (hypoxia),
3) an increased arterial hydrogen-ion concentration (acidosis).

Urinary System

The urinary system helps maintain homeostasis of the body by excreting wastes and regulating the content of the blood. It consists of two kidneys, two ureters, a urinary bladder and a urethra.

Structure of the Kidney

The kidney is a bean-shaped organ encased by a fibrous capsule and embedded within a fatty connective tissue and perirenal fascia. The internal aspect of the kidney when bisected in a medial to lateral plane presents two zones, an outer *cortex* and an inner *medulla*.

The kidney is divided into functional *lobes*. The functional unit of the kidney is the *uriniferous tubule*, which consists of a *nephron* and a *collecting tubule* (duct) within the kidney. There are 1 to 3 million per kidney.

Nephron: The nephron is a tubular structure about 30 to 40 millimeters long and lined by epithelium. It functions in producing an ultrafiltrate and then reabsorbing material from and excreting substances into the filtrate resulting in an excretory product.

Collecting Tubules: The route for the filtrate and excretory product is from Bowman's space through the proximal convoluted tubule, descending thick and thin limbs of the loop of Henle, ascending thin and thick limbs, distal convoluted tubule and then into the collecting tubule. The latter unite and form 10-25 larger collecting ducts (papillary ducts of Bellini) which extend into the renal pyramids and terminate at the papillae.

Tubular Passageways

The *ureter* is a long muscular tube which connects the renal pelvis to the urinary bladder.
The *urinary bladder* is located in the pelvis superior and posterior to the pubic bone, anterior to the uterus in the female, anterior to the rectum in the male. The *urethra* is a fibromuscular tube that transmits urine to the outside of the body. It is continuous inferiorly with the urinary bladder.

Functions of the Kidney and Uriniferous Tubules

The kidney, during production of urine,

a) excretes the waste products of metabolism;
b) maintains the fluid volume of the extracellular regions of the body;
c) excretes foreign materials from the body;
d) regulates the type and concentration of salts retained in the body (maintain electrolyte balance);
e) regulates the total body water;
f) regulates the acid-base balance of the body.

The physiological processes occurring during the production of urine are

a) *filtration*—the production of an ultrafiltrate of plasma within Bowman's space;
b) *reabsorption*—the selective removal of material from the ultrafiltrate as it passes through the tubular nephron and the return of these substances into paritubular capillaries;
c) *secretion*—the cells forming the nephron actively secrete material into the filtrate;
d) *passive diffusion*—diffusion of fluids along the osmotic gradient.

Filtration: Filtration occurs at the renal corpuscles through the filtration barrier, which permits the passage of water and various solutes from the capillary lumen into Bowman's space but retains cells and large proteins.

Reabsorption: The isotonic ultrafiltrate enters the proximal convoluted tubules which are lined by cuboidal or low columnar epithelium with numerous apical microvilli (brush border). Major resorption of substances from the ultrafiltrate occurs, therefore, in the PCT and results in:

a) the active reabsorption of all the glucose;
b) the active reabsorption of 85% of the sodium chloride;
c) the passive diffusion, due to the osmotic gradient, of 85% of the water from the filtrate;
d) the active transport of all amino acids, ascorbic acid and proteins. (Protein is broken down to amino acids in phagolysosomes following pinocytosis at the apical microvillar border.)

Secretion: The cells of the proximal convoluted tubule also secrete creatinine into the tubular lumen, as well as materials foreign to the body, such as phenol red, antibiotics and various radiopaque dyes.

Passive Diffusion: The loop of Henle functions by setting up the mechanism (countercurrent multiplier system) in the renal medulla for the production of *hypertonic urine*.

Hormonal Control of More Secretion and Resorption

The simple cuboidal epithelium lining the distal convoluted tubule may also increase the Na^+ concentration in the interstitium by reabsorbing Na^+. At the same time, potassium ions (K^+) are excreted into the

tubular lumen. The latter processes are regulated by *aldosterone*, a hormone produced by the adrenal cortex. The distal convoluted tubules also participate in maintaining the acid-base balance of the blood by adding hydrogen and ammonium ions into the filtrate.

Integumentary (Skin) System

The skin and the specialized organs derived from the skin (hair, nails and glands) form the integumentary system.

Functions: The skin functions by surfacing the body and thus protecting it from dehydration as well as from damage by the elements in the external environment. The skin also helps maintain normal body activities.

Structure: Skin consists of the *epidermis* and *dermis* (*corium*). Deep to the dermis and therefore, the skin, is the *hypodermis*, which is also known as the *subcutaneous* or superficial connective tissue of the body.

Epidermis: The epidermis is derived from the ectoderm and is composed of a keratinized stratified squamous epithelium. *Thick skin* denotes skin with a thicker epidermis which contains more cell layers when compared to *thin skin*. The epidermis ranges in thickness from 0.07 millimeter to 1.4 millimeters. The epidermis consists of specific cell layers:

1. stratum basale or germinativum
2. stratum spinosum

3. stratum granulosum
4. stratum lucidum
5. stratum corneum

Glands

Glands are specialized organs derived from skin. There are two basic types: sebaceous and sweat.

Sebaceous Glands: Sebaceous glands are *simple branched alveolar* (*acinar*) *glands* with a *holocrine* mode of secretion.

Sweat Glands: Sweat is a watery fluid containing ammonia , urea, uric acid and sodium chloride. There are two types of sweat glands: eccrine and apocrine.

Eccrine Sweat Glands: The *eccrine sweat glands* are simple, coiled tubular glands with a merocrine mode of secretion.

Apocrine Sweat Glands: the *apocrine sweat glands* are very large glands which are thought to have a merocrine mode of secretion.

Hair

Hairs are long, filamentous keratinized structures derived from the epidermis of skin.

Structure: A hair consists of a *shaft* and a *root*.

Hair Follicles: The *hair follicle* consists of two sheathes, the *epithelial root sheath* and the *connective tissue root sheath*.

Hair Growth: Growth of a hair depends on the viability of the epidermal cells of the hair matrix which lie adjacent to the dermal papilla in the hair bulb. The matrix cells abutting the dermal papilla proliferate and give rise to cells which move upward to become part of the specific layers of the hair root and the inner epithelial root sheath.

Hair Musculature: Hairs are oriented at a slight angle to the skin surface and are associated with *arrector pili muscles*. These smooth muscle bundles extend from the dermal root sheath to a dermal papilla. Contraction results in the standing up of the hairs and raising of the skin surrounding the hair.

Nails

Nails are translucent plates of keratinized epithelial cells on the dorsal surface of distal phalanges of fingers and toes.

Digestive System and Nutrition

Nutrition

The environment must supply its organisms with adequate nutrients via the food supply. No organism is independent of the environment, but on nutritional self-sufficiency we can classify organisms into autotrophs and heterotrophs. Heterotrophs include all animals;

autotrophs include all those that carry out photosynthesis and can manufacture organic constituents from inorganic material.

Unit for Measuring Value of Foods: The kilocalorie (kcal) is the unit of heat used in measuring the value of foods for producing heat and energy in the human body. It is equivalent to the amount of heat that is required to raise the temperature of one kilogram of water one degree Celsius.

Proteins: Few free amino acids are available in the diet. Amino acid intake is primarily in the form of proteins (high molecular weight heteropolymers of amino acids). Amino acids are necessary for the production and maintenance of protoplasm.

Carbohydrates: Of primary importance in human nutrition are the monosaccharides, disaccharides, and polysaccharides. Monosaccharides ordinarily are simple 5- or 6-carbon sugars; they cannot be broken down into smaller units common examples are glucose and fructose.

Fats: Fats may be grouped into simple lipids, compound lipids, and lipids derived from simple and compound lipids by hydrolysis. Fat are composed of three fatty acid molecules joined to a molecule of glycerol.

Vitamins: Vitamins are organic substances which are needed in minute quantities; vitamins often play a role as part of an enzyme system vitamins are used up in the metabolic activities and must be constantly replaced.

Fat-soluble Vitamins:

1. Vitamin A
2. Vitamin D
3. Vitamin E
4. Vitamin K

Water-soluble Vitamins:

1. Thiamine (Vitamin B_1)
2. Riboflavin (Vitamin B_2)
3. Niacin (Nicotinic acid)

Minerals: Minerals are also utilized by the tissues of the body. Among the most common ones are calcium, phosphorus, potassium, sodium, magnesium, chlorine, manganese, iodine, iron, zinc, copper, cobalt, bromine and fluorine.

The Digestive System

Regionalization of the Embryonic Gut:

1) Foregut (supplied mainly by celiac artery): pharynx, esophagus, stomach, and cranial portion of duodenum from which the primordial of the liver, gall bladder and pancreas arise.
2) Midgut (supplied by superior mesenteric artery): caudal duodenum, jejunum, ileum, and ascending colon and 2/3 of

transverse colon including the appendages cecum and vermiform appendix.

3) Hindgut (supplied by inferior mesenteric artery): distal third of transverse colon, descending colon, sigmoid colon, and rectum.

The Major Digestive Glands

Pancreas: Pancreatic lipase, amylase and proteases are controlled by the presence of foodstuffs and hormones. As acid chyme enters the duodenum from the stomach, secretin is released and fluid and bicarbonate are secreted.

Pancreatic juice:

1) neutralizes the acid chyme in the duodenum
2) provides enzymes for the digestion of proteins, carbohydrates and fats.

Islets of Langerhans are the endocrine portion of the pancreas. Three cell types can be identified:

1) A, or alpha, cells, which are presumed to form glucagons.
2) B, or beta, cells, which are more numerous than A cells and produce insulin.
3) D, or delta, cells; their significance is uncertain but they might represent multipotent resting cells.

Liver: The liver has the following functions:

a) removal of bile pigments from blood which are excreted in bile
b) storage of glycogen
c) conversion of fats, and perhaps proteins, to carbohydrates (*gluconeog enesis*)
d) maintenance of the constancy of blood glucose level
e) deamination of amino acid with urea as a by-product
f) metabolism of fat and storage in the liver
g) synthesis of plasma proteins such as fibrinogen, prothrombin, and albumin
h) storage of essential vitamins (A, D, B_2, B_3, B_4, B_{12}, and K)
i) embryonic hemopoietic (blood cell forming) organ

Gallbladder: When demand exists bile is released and flows into the cystic duct which connects with the common bile duct (formed by union of common hepatic and cystic ducts), which empties into the second part of the duodenum.

Oral Cavity:

a) receives food and perceives taste, odor, texture and temperature
b) grinds foodstuffs to facilitate the action of enzymes
c) adds enzymes, mucus and moisture and shapes the bolus for the process of swallowing

Pharynx and Esophagus: The oral and laryngeal pharynx, and the esophagus are essentially conduits for food to reach the stomach.

Stomach: Food is received, stored and churned; digestive juices are added; and the digestive process started in the mouth is continued. Intrinsic factor (anti-pernicious anemia factor) is secreted.

Small Intestines: Digestion is completed and most absorption takes place in jejunum and ileum.

Large Intestines:

a) water and electrolytes are reabsorbed to preserve that delicate balance in the body
b) food is propelled along for elimination (egestion).

Intestinal Motility

Intestinal motility facilitates:

1) the mixing of food with secretions and enzymes
2) the contact of foodstuffs with the intestinal mucosa
3) propulsion along the tube (peristalsis)

This process is controlled by the nervous system, hormonal secretions, and intestinal distension and similar phenomena.

Epinephrine (from the adrenal) inhibits contraction; serotonin (from the small intestines) stimulates contractions.

Innervation of the Intestinal Tract

The nerves supplying the intestinal tract affect smooth muscle, glands, endocrine tissue and control motility and secretion. Motility or

peristalsis is a wave of compression (contraction) that is followed by a regional relaxation. The gut musculature (smooth) is controlled by the autonomic nervous system.

Sympathetic Innervation: Effects of sympathetic Innervation are:

A) some excitation of salivary secretion

B) a decrease of motility and secretion in the stomach and small intestines due mainly to the vasoconstrictive action.

C) An inhibition of muscular contraction and intrinsic ganglion cell activity due to the release of the neurotransmitters epinephrine and norepinephrine

Parasympathetic Innervation: Effects of the parasympathetic Innervation are:

A) stimulation of motility and secretion via its supply of the intrinsic plexi and the release of the neurotransmitter acetylcholine

B) release of gastrin

Summary of Digestive Juices

Saliva: saliva is protective and digestive. In this manner, it

A) dissolves food

B) starts starch digestion

C) lubricates food

D) contains antibacterial enzymes

Saliva is composed of

A) water

B) electrolytes

C) enzymes

D) mucin

E) glycoproteins

F) blood group proteins]

G) gamma globulins

Gastric Juice: Gastric juices is composed of

A) water

B) hydrochloric acid (HCI)

C) inorganic salts

D) mucus

E) enzymes (pepsin, rennin, and lipase)

About 2 or 3 liters of gastric juices are secreted within a 24- hour period.

Pancreatic Juice: pancreatic Juice contains proteolytic, lipolytic, and amylolytic enzymes.

Hormones of the Digestive Tract

Gastro intestinal hormones are polypeptides which effect:

1) water balance;
electrolyte balance;
2) enzyme secretions;
3) motility
4) digestion;
5) absorption;
6) growth; and
7) hormonal release.

The general stimuli for their release are:

1) nervous activity;
2) physical extension;
3) chemical stimuli

Specific stimuli for the three key hormones are:

1) Gastrin, distension, vagal stimulation and presence of proteins and amino acids
2) Secretin, acid chyme (hydrogen ion) released when the PH falls below 4.5
3) Cholecystokinin, presence of proteins and amino acids and the monoglycerides, fatty acids.

Nervous System

The nervous system is usually divided into:

A) central nervous system (brain and spinal cord)

B) peripheral nervous system (peripheral nerves and ganglia)

The peripheral nervous system is divided into a somatic system and visceral (autonomic) system.

Nervous Tissue

Nervous tissue consists of neurons and supportive elements. Neuroglia in the central nervous system and Schwann cells in the peripheral nervous system are the supportive elements.

The Neuron

The neuron is a cellular element and, as a highly specialized cell, it carries out the function of nervous transmission. It consists of a nucleus with associated nucleolus and a cytoplasm which is rich in organelles.

The Dendrites:

1. are direct extensions of the cytoplasm
2. are generally multiple
3. provide an increased surface area, the dendritic zone to allow for synaptic intersection

The Axon:

1. There is only one neuron

2. This process arises from a conical elevation of cytoplasm which is devoid of rough surfaced endoplasmic Reticulum (Nissl) and this area is called the *axon hillock*
3. Its usually thinner and longer than the dendrites of the same neuron
4. It may be surrounded by a *Myelin sheath*
5. At its ending the axon transmits impulses

The Action Potential:

An impulse traveling along a neuron is an electrical phenomenon initiated
by a temporary change in the permeability of the neuron's cell membrane.

The Synapse:

The synapse is the site of contact between two neurons.

Classification of Neurons

Multipolar Neurons: Most abundant; somatic and visceral motor, and associational.

Unipolar Neurons: Somatic and visceral sensory neurons; cell bodies are located in cranial sensory and dorsal root ganglia; peripheral process goes out to receptor and central process travels into the central nervous system.

Groups of Neurons

Nucleus: cluster of nerve cell bodies within the central nervous system

Ganglion: cluster of nerve cells bodies outside the central nervous system.

Cortex: layered arrangement of nerve cell bodies on the surface of the cerebrum and cerebellum (gray matter)

Supportive Elements of the Peripheral Nervous System:

1. Schwann Cells
2. Satellite Cells

The Central Nervous System

The central nervous system is made up of the brain and the spinal cord.

The Peripheral Nervous System

The peripheral nervous system is made up of a somatic portion and an autonomic portion.

The somatic portion is made up of cranial nerves and spinal nerves.

The autonomic nervous system innervates all smooth muscle, cardiac, muscle and glands. The autonomic system is further divided into the sympathetic and the (fight and light) and the parasympathetic (maintains homeostasis).

Reflex Arc

The typical pathway of a reflex may be outlined as follows: sensory receptor on dendrite of dorsal root ganglion cell --------→ ganglion cell ----------→ axon cell --------→ dorsal root --------→dorsal horn of spinal cord--------→ either directly to motor cell in ventral horn or via internuncial (association) neuron to ventral horn motor cell-------→ axon via ventral root ------→ spinal nerve-------→ effector organ (e.g., muscle).

Organs of Special Sense

The eye

The visual system is made up of the eye and the complex nerve pathways for interpretation by the cerebral cortex and subcortical centers for the purpose of:

1. Refraction of light rays and focusing thereof on the retina for the production of an image;
2. Conversion of light rays into a nervous impulse;
3. Transmission of visual centers of the brain for interpretation.

The Ear

It is an auditory organ for the sense of hearing, monitors the effects of gravity and position of the head.

The auditory functions of the ear are:

1) reception and conduction of sound waves,
2) amplification of the waves,
3) transduction of the waves into nerve impulses,
4) transmission of the impulse to conscious centers.

The Olfactory System

The olfactory system may be visualized as a highly specialized mucus membrane located in the roof of each nasal cavity. Four primary odors , fragrant, acid, burnt, and rancid are perceived.

The Gustatory System

In higher vertebrates the sense of taste is generally restricted to the oral cavity (tongue and epiglottic region). Taste buds are located in vallate, foliate, and fungiform papillae.

Reproductive System

Reproductive organs

Male: Seminiferous tubules of the testis, epididymis, vas deferens, seminal vesicles, prostate, prostatic urethra, membranous urethra, penile urethra, glans penis

Female: Ovaries, oviduct, uterus, vagina; the breasts (accessory organs).

Mendelian Genetics

Mendel

MENDEL set great store by the evaluation of the numerical proportions of the hybrids and he analyzed the plants gained by hybridization independently. He found it also essential to work with as great a number as plants as possible in order to outrule chance. His research enabled him to detect three principles of heredity.

***MENDEL's first law*,** is the principle of uniformity. It says that, if two plants that differ in just one trait are crossed, then the resulting hybrids will be uniform in the chosen trait. Depending on the traits is the uniform feature either one of the parents' traits (a dominant-recessive pair of characteristics) or it is intermediate.

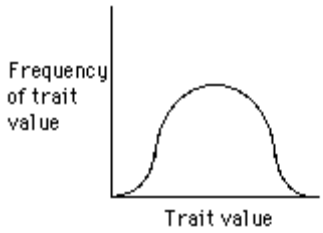
MENDEL's second law, is the principle of segregation. It states that the individuals of the F2 generation are not uniform, but that the traits segregate. Depending on a dominant-recessive crossing or an intermediate crossing are the resulting ratios 3:1 or 1:2:1. According to this principle hereditary traits are determined by discrete factors (now called genes) that occur in pairs, one of each pair being inherited from each parent. This concept of independent traits explains how a trait can persist from generation to generation without blending with other traits. It explains, too, how the trait can seemingly disappear and then reappear in a later generation. The principle of segregation

was consequently of the utmost importance for understanding both genetics and evolution.

MENDEL's third law, is also called the principle of independent assortment. It says that every trait is inherited independently of the others and it thus covers the case that new combinations of genes can arise, which were not existing before. We know today that this principle is just valid in the case of genes that are not coupled, i.e. that are not located at the same chromosome.

Polygenic Traits

The distribution of individuals with different trait values for polygenic (quantitative) traits in a population is typically a bell-shaped curve, as shown here:



There are three main ways selection could act on a population, given a distribution of traits such as this. These are:

1. **Directional selection:** the situation in which one extreme form of the trait has highest fitness.
2. **Stabilizing selection:** the situation in which the average form of the trait has higher fitness than does either extreme.
3. **Disruptive selection:** the situation in which both extreme forms of the trait have higher fitness than does the average.

The results of selection on quantitative traits generally makes sense -- the forms that have highest fitness become most common. As shown, directional selection results in a change in the mean value of the trait toward the form that has highest fitness. Stabilizing selection results in the loss of the extreme forms of the trait; this means there is a decrease in genetic variation -- eventually, genetic variation may be lost, as all individuals will have the alleles for the highest fitness, average, trait value. At this point, any phenotypic variation would depend on direct environmental effects rather than on genetic differences among individuals, and the heritability of the trait would be zero, or at least very low. Disruptive selection results in an increase in both extremes and a loss of intermediate forms.

Over a long period of time directional selection will result in a shift in the frequency of individuals with different traits until the average form has highest fitness. At this point, the situation becomes one of stabilizing selection, and the extreme forms of the trait will be lost. So directional selection eventually will lead to a situation where genetic variation will be lost (heritability will become zero) and all individuals will have the alleles for the highest fitness form of the trait.

Probability

Probability Events are possible outcomes of some random processes

Examples of events:

you pass 320
The genotype of a random individual is Bb

the weight of a random individual is less than 150 pounds

We can define the probability of a particular event, say A, as the fraction of outcomes in which event A occurs.

Denote Probability of A by Pr(A), or Prob(A)

For example, when flipping a coin once, the possible outcome is heads or tails.
Pr(Head) = 0.75 means that chance is 75% that the coin will be a head and hence

Pr(Tail) = 1 - Pr(Head) = 0.25.

Useful Rules of Probability

Probabilities are between zero (never occur) and one (always occur)
Pr(A) lies between zero and one for all A.

Probabilities sum to one
The sum of probabilities of all mutually exclusive events is one.
For example, if there are n possible outcomes, Pr(1) + Pr(2) + .. + Pr(n) = 1

Hence, Pr(1) = 1 - (Pr(2) + .. + Pr(n))

The AND and OR Rules

AND rule: If A and B are independent events (knowledge of one event tells us nothing about the other event), then the probability that BOTH A and B occur is
Pr(A and B) = Pr(A) Pr(B)

Hence generally AND = multiply probabilities

OR rule: If A and B are exclusive events (non overlapping), then the probability that EITHER A or B occurs is
Pr(A or B) = Pr(A) + Pr(B)

Hence generally OR = add probabilities

Example:

Suppose we are rolling a fair dice and flipping a fair coin

What is the probability of rolling an even number on the dice?
A single roll of a fair dice has possible outcomes 1, 2, 3, 4, 5, 6 each with the same probability, 1/6. Rolling an even number means rolling 2 OR 4 OR 6. These three events (2, 4, 6) are non overlapping, and hence exclusive, so we can use the OR = add rule, giving
Pr(Roll even) = Pr(2) + Pr(4) + Pr(6) = 3/6 = 1/2

What is the probability of rolling a 5 and then getting a head in the coin flip?

The dice roll and coin flip are independent events as the outcome of one does not influence the outcome of the other. Hence,
Pr(Head AND roll 5) = Pr(Head) * Pr(5) = 1/2*1/6 = 1/12

Conditional Probability

How do we compute joint probabilities when A and B are NOT independent (i.e., knowing that A has occurred provides information on whether or not B has occurred).
The joint probability of A and B, Pr(A,B) , is the product of the probability of B, Pr(B), with the Probability of A given B, Pr(A | B).
Pr(A,B) = Pr(A | B) Pr(B)

Pr (A | B) is called the conditional probability of A given B
Pr (A | B)= Pr(A,B) / Pr(B)
A and B are said to be independent if Pr(A | B) = Pr(A), so that knowing event B occurred gives us no information about event A.

An important use for conditional probabilities is to compute the probability of some complex event by conditioning on other events. For example, suppose that event A occurs under one of three other (mutually exclusive) events, say B, C, and D. Then Pr(A) = Pr(A|B)*Pr(B) + Pr(A|C)*Pr(C) + Pr(A|D)*Pr(D) For example, suppose there are three genotypes with different disease risks, where event A is having the disease, and B, C, and D are three different genotypes. Pr(A|D) is the risk of the disease for genotype D, and so forth. The overall risk of the disease is just the weighted risk over all genotypes.

Disease Relative Risks

What is the risk that you will have a disease given your sib (brother/sister) does?

This is quantified by the **disease relative risk**, RR, where

- RR = Prob(sib 1 affected | sib 2 is) / Prob(random individual affected)
- Thus, RR is the **increase in your risk over that for a random individual.**
- Note that RR = 1 if Prob(sib 1 affected | sib 2 is) = Prob(random individual affected), i.e. you have no increased risk given a relative has the disease.

Hence the disease relative risk is the increase in the conditional probability for a sib (or other relative) vs. a random individual.

As an example, consider diabetes. The probability that a random individual (from the US population) has type 1 diabetes is 0.4 percent. This is also referred to as the population prevalence, K. However, the frequency of diabetes in families with an affected sib is 6 percent. The resulting relative risk that an individual has diabetes, given that its sib does, is 6/0.4 = 15.

What is the probability that a pair of sibs both have diabetes?

- Pr(Both sibs affected) = Pr(2nd affected | 1st is) Pr(1st affected) = 0.06 * 0.004 = 0.00024
- Note that Pr(2nd affected | 1st is) = RR*K, as RR = Pr(2nd affected | 1st is) / K. Hence Pr(Both sibs affected) = (RR*K)*K = (K^2)* RR

- Hence, the population frequency of families with both sibs affected is 15 times more common than expected by chance (i.e., if the disease is independent of family membership, which is K^2).

Example : Rheumatoid Arthritis

Consider the following data for individuals with rheumatoid arthritis (from Del Junco et al, 1984)

	Disease	No disease	Total
Sibs of affected individuals	21	475	496
Spouses of affected individuals	12	661	673

- Prob(2nd sib affected | 1st sib affected) = 21 / 496 = 0.042
- Prob(random affected) = 12 / 673 = 0.018
- Relative Risk, RR = 0.042 / 0018 = 2.374

Evolution

Evolution = changes in gene (allele) frequencies through time

A. Evolution takes place at the population, not species level. I.e. populations, not species evolve

B. **Population** = a group of interbreeding individuals of the same species sharing a common geographical area

C. **Species** = a group of populations that have the potential to interbreed in nature and produce viable offspring

D. Gene pool = sum total of all the alleles within a population

E. **Four processes of evolution**:

1. **mutation** - changes in nucleotide sequences of DNA. Mutations provide new alleles, and therefore are the ultimate source of variation

2. **recombination** - reshuffling of the genetic material during meiosis (prophase I & metaphase I)

3. **natural selection** - differential reproduction (discussed below)

4. **reproductive isolation** (discussed shortly)

F. Mutation and recombination provide **natural variation**, the raw material for evolution

II. Hardy-Weinberg Law

A. Prior to the beginning of the 20th century biologists believed that natural selection would eventually result in the dominant alleles driving out or eliminating the recessives. Therefore, over a period of time genetic variation would eventually be eliminated in a population

B. The geneticist Punnett was asked to explain the prevalence of blue eyes in humans despite the fact that it is recessive to brown. He couldn't do it so he asked a mathematician colleague named Hardy to explain it. Coincidentally, a physician named Weinberg also came up with an explanation similar to Hardy's

C. **Hardy-Weinberg law -** the frequencies of alleles in a population will remain constant unless acted upon by outside agents or forces (listed below)

D. Hardy-Weinberg law describes the genetics of **non-evolving populations**. A non-evolving population is said to be in **Hardy-Weinberg equilibrium**

E. The following will disrupt Hardy-Weinberg equilibrium causing evolution to occur:

1. **Mutation** - by definition mutations change allele frequencies causing evolution

2. **Migration** - if new alleles are brought in by immigrants or old alleles are taken out by emigrants then the frequencies of alleles will change causing evolution

3. **Genetic drift** - random events due to small population size. Random events have little effect on large populations.

E.g., consider a population of 1 million almond trees with a frequency of r at 10%. If a severe ice storm wiped out half, leaving 500,000, it is very likely that the r allele would still be present in the population. However, suppose the initial population size of almond trees were 10 (with the same frequency of r at 10%). It is likely that the same ice storm could wipe the r allele out of the small population

a. Intense natural selection or a disaster can cause a **population bottleneck**, a severe reduction in population size which reduces the diversity of a population. The survivors have very little genetic variability and little chance to adapt if the environment changes

By the 1890's the population of northern elephant seals was reduced to only 20 individuals by hunters. Even though the population has increased to over 30,000 there is no genetic variation in the 24 alleles sampled. A single allele has been fixed by genetic drift and the bottleneck effect. In contrast southern elephant seals have wide genetic variation since their numbers have never reduced by such hunting

b. Bottleneck effect, combined with inbreeding, is an especially serious problem for may endangered species because great reductions in their numbers has reduced their genetic variability. This makes them especially vulnerable to changes in their environments and/or diseases. The Cheetah is a prime example

c. Sometimes a population bottleneck or migration event can cause a **founder effect**. A founder effect

occurs when a few individuals unrepresentative of the gene pool start a new population

E.g., a recessive allele in homozygous condition causes Dwarfism. In Switzerland the condition occurs in 1 out of 1,000 individuals. Amongst the 12,000 Amish now living in Pennsylvania the condition occurs in 1 out of 14 individuals. All the Amish are descendants of 30 people who migrated from Switzerland in 1720. The 30 founder individuals carried a higher than normal percentage of genes for dwarfism

4. **Nonrandom Mating** - for a population to be in Hardy-Weinberg equilibrium each individual in a population must have an equal chance of mating with any other individual in the population, i.e. mating must be random

a. If mating is random then each allele has an equal chance of uniting with any other allele and the proportions in the population will remain the same. However in nature most mating is not random because most individuals choose their partner

Sexual selection - nonrandom mating in which mates are selected on the basis of physical or behavioral characteristics

5. **Natural Selection** - For a population to be in Hardy-Weinberg equilibrium there can be **no** natural selection. This means that all genotypes must be equal in reproductive success. But recall Darwin's reasoning:

a. all species reproduce in excess of the numbers that can survive

b. yet adult populations remain relatively constant

c. therefore there must be a severe struggle for survival

d. all species vary in many characteristics and some of the variants confer an advantage or disadvantage in the struggle for life

e. the result is a natural selection favoring survival and reproduction of the more advantageous variants and elimination of the less advantageous variants

F. The Hardy-Weinberg principle sets up conditions which probably **never** occur in nature. One or more of mutation, migration, genetic drift, non-random mating or natural selection are probably always acting upon natural populations. This means that evolution is occurring in that population

G. The Hardy-Weinberg principle can also be expressed mathematically:

p2 + 2pq + q2 = 1, let p = the dominant allele and q = the recessive

Construct a Punnett square crossing two heterozygous (pq) individuals

	p	q
p	pp (p2)	pq
q	pq	qq (q2)

p2 + 2pq + q2 must equal 1 because the proportion of all alleles in a population must add up to 1 (100%)

III. Natural Selection = *differential reproduction*. Organisms with more advantageous gene combinations secure more resources, allowing them to leave more progeny. It is a negative force, nature selects against, not for

It is convenient to recognize three types of selection:

A.. **Stabilizing Selection** - selection maintains an already well adapted condition by eliminating any marked deviations from it. As long as the environment remains unchanged the fittest organisms will also remain unchanged

1. Human birth weight averages about seven pounds. Very light or very heavy babies have lower chances of survival. Fur color in mammals varies considerably but certain camouflage colors predominate in specific environments. Stabilizing selection accounts for "living fossils" - organisms that have remained seemingly unchanged for millions of years

B. **Directional Selection** - favors one extreme form over others. Eventually it produces a change in the population. Directional selection occurs when an organism must adapt to changing conditions

1. Industrial melanism in the peppered moth (Biston betularia) during the industrial revolution in England is one of the best document examples of directional selection

The moths fly by night and rest during the day on lichen covered tree trunks where they are preyed upon by birds. Prior to the industrial revolution most of the moths were light colored and well camouflaged. A few dark (melanistic) were occasionally noted

During the industrial revolution soot began to blacken the trees and also cause the death of the lichens. The light colored moths were no longer camouflaged so their numbers decreased quite rapidly. With the blackening of the trees the numbers of dark moths rapidly increased

The frequency of the dark allele increased from less than 1% to over 98% in just 50 generations. Since the 1950's attempts to reduce industrial pollution in Britain have resulted in an increase in numbers of light form

2. Antibiotic resistance in bacteria is another example of directional selection. The overuse/misuse of antibiotics has resulted in many resistant strains

3. Pesticide resistance in insects is another common example of directional selection

C. **Disruptive Selection** - occurs when two or more character states are favored

1. African butterflies (Pseudacraea eurytus) range from orange to blue. Both the orange and blue forms mimic (look like) other foul tasting species (models) so they are rarely eaten. Natural selection eliminates the intermediate forms because they don't look like the models

D. Ultimately natural selection leads to **adaptation** - the accumulation of structural, physiological or behavioral traits that increase an organism's fitness

IV. Fitness

A. Darwin marveled at the "perfection of structure" that made it possible for organisms to do whatever they needed to do to stay alive and produce offspring

B. He called this perfection of structure **fitness**, by which he meant the combination of all traits that help organisms survive and reproduce in their environment

C. Fitness is now measured as **reproductive success**, i.e. the number of progeny left behind who carry on the parental genes. Those who fail to contribute to the next or succeeding generations are unfit

V. Diploidy and heterozygosity - help maintain genetic variation

A. Only alleles that are exposed (cause a phenotypic difference) are subject to natural selection

B. In sexually reproducing diploid organisms a heterozygote may be a repository of rare recessive alleles

C. Recessive alleles provide "genetic insurance" should the environment change

VI. Sickle Cell Anemia

A. A fatal disease resulting from homozygous recessive alleles which code for one of the four polypeptide chains which make up hemoglobin, the oxygen transporting molecule in human blood

B. Red blood cells collapse, forming a variety of odd shapes, including some sickle shaped. As a result their oxygen carrying capacity is much reduced and they tend to clog up tiny capillaries. Affected individuals exhibit a variety of symptoms and they usually have considerably shortened lives

C. The deformed blood cells are the result of a **single** nucleotide substitution. GAA which, codes for Glutamic Acid, is replaced by GUA, which codes for Valine.

D. Despite the lethality of the allele, it occurs at frequencies as high as 40% some parts of tropical Africa. By contrast it occurs at less than 5% in African Americans and 0.1% in Caucasian Americans

E. The high frequency in tropical Africa is maintained because the heterozygous condition confers resistance to malaria, natural selection has acted to preserve it in areas traditionally high in malaria.

F. Note the same trait may be an advantage in one environment, yet a disadvantage in another

Adaptive radiation

adaptive radiation: the evolution of a single evolutionary stock into a number of different species.

Analogy and Homology

Homology (Homologous traits) similar characteristics in two animals that are a result of common ancestry (descent)

Analogy (Analagous traits) similarity (or equivalence) in function, morphology etc. that has arisen independently (i.e. similar selective pressures have resulted in similar traits in unrelated taxa)

Convergent Evolution (from text) the independent acquisition over time of similar characteristics in unrelated species subject to similar selection pressures (convergence of analogous traits)

Divergent Evolution (from text) the evolution of differences among closely related species because of differing selection pressures in their different environments (divergence of homologous traits)

Example of Convergent Evolution

Spiny anteaters, pangolins and giant anteaters all eat a diet of mainly ants and termites. Each of these animals lives on a different continent and are basically unrelated to each other. Each of them has a long sticky wormlike tongue and big claws to dig with. So, despite the fact that each of them has come from a different ancestor, they resemble each other and make a living in a similar way (they eat ants). So while the ancestors of these animals were different, these animals have evolved similar ways to exploit a resource that's hard to eat.

Example of Divergent Evolution

Male wolf spiders can use vibrations or visual signals to attract and mate with females. In two species that came from a common ancestor that uses visual and vibratory signals, one uses a visual signal while the other uses vibrations (beating its legs on the ground). One lives in a forest with a complex habitat in which you cannot see very far and it uses vibrations to signal. The other lives in a flat habitat in which vision is not obscured at all and uses visual signals. These two species have diverged in their signaling behavior because of different selective pressures acting on them.

Where do homology and analogy come in?

So, animal species that come from the same ancestor are usually similar (i.e. they share characteristics). This is homology or similarity as a result of descent. However if a trait that is homologous changes

(see example above) in two closely related species because they are using different habitats etc., it is an indication that those changes in the trait are an adaptation. So what about analogy. Well, convergent evolution results in analogous traits (that is they are similar because that's a good way to do it, not because of descent).

Analogous traits indicate adaptation and convergent evolution.
In our discussion of this what I wanted to get across was that similarity in traits is a result of two processes. One that does not indicate adaptation (homology or similarity as a result of descent) and one that does (analogy or similarity between traits due to convergent evolution i.e. finding a really good way to do it not because you're related). Thus, it is necessary to know the evolutionary history of a group of animals to use the comparative method.

Essay

You need to know that in evaluating your essays, readers are looking for your essay to be well organized and properly developed. All of the main ideas should be clearly outlined and explained. They should be error free and contain a variety of examples and reasoning to explain your ideas.

Planning Stage

You should spend a few minutes planning and jotting down a few quick notes. Consider the position you are taking, determine a few good reasons for making your choice, some evidence or explanation that support the choice, some effective details you might include, and what order you should use to effectively present your points.

Sticking to the Plan

You should spend the bulk of your time writing your essay. Refer back to your plan, remembering that the topic requires you to make a choice or take a position, and explain your reasoning in some detail. You should also consider the criterion specified so that your essay is convincing to the addressed audience. Make sure that the language you choose communicates your ideas clearly and appropriately.

Reviewing the Plan

You should spend a few minutes reviewing your writing, adding or removing as necessary and making any changes needed to enhance clarity.
You should make clear the answer and angle you will choose for your essay, offering a few good reasons for your choice and explaining your reasoning in some detail. As you explain the reasons for your choice, you should develop explanations for each, including such things as evidence, examples, or observations.

Brainstorming Smart

Brainstorming is a process of directing your mind toward idea generation.
Every book on essays will advise you to brainstorm. It's a method proven to be successful for several reasons. This is the point at which different writers will begin to disagree about how to brainstorm.

The method of brainstorming that is recommended here is two-tier. First you have to brainstorm about what you are going to write about. You want to determine what is going to be the focus of your essay.

Example:
Sample topic: "If you could change one thing about yourself, what would it be? Discuss why."

Example Brainstorming Level 1: What should I write about?

Intelligence, looks, personality, wealth, family, friends, time, fame, etc.

Your first impulse, and honest reaction, might be to respond with something such as making yourself more beautiful, more intelligent, or more popular. But remember that you want to be able to write at length about this topic. If you choose an answer that while truthful, may sound shallow to an essay reader, such as to become more beautiful and better looking, then you probably won't win any points with the reader.

Don't automatically go with your first impulse. The scorer is not giving points for essays that are the most honest, but for essays that are the best written. A well-written essay needs substantial support to explain the reasoning behind your choice.

A choice such as more intelligence could sound shallow, but with a little creativity, you can turn this into an excellent essay. Instead of stating that you want to be more intelligent in order to get better grades, use deeper reasoning. Explain what you would do with that added intelligence. Give examples of how your side research into molecular biology and genetics would be greatly improved with added intelligence and enable you to have a greater chance at your goal of contributing to finding a cure for cancer or diabetes.

If you choose "more popularity" as your topic, you could discuss how you would use your popularity in order to persuade more people to support your humanitarian causes and to be a positive role model for others.

After you've decided which topic you are going to write about, then you should begin the second wave of brainstorming, which will be about what you want to discuss about your chosen topic, which examples you want to use and which observations you hope to present.

Example Brainstorming Level 2: You've chosen to write about having more free time. Now you brainstorm about what you should say to support that choice.
spend more time with friends and family, work at a local homeless shelter, write a novel, open a new business, adopt some children, enjoy your hobbies, etc.

You have to have a proper balance at each level. If you spent too much time at brainstorming level 1, then you won't have time to decide on what you want to use as examples in level 2. But if you spend too little time at brainstorming level 1, then you may not come up with a really good topic to use for your essay. A good strategy is to practice using this two level brainstorming process until you get comfortable with using it and quickly generating lots of ideas.

Making the Cuts

Once you've finished the brainstorming level 2 process, you should look over the supporting ideas you hope to use and the examples you've written down from the brainstorming process. Look back over the ideas and see which ones look the best. Which ones could you

write the most about and would give you the most sound reasoning and logic to back up your initial decision of what to write about?

Make mental notes about which supporting ideas from brainstorming level 2 you hope to use, because those will be the ones that will comprise your successive body paragraphs.

Your goal is to hit the high notes. Pick the best ideas you've developed and write about those. You only need 3-5 good ideas to write about and may have a loss of focus if you try to write about more than a few important supporting topics.

Ending at the Start

Many essay writers will start off by writing their introductory paragraph, along with the main ideas and supporting ideas that will be used, and then force fit the essay into the guidelines that they have predetermined for their essay.

The problem with this is that many of the best ideas will occur to a writer while writing the essay. Rather than immediately jumping into writing your introductory paragraph, take the brainstorming ideas that you've developed and begin writing your essay, by expanding on each of the supporting ideas that you've chosen and writing your body paragraphs first.

As you write your body paragraphs, new ideas may occur to you that you would prefer to use. Rather than having to go back and make changes to your introductory paragraph, since you haven't written it

yet, you can just adopt the new ideas as you write and incorporate them into your body paragraphs.

When you're finished writing your body paragraphs, which should each include at least one primary supporting idea, then you can go back and write your introductory paragraph and make sure that it matches up with each of your body paragraphs and covers the overall topic you are discussing.

Additionally, don't make the mistake of writing too much in your introductory paragraph. The introduction is not where you explain your reasoning. Save your logic for the body paragraphs, and only use the introductory paragraph in order to briefly outline what you are going to discuss. Brevity is better than wordiness in an introduction.

Staying Consistent

A lot of writers write their introductory paragraph, then their body paragraphs, and then their conclusion at the end. The problem with this is that often the whole focus of the essay may have morphed as the writer wrote the essay and the conclusion seems to have a completely different focus than the introduction and the body paragraphs seem to lead take the reader through a tortuous path that changes course with every sentence.

It is vitally important that the introductory and concluding paragraphs are consistent with each other and that the body paragraphs match the introduction and conclusion. You want your paper to be consistent throughout.

Writing your introduction at the end, after you've written your body paragraphs, and then following it with your conclusion will be a huge help in maintaining the consistency, but always look back over your essay when you're finished and make sure that the essay keeps the same focus all the way through.

Maintaining the Flow

Part of maintaining consistency in your essay is the proper use of transition words while you're writing. Use transition words to maintain the essay's flow. Transition words such as first, second, third, finally, also, additionally, in conclusion, in summary, and furthermore all give the reader an understanding of how the paragraphs flow together.

Example:
Paragraph 1: Introduction
Paragraph 2: First of all, …
Paragraph 3: Secondly, …
Paragraph 4: Finally, …
Paragraph 5: In summary, …

Backing up Your Points

If you make a point or statement in your essay, make sure that you back it up with clear examples from your personal experience or observation. Don't let your points remain unsupported, but ensure that they are provided with some back up substance.

Example: You make the statement, "Renovating older downtowns can be expensive, but is definitely a worthwhile endeavor."

While many readers may agree with this statement, it shouldn't be made without backup support:

Consider the following as backup for that example statement: My own hometown created a ten-year plan to renovate their downtown area. A higher sales tax was passed in order to pay for the renovation, which ultimately cost $1 million dollars. But once it was finished, the sales tax was removed and the antique shops, which now fill much of the downtown, attract tourists and collectors from hundreds of miles away. The downtown is now completely self-supporting and is a constant source of both pride and new tax revenue to the town's residents.

Using Proper Grammar

Remember that this essay is your chance to write and make yourself look good and well educated. It is not a test of your knowledge of grammar rules. You don't have to demonstrate knowledge of every nuance of grammar. Therefore, if you find yourself wondering whether a given phrase should have commas around it or not, rewrite the phrase such that you're confident it doesn't need commas or does need commas. There is no need to have any punctuation in your essay that you are only 50% confident of being correct and conforming to the rules of grammar.

Example: You write, "Each of us must choose which path to take in life, whether to strive for improvement, or to settle in to their surroundings."

You aren't sure whether you need a comma or a colon after the phrase "to take in life" in the preceding sentence.

Simply rewrite the sentence until you are confident in how it is phrased. Change it to something such as:

"There are two paths: strive for improvement, or settle into surroundings."

At this point you know you are using the colon properly, and so you can feel free to move on in your essay without fear of having made a grammar mistake.

Watching Your Vocabulary

Many essay writers feel that they have to impress the reader with the vocabulary that they have at their disposal. While a good vocabulary can be impressive, and the right word used at the right time can make an essay appear much more professional, they should only be used with caution.

Often a big vocabulary word will be used out of context and it will have the reverse effect. Rather than looking impressive, a vocabulary word used improperly will detract from the essay. So, if you think of a word that you don't commonly use, only use it if you are absolutely positive

of its meaning and are sure that you are using it at the right place. Most of the time, you will be safer by sticking with words you are familiar with and accustomed to using.

Avoiding Tunnel Vision

Remember that the goal of your essay is to properly cover a topic and write an essay that is somewhat exhaustive in showing every angle and perspective. A lot of writers get tunnel vision. One particular angle occurs to them as the most important and they hammer away at that angle of the topic throughout the entire essay.

Discussing the same angle of a topic at length is considered essay depth. Discussing different angles of the same topic is considered essay breadth. Your goal is to have greater breadth than depth. This isn't a 20-page thesis written on a specific, obscure topic. Your topics will be fairly generic and broad-based and should have lots of different angles to consider and write about. You want to touch on as many different angles as you can, while still providing supporting backup for each statement you make.

Don't get stuck in a rut with tunnel vision. Be sure you are spending proper amounts of time on each angle you intend to discuss and not spend the entire essay writing about the same angle.

Example: The topic is whether or not athletics represents too much a part of today's academic institutions, and you intend to take the side that athletics is not too much of a part.

Your main angle is that an education is far more than simply academics and that athletics programs foster a richer, more diverse education. However, don't get stuck talking about that one angle. Consider writing about how athletic programs create ties to the community that academics does not. Discuss how athletic programs also encourage donations that benefit academics, as well as athletics.

Always try to consider multiple angles and avoid getting tunnel vision.

Just Do It

Some writers will begin their essay by rephrasing the question and talking about the different possibilities. Rather than stating what you're going to do: just do it.

Don't use the introduction as a chance to expose your mental ramblings. The introduction should be concise and to the point.

Example – Bad introduction: In this essay, I am going to discuss the thing that I consider to be the most important quality in an individual. It was a difficult decision to make, because there were so many qualities to choose from. Good looks is only skin deep, but intelligence, character, and personality run much deeper. I think the one that is most important is character. Character is the most important because it defines a person, exposes their true nature, and provides strength to overcome any obstacle.

Example – Good introduction: While every characteristic in an individual is important, one stands alone: character. Character defines

individuals, and exposes their true nature. When obstacles arise, character provides the strength to overcome them.

Notice how this second example is clear, concise, and does not ramble on about the decision or ideas that are occurring to the writer.

Conclusion is Review

A conclusion is just that: a conclusion. It wraps everything that you've written thus far up into a neat summary paragraph. This is not the time to begin introducing new arguments and new reasoning. You want to make sure that you are quickly and concisely reviewing what you've written and have a solid ending in which you come across as having proved your point, and made your case effectively.

So, when you're ready to begin your conclusion, make sure that you've flushed out all the new angles you want to cover. Then go back over what you're written and tie it all together at the end, hitting briefly on all the angles that you've discussed.

Additionally, a conclusion is not an apology. You should never apologize for not knowing more or writing more. End your essay with purpose and definitively summarize what you have stated.

Communicating Reason, not Passion

The readers that read and score your essay are not looking for passionate essays that are full of hot air and lacking in reason. They are interested in well thought out essays that communicate reasonable

arguments and logic, backed up by sound examples and observations. If the topic you choose is one that you are passionate about, make sure that you present more than just heated emotion, but also cool logic.

Example: The topic is about school uniforms, and you are passionately opposed.

Rather than writing, "School uniforms is a stupid idea, and will never work," try writing, "School uniforms have been an admitted failure by their original sponsors in all three implementation efforts during the last decade."

The first statement may be full of passion, but clearly lacks reason, while the second statement contains solid facts as examples.

Answering the Why?

While it's important that you communicate reason, misguided reason is ineffective. Always make sure that the examples you are providing and the reasoning you are using is being directed at answering the topic question.

Flawless logic that doesn't answer the question and doesn't contribute to the point you're trying to make is completely useless. As you think of main ideas and supporting ideas to use, take a few seconds and confirm that they will adequately answer the topic and veer off down a tangent that is not directly related.

Example: The topic is about what was the most important thing you have ever learned in school and asks you to discuss why.
Your answer is a quest for knowledge. Your supporting ideas include having been forced to work on large projects and do exhaustive research into topics that you normally wouldn't read about, which expanded your mind.

A tangent that you would not want to pursue might be to provide statistics on how many hours you worked on a research paper in elementary school. While factual, those facts do not help answer why a quest for knowledge is the most important thing you have ever learned in school.

Make sure that the facts and reasons you are stating directly help you in your goal of answering the topic question.

Getting Ready For Test Day

You're all set to take your PCAT! Now here are a few things to remember for test day:

Get there early. Know exactly where the test will be held and how you will get yourself there. Pay attention to traffic reports so that you can compensate for any unexpected issues on the road. Leaving early will mean that you'll be more relaxed; red traffic lights won't raise your stress level, and you won't be pulled over by the first officer who has to fill his speeding ticket quota. And most importantly, you'll have time to use the rest room.

If you've got butterflies in your stomach, feed them! You've already done all the practice tests you can do, and you've had a good night's sleep. Now it's time to get a good, healthy breakfast - though it is wise not to overeat. Your body and mind will need the energy; plus it's distracting to listen to your stomach growl.

Give yourself a massage! Rub your head, neck and shoulders. Place your hand over your heart while taking a very slow, deep breath.

Stay on track. Remember, you don't want to rush, you only want to perform in a timely manner. Although there are time restrictions, if you misread direction, accidentally fill in the wrong answer-choice, or think illogically due to rushing, it won't be worth all the time you save. Remember, haste makes waste! Also, keep in mind that incorrect answers don't count against you, so you can always guess at any answers that you are unsure of. Remember, an educated guess is

better than no guess at all! Moving through a test methodically and efficiently will likely mean that you'll have more time at the end than if you were to rush and stumble, or dawdle over questions that you're struggling with.

Most importantly (at least to your sanity), remember that once it's over, it's over. Clear your mind of it, because you did your best. Go treat yourself to a hot chocolate or an ice cream cone, catch a movie with some friends and relax!

Post PCAT

After the PCAT, when you've had the time to rest and relax from the stress you put your brain through, take the time to critically evaluate your test performance. This will help you gain valuable insight into how you performed, what sort of score you should be expecting (and therefore what schools will be within your scope for application) and the sort of mindset you'll be expected to utilize when you're actually in pharmacy school.

Remember, this is neither an opportunity to over-inflate your ego, nor to put yourself down. The main idea is to make your self-evaluation objective and critical, so that you will achieve an accurate view of how things will pan out.

This doesn't mean that you should begin a session of "if only I'd…" or "I shouldn't have…" This will only depress you. The point of this exercise is to keep you grounded, open minded and optimistic.

Soon enough, you'll receive your score, and the applications will start rolling out. Make it an organized procedure, keeping as prepared and informed as you were with your PCAT, and this will only lead to a bright, successful pharmacy career in your future!