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WEST-E Biology (022) Secrets

Study Guide

Your Key to Exam Success

WEST-E Test Review for the
Washington Educator Skills Tests-Endorsements

Published by
Mometrix Media LLC

Dear Future Exam Success Story:

Congratulations on your purchase of our study guide. Our goal in writing our study guide was to cover the content on the test, as well as provide insight into typical test taking mistakes and how to overcome them.

Standardized tests are a key component of being successful, which only increases the importance of doing well in the high-pressure high-stakes environment of test day. How well you do on this test will have a significant impact on your future- and we have the research and practical advice to help you execute on test day.

The product you're reading now is designed to exploit weaknesses in the test itself, and help you avoid the most common errors test takers frequently make.

How to use this study guide

We don't want to waste your time. Our study guide is fast-paced and fluff-free. We suggest going through it a number of times, as repetition is an important part of learning new information and concepts.

First, read through the study guide completely to get a feel for the content and organization. Read the general success strategies first, and then proceed to the content sections. Each tip has been carefully selected for its effectiveness.

Second, read through the study guide again, and take notes in the margins and highlight those sections where you may have a particular weakness.

Finally, bring the manual with you on test day and study it before the exam begins.

Your success is our success

We would be delighted to hear about your success. Send us an email and tell us your story. Thanks for your business and we wish you continued success-

Sincerely,

Mometrix Test Preparation Team

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Secret Key #1 - Time is Your Greatest Enemy

Pace Yourself

Wear a watch. At the beginning of the test, check the time (or start a chronometer on your watch to count the minutes), and check the time after every few questions to make sure you are "on schedule."

If you are forced to speed up, do it efficiently. Usually one or more answer choices can be eliminated without too much difficulty. Above all, don't panic. Don't speed up and just begin guessing at random choices. By pacing yourself, and continually monitoring your progress against your watch, you will always know exactly how far ahead or behind you are with your available time. If you find that you are one minute behind on the test, don't skip one question without spending any time on it, just to catch back up. Take 15 fewer seconds on the next four questions, and after four questions you'll have caught back up. Once you catch back up, you can continue working each problem at your normal pace.

Furthermore, don't dwell on the problems that you were rushed on. If a problem was taking up too much time and you made a hurried guess, it must be difficult. The difficult questions are the ones you are most likely to miss anyway, so it isn't a big loss. It is better to end with more time than you need than to run out of time.

Lastly, sometimes it is beneficial to slow down if you are constantly getting ahead of time. You are always more likely to catch a careless mistake by working more slowly than quickly, and among very high-scoring test takers (those who are likely to have lots of time left over), careless errors affect the score more than mastery of material.

Secret Key #2 - Guessing is not Guesswork

You probably know that guessing is a good idea - unlike other standardized tests, there is no penalty for getting a wrong answer. Even if you have no idea about a question, you still have a 20-25% chance of getting it right.

Most test takers do not understand the impact that proper guessing can have on their score. Unless you score extremely high, guessing will significantly contribute to your final score.

Monkeys Take the Test

What most test takers don't realize is that to insure that 20-25% chance, you have to guess randomly. If you put 20 monkeys in a room to take this test, assuming they answered once per question and behaved themselves, on average they would get 20-25% of the questions correct. Put 20 test takers in the room, and the average will be much lower among guessed questions. Why?

1. The test writers intentionally write deceptive answer choices that "look" right. A test taker has no idea about a question, so picks the "best looking" answer, which is often wrong. The monkey has no idea what looks good and what doesn't, so will consistently be lucky about 20-25% of the time.
2. Test takers will eliminate answer choices

from the guessing pool based on a hunch or intuition. Simple but correct answers often get excluded, leaving a 0% chance of being correct. The monkey has no clue, and often gets lucky with the best choice.

This is why the process of elimination endorsed by most test courses is flawed and detrimental to your performance- test takers don't guess, they make an ignorant stab in the dark that is usually worse than random.

$5 Challenge

Let me introduce one of the most valuable ideas of this course- the $5 challenge:

You only mark your "best guess" if you are willing to bet $5 on it.
You only eliminate choices from guessing if you are willing to bet $5 on it.

Why $5? Five dollars is an amount of money that is small yet not insignificant, and can really add up fast (20 questions could cost you $100). Likewise, each answer choice on one question of the test will have a small impact on your overall score, but it can really add up to a lot of points in the end.

The process of elimination IS valuable. The following shows your chance of guessing it right:

If you eliminate wrong answer choices until only this many remain:	Chance of getting it correct:
1	100%
2	50%
3	33%

However, if you accidentally eliminate the right answer or go on a hunch for an incorrect answer, your chances drop dramatically: to 0%. By guessing among all the answer choices, you are GUARANTEED to have a shot at the right answer.

That's why the $5 test is so valuable- if you give up the advantage and safety of a pure guess, it had better be worth the risk.

What we still haven't covered is how to be sure that whatever guess you make is truly random. Here's the easiest way:

Always pick the first answer choice among those remaining.

Such a technique means that you have decided, **before you see a single test question**, exactly how you are going to guess- and since the order of choices tells you nothing about which one is correct, this guessing technique is perfectly random.

This section is not meant to scare you away from making educated guesses or eliminating choices- you just need to define when a choice is worth eliminating. The $5 test, along with a pre-defined random guessing strategy, is the best way to make sure you reap all of the benefits of guessing.

Secret Key #3 - Practice Smarter, Not Harder

Many test takers delay the test preparation process because they dread the awful amounts of practice time they think necessary to succeed

on the test. We have refined an effective method that will take you only a fraction of the time.

There are a number of "obstacles" in your way to succeed. Among these are answering questions, finishing in time, and mastering test-taking strategies. All must be executed on the day of the test at peak performance, or your score will suffer. The test is a mental marathon that has a large impact on your future.

Just like a marathon runner, it is important to work your way up to the full challenge. So first you just worry about questions, and then time, and finally strategy:

Success Strategy

1. Find a good source for practice tests.
2. If you are willing to make a larger time investment, consider using more than one study guide- often the different approaches of multiple authors will help you "get" difficult concepts.
3. Take a practice test with no time constraints, with all study helps "open book." Take your time with questions and focus on applying strategies.
4. Take a practice test with time constraints, with all guides "open book."
5. Take a final practice test with no open material and time limits

If you have time to take more practice tests, just repeat step 5. By gradually exposing yourself to the full rigors of the test environment, you will condition your mind to the stress of test day and maximize your success.

Secret Key #4 - Prepare, Don't Procrastinate

Let me state an obvious fact: if you take the test three times, you will get three different scores. This is due to the way you feel on test day, the level of preparedness you have, and, despite the test writers' claims to the contrary, some tests WILL be easier for you than others.

Since your future depends so much on your score, you should maximize your chances of success. In order to maximize the likelihood of success, you've got to prepare in advance. This means taking practice tests and spending time learning the information and test taking strategies you will need to succeed.

Never take the test as a "practice" test, expecting that you can just take it again if you need to. Feel free to take sample tests on your own, but when you go to take the official test, be prepared, be focused, and do your best the first time!

Secret Key #5 - Test Yourself

Everyone knows that time is money. There is no need to spend too much of your time or too little of your time preparing for the test. You should only spend as much of your precious time preparing as is necessary for you to get the score you need.

Once you have taken a practice test under real conditions of time constraints, then you will know if you are ready for the test or not.

If you have scored extremely high the first time that you take the practice test, then there is not much point in spending countless hours studying. You are already there. Benchmark your abilities by retaking practice tests and seeing how much you have improved. Once you score high enough to guarantee success, then you are ready.

If you have scored well below where you need, then knuckle down and begin studying in earnest. Check your improvement regularly through the use of practice tests under real conditions. Above all, don't worry, panic, or give up. The key is perseverance!

Then, when you go to take the test, remain confident and remember how well you did on the practice tests. If you can score high enough on a practice test, then you can do the same on the real thing.

General Strategies

The most important thing you can do is to ignore your fears and jump into the test immediately- do not be overwhelmed by any strange-sounding terms. You have to jump into the test like jumping into a pool- all at once is the easiest way.

Make Predictions

As you read and understand the question, try to guess what the answer will be. Remember that several of the answer choices are wrong, and once you begin reading them, your mind will immediately become cluttered with answer choices designed to throw you off. Your mind is typically the most focused immediately after you have read the question and digested its contents. If you can, try to predict what the correct answer will be. You may be surprised at what you can predict.

Quickly scan the choices and see if your prediction is in the listed answer choices. If it is, then you can be quite confident that you have the right answer. It still won't hurt to check the other answer choices, but most of the time, you've got it!

Answer the Question

It may seem obvious to only pick answer choices that answer the question, but the test writers can create some excellent answer choices that are wrong. Don't pick an answer just because it sounds right, or you believe it to be true. It MUST answer the question. Once you've made your selection, always go back and check it against the question and make sure that you didn't misread the question, and the answer choice does answer the question posed.

Benchmark

After you read the first answer choice, decide if you think it sounds correct or not. If it doesn't, move on to the next answer choice. If it does, mentally mark that answer choice. This doesn't mean that you've definitely selected it as your answer choice, it just means that it's the best you've seen thus far. Go ahead and read the next choice. If the next choice is worse than the one you've already selected, keep going to the next answer choice. If the next choice is better than the choice you've already selected, mentally mark the new answer choice as your best guess.

The first answer choice that you select becomes your standard. Every other answer choice must be benchmarked against that standard. That

choice is correct until proven otherwise by another answer choice beating it out. Once you've decided that no other answer choice seems as good, do one final check to ensure that your answer choice answers the question posed.

Valid Information

Don't discount any of the information provided in the question. Every piece of information may be necessary to determine the correct answer. None of the information in the question is there to throw you off (while the answer choices will certainly have information to throw you off). If two seemingly unrelated topics are discussed, don't ignore either. You can be confident there is a relationship, or it wouldn't be included in the question, and you are probably going to have to determine what is that relationship to find the answer.

Avoid "Fact Traps"

Don't get distracted by a choice that is factually true. Your search is for the answer that answers the question. Stay focused and don't fall for an answer that is true but incorrect. Always go back to the question and make sure you're choosing an answer that actually answers the question and is not just a true statement. An answer can be factually correct, but it MUST answer the question asked. Additionally, two answers can both be seemingly correct, so be sure to read all of the answer choices, and make sure that you get the one that BEST answers the question.

Milk the Question

Some of the questions may throw you completely off. They might deal with a subject you have not been exposed to, or one that you haven't reviewed in years. While your lack of knowledge about the subject will be a hindrance, the question itself can give you many clues that will help you find the correct answer. Read the question carefully and look for clues. Watch particularly for adjectives and nouns describing difficult terms or words that you don't recognize. Regardless of if you completely understand a word or not, replacing it with a synonym either provided or one you more familiar with may help you to understand what the questions are asking. Rather than wracking your mind about specific detailed information concerning a difficult term or word, try to use mental substitutes that are easier to understand.

The Trap of Familiarity

Don't just choose a word because you recognize it. On difficult questions, you may not recognize a number of words in the answer choices. The test writers don't put "make-believe" words on the test; so don't think that just because you only recognize all the words in one answer choice means that answer choice must be correct. If you only recognize words in one answer choice, then focus on that one. Is it correct? Try your best to determine if it is correct. If it is, that is great, but if it doesn't, eliminate it. Each word and answer choice you eliminate increases your chances of getting the question correct, even if you then have to guess among the unfamiliar choices.

Eliminate Answers

Eliminate choices as soon as you realize they are wrong. But be careful! Make sure you consider all of the possible answer choices. Just because one appears right, doesn't mean that the next one won't be even better! The test writers will usually put more than one good answer choice for every question, so read all of them. Don't worry if you are stuck between two that seem right. By getting down to just two remaining possible choices, your odds are now 50/50.

Rather than wasting too much time, play the odds. You are guessing, but guessing wisely, because you've been able to knock out some of the answer choices that you know are wrong. If you are eliminating choices and realize that the last answer choice you are left with is also obviously wrong, don't panic. Start over and consider each choice again. There may easily be something that you missed the first time and will realize on the second pass.

Tough Questions

If you are stumped on a problem or it appears too hard or too difficult, don't waste time. Move on! Remember though, if you can quickly check for obviously incorrect answer choices, your chances of guessing correctly are greatly improved. Before you completely give up, at least try to knock out a couple of possible answers. Eliminate what you can and then guess at the remaining answer choices before moving on.

Brainstorm

If you get stuck on a difficult question, spend a few seconds quickly brainstorming. Run through the complete list of possible answer choices. Look at each choice and ask yourself, "Could this answer the question satisfactorily?" Go through each answer choice and consider it independently of the other. By systematically going through all possibilities, you may find something that you would otherwise overlook. Remember that when you get stuck, it's important to try to keep moving.

Read Carefully

Understand the problem. Read the question and answer choices carefully. Don't miss the question because you misread the terms. You have plenty of time to read each question thoroughly and make sure you understand what is being asked. Yet a happy medium must be attained, so don't waste too much time. You must read carefully, but efficiently.

Face Value

When in doubt, use common sense. Always accept the situation in the problem at face value. Don't read too much into it. These problems will not require you to make huge leaps of logic. The test writers aren't trying to throw you off with a cheap trick. If you have to go beyond creativity and make a leap of logic in order to have an answer choice answer the question, then you should look at the other answer choices. Don't overcomplicate the problem by creating theoretical relationships or explanations that will warp time or space. These are normal problems rooted in reality. It's just that the applicable relationship or explanation may not be readily apparent and you have to figure things out. Use your common sense to interpret anything that isn't clear.

Prefixes

If you're having trouble with a word in the question or answer choices, try dissecting it. Take advantage of every clue that the word might include. Prefixes and suffixes can be a huge help. Usually they allow you to determine a basic meaning. Pre- means before, post- means after, pro - is positive, de- is negative. From these prefixes and suffixes, you can get an idea of the general meaning of the word and try to put it into context. Beware though of any traps. Just because con is the opposite of pro, doesn't necessarily mean congress is the opposite of progress!

Hedge Phrases

Watch out for critical "hedge" phrases, such as

likely, may, can, will often, sometimes, often, almost, mostly, usually, generally, rarely, sometimes. Question writers insert these hedge phrases to cover every possibility. Often an answer choice will be wrong simply because it leaves no room for exception. Avoid answer choices that have definitive words like "exactly," and "always".

Switchback Words

Stay alert for "switchbacks". These are the words and phrases frequently used to alert you to shifts in thought. The most common switchback word is "but". Others include although, however, nevertheless, on the other hand, even though, while, in spite of, despite, regardless of.

New Information

Correct answer choices will rarely have completely new information included. Answer choices typically are straightforward reflections of the material asked about and will directly relate to the question. If a new piece of information is included in an answer choice that doesn't even seem to relate to the topic being asked about, then that answer choice is likely incorrect. All of the information needed to answer the question is usually provided for you, and so you should not have to make guesses that are unsupported or choose answer choices that require unknown information that cannot be reasoned on its own.

Time Management

On technical questions, don't get lost on the technical terms. Don't spend too much time on any one question. If you don't know what a term means, then since you don't have a dictionary, odds are you aren't going to get much further. You should immediately recognize terms as whether or not you know them. If you don't, work with the other clues that you have, the other answer choices and terms provided, but don't waste too much time trying to figure out a difficult term.

Contextual Clues

Look for contextual clues. An answer can be right but not correct. The contextual clues will help you find the answer that is most right and is correct. Understand the context in which a phrase or statement is made. This will help you make important distinctions.

Don't Panic

Panicking will not answer any questions for you. Therefore, it isn't helpful. When you first see the question, if your mind goes blank, take a deep breath. Force yourself to mechanically go through the steps of solving the problem and using the strategies you've learned.

Pace Yourself

Don't get clock fever. It's easy to be overwhelmed when you're looking at a page full of questions, your mind is full of random thoughts and feeling confused, and the clock is ticking down faster than you would like. Calm down and maintain the pace that you have set for yourself. As long as you are on track by monitoring your pace, you are guaranteed to have enough time for yourself. When you get to the last few minutes of the test, it may seem like you won't have enough time left, but if you only have as many questions as you should have left at that point, then you're right on track!

Answer Selection

The best way to pick an answer choice is to eliminate all of those that are wrong, until only one is left and confirm that is the correct answer.

Sometimes though, an answer choice may immediately look right. Be careful! Take a second to make sure that the other choices are not equally obvious. Don't make a hasty mistake. There are only two times that you should stop before checking other answers. First is when you are positive that the answer choice you have selected is correct. Second is when time is almost out and you have to make a quick guess!

Check Your Work

Since you will probably not know every term listed and the answer to every question, it is important that you get credit for the ones that you do know. Don't miss any questions through careless mistakes. If at all possible, try to take a second to look back over your answer selection and make sure you've selected the correct answer choice and haven't made a costly careless mistake (such as marking an answer choice that you didn't mean to mark). This quick double check should more than pay for itself in caught mistakes for the time it costs.

Beware of Directly Quoted Answers

Sometimes an answer choice will repeat word for word a portion of the question or reference section. However, beware of such exact duplication – it may be a trap! More than likely, the correct choice will paraphrase or summarize a point, rather than being exactly the same wording.

Slang

Scientific sounding answers are better than slang ones. An answer choice that begins "To compare the outcomes…" is much more likely to be correct than one that begins "Because some people insisted…"

Extreme Statements

Avoid wild answers that throw out highly controversial ideas that are proclaimed as established fact. An answer choice that states the "process should used in certain situations, if…" is much more likely to be correct than one that states the "process should be discontinued completely." The first is a calm rational statement and doesn't even make a definitive, uncompromising stance, using a hedge word "if" to provide wiggle room, whereas the second choice is a radical idea and far more extreme.

Answer Choice Families

When you have two or more answer choices that are direct opposites or parallels, one of them is usually the correct answer. For instance, if one answer choice states "x increases" and another answer choice states "x decreases" or "y increases," then those two or three answer choices are very similar in construction and fall into the same family of answer choices. A family of answer choices is when two or three answer choices are very similar in construction, and yet often have a directly opposite meaning. Usually the correct answer choice will be in that family of answer choices. The "odd man out" or answer choice that doesn't seem to fit the parallel construction of the other answer choices is more likely to be incorrect.

Top 20 Test Taking Tips

1. Carefully follow all the test registration procedures
2. Know the test directions, duration, topics, question types, how many questions
3. Setup a flexible study schedule at least 3-4 weeks before test day
4. Study during the time of day you are most alert, relaxed, and stress free
5. Maximize your learning style; visual learner use visual study aids, auditory learner use auditory study aids
6. Focus on your weakest knowledge base
7. Find a study partner to review with and help clarify questions
8. Practice, practice, practice
9. Get a good night's sleep; don't try to cram the night before the test
10. Eat a well balanced meal
11. Know the exact physical location of the testing site; drive the route to the site prior to test day
12. Bring a set of ear plugs; the testing center could be noisy
13. Wear comfortable, loose fitting, layered clothing to the testing center; prepare for it to be either cold or hot during the test
14. Bring at least 2 current forms of ID to the testing center
15. Arrive to the test early; be prepared to wait and be patient
16. Eliminate the obviously wrong answer choices, then guess the first remaining choice
17. Pace yourself; don't rush, but keep working and move on if you get stuck
18. Maintain a positive attitude even if the test is going poorly
19. Keep your first answer unless you are positive it is wrong
20. Check your work, don't make a careless mistake

Communities and Ecosystems

Types and characteristics of ecosystems

Ecosystem of soil

Soil is the end product of dispersed mineral and organic matter. It results from several factors, including climate, base material, time, and geography. Soil begins with the degrading of rock and minerals. Both chemical reactions and natural elements operate to make soil. Living organisms also are important in soil formation. Soil develops in strata called horizons. Among them are accumulated organic matter, mineral and clay, and base material. These horizons have many subunits. Soils vary in texture, color, structure, wetness, and other qualities. A wide diversity of life exists in soil, including microorganisms and simple multicelled plants and animals. Soil erosion is a major problem in ecology. Natural erosion through wind and soil is exacerbated by the development of cities, destruction of rainforests, destructive farming, and mankind's general disregard for the land. This soil erosion impacts food production and quality of life: It has lasting effects on society.

Ecosystems of nutrition

Plants

The amount of usable nutrients impacts plants' ability to grow and develop. The nutrient concentrations in the soil and climatic conditions determine the nutrient quality available to plants. The acidity of soil affects the ability of plants to use the soil's nutrition. Very acidic soils offer fewer usable nutrients to plants.

Animals

Since ultimately all life depends on plants, the nutritive health of plants affects animal nutrition. This is particularly true for herbivores, who must obtain all their nutrients from plants. Carnivores consume animal flesh, in which the nutrients have already been processed once. Carnivores must deal with the problem of getting enough food.

Macronutrients are those that contain ample quantities of oxygen, carbon, potassium, calcium, nitrogen, and phosphorus. Micronutrients are trace elements, including iron and zinc, required in much smaller amounts to sustain life.

Ecosystems and pest control

Pests are organisms that are detrimental to a population's activities. Biological control of pests is maintained by predators and diseases to control the density of pests. Pests are most damaging to humans when they attack agricultural crops. Chemical agents

may be used to obtain temporary results, but toxic chemicals affect other life, and pests soon develop a genetic resistance to the pesticides used. Predators are sometimes introduced to decimate the pest population. These tactics have yielded mixed results. Genetic control of pests can be accomplished by developing pest-resistant crops or by reducing the pest population by genetic interventions that shorten pests' lives. Mixed results have been accomplished using these methods. All pest control provokes ecological issues regarding the effective control of pests. For now, a combination of biological, chemical, and genetic controls offers the best solutions.

Flow of matter and energy

Carbon

All organic life requires carbon as its base. Carbon dioxide (CO_2) in the atmosphere is the source of all carbon. Through photosynthesis by plants, carbon becomes available to all organisms through assimilation. Assimilation requires energy from the degrading of carbon compounds in respiration. Plants, which receive their energy directly from the sun, are called primary producers of carbon. Organisms that receive their energy from plants are called secondary producers. All life must either be a primary or secondary producer of carbon. Cellular respiration releases energy from carbohydrates in the form of water and CO_2. Death and decomposition causes much of the carbon released to be incorporated in the decomposer organisms. The CO_2 is then eventually released back into the atmosphere and the cycle begins again.

Ecology

<u>Climate</u>

Earth acquires solar radiation from the atmosphere. This radiation generates wind and ocean currents, which determine rainfall patterns. The amount of solar radiation varies widely with latitudes, causing differences in climate. Tropical regions receive the most solar radiation while higher latitudes receive the least. Temperatures rise in the tropics and decline toward the poles. One climate can offer a number of microclimates where organisms live. These variations are caused by multiple factors including topography, vegetation, prevailing winds, and ocean currents. These microclimates rarely match the general climate. Among many other factors, the specific microclimate which an organism inhabits determines the necessity for adaptation. Of course, climate is only one variable among many to which an organism must adapt.

<u>Light</u>

Light impacts all living organisms. The density and organization of vegetation depends on the amount of light that reaches the ground. This has profound implications for photosynthesis and all life in the region.

Plants are either sun plants or shade plants depending on their adaptation to the qualities of light in their microclimate. Sun plants grow best in open spaces with maximum sunlight exposure. Shade plants grow more slowly, and have lower rates of photosynthesis. Being either a sun or shade plant affects the shape of a plant's leaves and its overall structure, which in turn affects photosynthesis. House plants are often categorized by the amount of sun they require to grow and prosper.

Aquatic plants live in a shaded environment and this limits their capacity for photosynthesis. The water depth at which aquatic plants prosper is related to the light intensity they require for ideal photosynthesis.

Thermal environment

All organisms live in a thermal environment and must maintain a viable temperature to thrive. Plants and animals have adapted differently to this potential problem. Plants experience a wide variation of heat and cold and have adapted to tolerate it. Plants tolerate cold by frost hardening and the formation of antifreeze chemicals in cells, roots, and buds. They also have good insulation for withstanding cold temperatures. Plants have less ability to adapt to heat but can make short term adjustments. Different animals have developed different adaptations to changes in temperature. Some animals, known as poikilotherms, depend on the environment for heat sources; they have low metabolic rates and the environment controls their metabolism. Others, known as homeotherms, rely on internal chemical reactions to produce heat; their internal temperature is fairly constant. Finally, heterotherms function as both poikilotherms and homotherms. Depending on the atmosphere, they can either utilize heat from their surroundings or generate it themselves.

Rhythms in life

Circadian rhythms - Circadian rhythms are a complex relationship between organisms and the daily cycle between light and dark. They are still not fully understood. Biological clocks control cycles of activity in living beings. Most animals have biological clocks and must be exposed to natural sunlight. Biological clocks have a natural cycle of 24 hours, operate in all types of weather, and run continuously.

Changes in day length responses - Organisms may be short-day or long-day sensitive, or combine both features.

Tidal cycles - Tidal cycles run in 12 four hour periods. They affect certain organisms and work in conjunction with circadian rhythms to modify an organism's behavior.

Seasonal responses - The study of seasonal biological changes is called phenology. Changes in light and temperature influence seasonality as does the amount of rainfall. Seasonality determines such basic activities as flowering, mating, dormancy, and migration.

Populations and communities

Populations

In ecology, the word "population" has a specific meaning. It refers to a group of organisms, reproductively isolated, that lives and breeds in a given geographic area. Populations have specific rates of growth, birth, and death and respond in unique ways from other populations. Animal and plant populations differ substantially. Animal populations tend to be made of unitary organisms with similar growth patterns and a fixed range of life. Plants are much more complex, containing subunits with such features as leaves, roots, and stems. These subunits may be considered as separate populations. A population's density is measured by the numbers of the population situated in its geographic area. These populations are dispersed over their habitat in patterns. Some are randomly dispersed, others may be uniformly dispersed. Careful study is necessary to measure these variables. Accurate accounting for population dispersal and density is made by complex and scientific statistical analysis, including patterns of growth, death, and migration.

Distribution of species

There are common patterns in geographical distribution. Most species have small geographic ranges, while a few have very wide ranges. There is a strong correlation between abundance of resources and population distribution. This pattern is called Hanski's Rule: widespread species are more abundant than species that have small geographical ranges. This rule is subject to considerable variation. Much is still unknown about geographic ranges. One guideline is Rapoport's rule, which states that polar species have larger geographical ranges than tropical species. Climate, glacial development, and competition are reasons for this latitudinal distribution. Geographical ranges for many species are not known due to lack of data. Even ranges for larger plants and animals in modern countries are usually just estimates.

Measuring population size

Ecologists debate the optimum way to measure population size. Gross absolute density can be measured by total counts or sophisticated statistical sampling and analysis. Relative density can be measured in several ways including analyzing mortality or immigration and emigration. Unitary organisms, including most animals, have definite physical shape and form. Unitary organisms are easy to recognize and count. However, modular organisms, including most plants, have multiple units or modules of construction. Plants have many leaves, roots, and stems, which makes recognizing and counting individuals much more difficult. Population changes in modular organisms can only be accurately counted by measuring the birth rates of new modules, and the death rates of old modules.

To measure accurately, statistical methods must be strictly followed.

Theories of change in populations

Differing theories of change in populations all agree that the dominant species in a population will be those that exhibit rapid growth and wide dispersal. Models of population change include the following:

- **Facilitated Model** - Species growth and replacement is facilitated by organisms already present.
- **Inhibition Model** - Species growth is inhibited by present organisms, leaving opportunity for growth by new organisms.
- **Tolerance Model** - New species are able to tolerate fewer resources and prosper.
- **Random Model** - New species arise randomly without specific organism interactions.

Succession in populations moves forward through a series of phases from the pioneer stage to the climax stage. The parts of any community are constantly growing and changing, depending on the variables present. These are so-called "patches" of cyclic change that ultimately determine total population makeup. Life cycles of dominant species cause these cyclic changes. Populations are rarely stable over long periods due to environment, climate, disease, and other factors.

Measure population changes

Statistical and quantitative tools are sometimes used to measure population changes. For instance, life tables summarize the mortality rates in a given population, while fertility schedules summarize reproduction rates relative to age in a population. By analyzing the intrinsic potential of population change based on life tables and fertility schedules, the rate of change can be anticipated. Simple models are also used to measure population changes. Populations can increase geometrically, at a fixed rate, or constantly depending on different circumstances. The age structure of a population is determined by rates of birth and deaths and is measured statistically. Populations must be precisely defined before an effective analysis of population changes can be made with any accuracy.

Population regulation

Population growth seems to have natural limits. There are several theories to explain this:

- **The Biotic Theory** - This school of thought says that density-dependent factors work to limit populations. Natural enemies are thought to be the major limiting factor to population growth.
- **The Climatic Theory** - Suggests that changes in climate act as density-dependent agents.

- **The Self-Regulation Theory** - This theory holds that populations may be limited by changes in behavior and physiology, including genetics, of individuals in the population.

Populations may be divided between local and met populations (groups of smaller populations) that may become extinct or colonized by new founders. Met populations are often stable while local populations are volatile. The theories of population regulation overlap and many scientists use elements from each theory to approach the question. The topic is of great importance because of its implications in community ecology.

Population harvesting

When populations of plants or animals are harvested by human beings, the density of the population is reduced and must be offset by an increase in reproduction, increased growth, or lower mortality. Harvesting can often cost a population its older and more reproductively active members. The goal for harvesters is to obtain the maximum sustained yield, gaining an ample harvest while sustaining the population. This model fails to account for environmental changes or exploitation caused by political and social pressure to harvest a larger crop. Perhaps the greatest challenge to modern ecology is to harvest effectively and insure that resources are sustainable. Uncertain ecological conditions and biological changes mandate a conservative approach to harvesting. Risk-aversive strategies include protected habitats and zones where harvesting is eliminated or significantly reduced. Fisheries have been somewhat successful using these methods in harvesting conservation.

Community

A community is defined as a group of populations living in a specific geographical area. The connection and amount of interaction between species in the community determines much about its organization and activities. The rivet model of communities suggests a close relationship between different species while the redundancy model suggests a more distant arrangement. Modern ecologists favor the redundancy model, also called the individualistic continuum model, noting that communities are not clearly divided and are subject to change over time. Communities tend to change gradually with various species dispersed in environmental patterns. Indicator species are those chosen by ecologists to identify a community and used to measure its vital characteristics. Most studies of communities have been in temperate climates; much less is known about tropical communities.

Biodiversity in communities

The biodiversity of a community is determined by counting the types of species in a population and calculating the approximate numbers of each. Communities

generally have a few dominant species and a larger number of rarer ones. Tropical environments have the most number of species, followed by temperate and polar areas. A number of varied qualities determine the biodiversity of a given population or community.

Among the most important are:

- **Climate** - Climate is a key determinant of biodiversity in communities. The amount of solar energy is particularly important.
- **History** - The evolutionary history of a population explains much of the biodiversity (or lack thereof) in a community.
- **Disturbance** - Disturbance operates on a local scale to affect the total community.

The controlling elements in biodiversity for any community are a species' present evolutionary factors, predation, climate, and a host of other local conditions. These factors may be critical in local communities, but not on a regional or global scale.

Theories of community organization

There are two major theories that seek to explain community organization:

- The **equilibrium model** stresses biotic interaction and community stability over a period of time.
- The **no equilibrium model** posits that communities are in a constant state of flux as a result of disturbances.

Communities may be organized by competition, predation, or mutualism working in concert. Food webs are a model for understanding the food chain in a community. These are often very complicated arrangements. Competitive food webs that utilize a central resource are called guilds. Species diversity is very important in stable communities. Conservationists argue that this diversity tends to promote stability, and the extinction of a species increases the probability of chaos in the community organization. Restoration ecology uses community interactions to promote the restoration of endangered species and disorganized communities.

Models of community organization

There are two models of community organization:

- The **top-down model** of community organization changes when food webs are driven by predators.
- The **bottom-up model** of community organization is determined by the abundance of food and nutrients in a community.

Both models represent extreme situations; most communities are actually governed by a combination of both. The species-area curve states that the larger the geographical area, the more species will be present.

Factors such as climate, disturbances, environmental changes, and multiple other circumstances are present in causing various community organizations. Some communities exist in multiple stable states as disturbances move them from one state to another. This is very important to conservation ecologists, who determine management strategies to preserve and protect communities.

Community metabolism

Primary production

Primary production is the amount of energy generated by green plants over a fixed unit of time. It is highest in tropical rainforests, lower in temperate climes, and very low in arctic and desert environments. Total primary production is evenly distributed over land and sea. Production on land and sea is limited mainly by the supply of usable nutrients in each community. An innovation in satellite imagery now allows ecologists to evaluate and measure primary production on land and in the ocean. This information is valuable to scientists and agronomists in understanding nutrient cycling in biological communities.

Communities, like individual organisms, convert solar energy into chemical energy to live. Therefore, photosynthesis is the basis for all levels of life in a community. Only a tiny amount of the solar energy that reaches the earth, perhaps one percent or less, is used by plants to sustain life.

Secondary production

Secondary production is the sum total of energy produced by green plants that is utilized and dissipated by the other organisms in the biosphere. Energy generated by green plants is either eaten, burned in respiration, or lost as waste. Much of the energy is lost at each stage of the food chain, thus requiring a large amount of green plant material to sustain a relatively small number of animals. This is the rationale some vegetarians use to emphasize the efficiency of plants over animals as food. Only a small percentage of energy passes from one level of the food chain to the next. Over 80 percent of the energy is lost as waste in the biosystem. Animals have a relatively minor role in the food chain; plants and detritus are the main elements in the functioning of ecosystems. Secondary production is also limited by interacting factors in the ecosystem. Nutrients, climate, environmental changes, and disturbances all upset and impact the secondary production of an ecosystem.

Ecology

Ecology is the science of the relationship between organisms and their environment, where the environment refers to the physical and biological world of the organism. A relationship between an organism, the physical world, and all other species is the scope of ecology.

Ecology translates literally into “the study of the family household.” The term was used

originally by the German zoologist Ernst Haeckel in 1866. He limited his definition to the study of animals in relationship to their environment. This definition has been broadened and deepened over time to be more inclusive. The basic unit of ecology is the ecosystem, viewing the totality of the environment as a system of related parts functioning as a unit. Ecosystems have two interacting parts, the biotic or living component; and the abiotic or physical component. These two entities weave the complex and sophisticated set of relationships that make up ecology.

Studying ecology

Ecology is both a pure and an applied science. Scientists study ecology to learn more about the world and to seek practical solutions to ecological problems. Ecologists are being asked to make predictions about the impact of a myriad of proposals including land development, transportation, urban planning, and resource conservation. Global climate change is an increasing threat to the health of the planet. The ability to end and reverse many of the planet's environmental problems currently exists. These problems are often driven by social, economic, and political reasons, regardless of the overall impact on the ecosystems. The extinction rate of species is at an all-time high and population growth threatens everyone. This very serious problem facing the biosphere mandates active ecological planning and intervention.

Ecology as a science

The past 100 years has seen an explosion of ecological knowledge in the world. Ecology has evolved from a descriptive science making observations to a truly experimental science using the scientific method to test ecological processes. The use of sophisticated statistical analyses, quantitative methods, and precise testable hypotheses has brought ecology into the mainstream of science.

The growth of theoretical and experimental ecology has been mutually beneficial, setting the stage for an era of applied ecology. Debate and argumentation, the lifeblood of scientific inquiry, is active in the field of ecology. Theories are abundant, and the true test will be to verify their hypotheses and provide applications to the very real problems facing humanity.

The challenge facing ecologists is not only to provide workable solutions to these huge environmental problems, but to become active participants in the political and economic processes that guide peoples' lives.

Conservation ecology

Conservation ecology is the applied biology of preserving endangered species. Size of the endangered population is an important variable in conservation ecology. Another is the reason or reasons for a population's decline and extinction. Small populations are subject to the vagaries of climate change, genetic drift, and environmental accidents.

All these variables can contribute to the reduction and extinction of a species. Smaller populations must be studied to determine causes and to develop interventions to maintain the population. Extinctions are increasing worldwide, mostly due to habitat loss and competition from other species. Reserves or conservation areas are valuable, but are usually too small to protect larger animals. The key problem of conservation ecology is the growing human population and its impingement on the natural habitats of plants and animals. This raises important social and political questions that must be addressed in coming generations.

Adaptation

In the biosphere, there are an infinite number of possibilities in which organisms live. Temperature, light, climatic conditions, and many other factors are constantly in flux, forcing an organism to adapt in order to survive. Any form of life must maintain a reasonably constant internal environment within a range of conditions to be viable. This range is the limit of tolerance for the organism. The population and distribution of organisms depends on these tolerances and environmental variation. An organism lives in a habitat, which defines its niche. Niche in this sense includes all biological and environmental factors at work in the habitat. Organisms in large niches are called generalists, while those in small niches are termed specialists. Generalists have a wider range of tolerance than specialists, able to adapt more readily to a wider variation of conditions than specialists, which need more specific conditions in order to survive.

Species interaction

Interactions between species can be grouped either by the mechanisms by which they occur or by the effects they cause. Grouping on the basis of mechanism provides six broad categories of interaction:

1. **Mutualism** - Occurs when two species live in close association to the benefit of both.
2. **Predation** - One animal species preys on another animal species.
3. **Competition** - Two species use the same limited resource, to the detriment of both.
4. **Herbivore** - An animal species that eats all or part of a plant species.
5. **Disease** - A relationship between a microbe and host in which the host suffers.
6. **Parasitism** - A relationship where a parasite depends metabolically on a host.

These definitions overlap and are used very loosely by ecologists. For example, some scientists do not differentiate parasitism from disease, or predation from herbivore.

<u>Predation</u>

Predator-prey relationships are caused by evolutionary races where prey are selected

for their escape ability and predators are selected for their hunting ability. Predator-prey relationships are most easily studied when there is a one-predator, one-prey system; they become much more complicated in a multi-predator, multi-prey model. Laboratory systems do not lend themselves to the study of predation. Predation can be broken down into the categories of numerical, functional, developmental, and aggregative responses of predators to prey. These categories facilitate the study and understanding of predator-prey relationships. Predator-prey activity causes several adaptation phenomena, including the evolution of escape behavior and protective coloration in animals. Predation is a major process in the organization of communities and often alters the behavioral patterns within the given community, which may result in major upheavals.

Species competition

Competition between two species occurs when the two species strive to obtain a limited resource that each needs for itself. Competition may be evaluated by relatively simple mathematical models based on the logistic growth equation. This competition may result in one of the species' displacement, or in an established equilibrium between the two. The competitive exclusion principle states that complete competitors cannot exist together. This principle is not universal, however, as there are many examples of the coexistence of competing species. Competition between members of the same species is common and has an impact on population size and growth. It is more common among herbivores than carnivores. Competition over time leads to niche differentiation, which subsequently reduces competition between the species. To understand competition completely, the mechanisms at work and the resources involved must first be understood.

Herbivore

A herbivore's method of predation is unusual, as it only eats a part of the plant it feeds upon. This is because plants are modular organisms that have various defenses and deterrents in different modules. Plant defense is a field unto itself, which considers such questions as a plant's mode of defense and the benefits of fast or slow growth. Herbivores seem to exist in a modified equilibrium. The abundance of plants in the world almost guarantees that herbivores are will never destroy their food sources completely. The resource availability hypothesis states that plants growing slowly in hostile habitats should develop the strongest defense to avoid extinction. Not all herbivores are detrimental. Animals spread seeds and pollinate plants as part of the predation process. Various mutuality interactions have evolved where both the plants and the herbivores benefit from their predator-prey relationship.

Disease

Disease is one of the major interactions between species. This interaction always results in the parasite gaining and the host losing. Host populations may be susceptible, infected, or recovered individuals. The most crucial factor in the spread of disease is the basic reproductive rate of the disease organism, which is the average number of new infections spread by the affected individual over its lifespan. Applied disease ecology has as its goal to determine how best to protect the host population. Diseases and parasites can alter the reproductive rates and affect the mortality of their hosts. Current thinking on the evolution of diseases is that infectious parasites and their hosts are waging an evolutionary war, each evolving to maximize its fitness. Human disease is the subject of intense research and experimentation by medical scientists. Much less is known about disease in ecological systems. It is conceded that diseases introduced to new hosts can have a dramatic effect on population dynamics.

Effects of human activities

Human interaction with the ecosystem

As the human population grows, so does its impact on the environment. The current number of humans on the planet is pushing the limits of the biosphere to sustain them. It is impossible for the earth to sustain its current population if the high consumption level of developed countries continues. The greenhouse effect and global warming have significant implications for the earth's ecosystems. The burning of fossil fuels for energy and the clearing of natural habitats raises the atmospheric levels of carbon dioxide, unbalancing the global cycles upon which ecosystems depend. Climate changes and other disturbances are the result of this imbalance, which may result in a radical redistribution pattern for life on earth. Animal communities will be adversely impacted as their use of plants for energy is affected. The entire fabric of earth's biosphere is endangered and ecological concerns will become increasingly important in coming years.

Ecosystem metabolism

Nutrients, the lifeblood of ecosystems, constantly cycle through the ecosphere. There are both local and global nutrient cycles that affect all life. Nutrients may be said to reside in compartments, which are transferred by physical and biological processes. Nutrient cycles must replenish lost elements in order to sustain themselves. If this does not occur, the ecosystem will deteriorate over time. Global nutrient cycles include the important sulphur and nitrogen processes. Human disturbances have altered these patterns, as evidenced by the phenomena of acid rain. Sulphur emissions must be reduced to reverse this condition, but it may take many decades to accomplish this recovery. Human activity can also benefit ecosystems. For example, human

additions to the nitrogen cycles enrich both water and land areas and reduce nitrogen requirements for plant growth. Overall however, civilization has had a negative impact on ecosystems, degrading energy cycles and causing grave damage.

Acid rain

The troubling increase in acid rain has two major causes: sulfur oxides and nitrogen oxides. Although sulfur oxides are injected into the atmosphere by volcanic eruptions, the vast majority of them are produced during fossil fuel combustion. Coal and petroleum contain small quantities of sulfur that, when burned, are released into the atmosphere. The sulfur combines with the oxygen in water droplets, and the resulting mixture falls as acid rain. Meanwhile, whenever gasoline or coal is burned, nitrogen combines with oxygen to form nitrogen oxides. These compounds dissolve in water droplets to form nitric acid, which falls as rain. Acid rain destroys the outer layers of limestone buildings. It also acidifies the soil, which degrades the forests and woodlands. Acid rain increases the acidity of the water in lakes and rivers, posing a threat to aquatic life. Measures to combat acid rain include removing sulfur compounds from industry and limiting automobile emissions.

Strategies of Life

Reproduction, development, and life cycles of living organisms

Asexual and sexual reproduction

Asexual reproduction occurs in many different and unusual forms in nature. The common feature of asexual reproduction is that one parent passes on all of its genetic material to an offspring. The result is that asexually produced offspring are exact copies of the parent. Sexual reproduction involves two parents, each with two genes for every characteristic. Both parents pass on one gene each so that the offspring inherit a pair of different genes.

Due to mutations over long periods, genes come in alternate forms, called alleles, which determine how a trait will be represented in the offspring. Different alleles govern many different traits. Sexual reproduction makes new combinations of existing alleles. These new combinations lead to variations in physical and behavioral traits that lead to adaptation and selection, which are key components of evolution.

Animal reproduction

As a rule, animals produce sexually. Evolution has ensured that separation into male and female structures maximizes the chances for successful fertilization and

nutritional support to the offspring. It has also played a role in shaping behaviors of animals to assure these goals. Humans have a pair of primary reproductive organs, one for each gender: the sperm-producing testes in males and the egg-producing ovaries in females. These organs have supplementary ducts, glands, and supporting structures. Human males produce sperm continually from puberty onward. Females produce and release eggs on a monthly cycle. Hormones such as estrogen, progesterone, FSH, and LH control this cycle. The six stages of development are gamete formation, fertilization, cleavage, gastrulation, organ formation, and the growth and development of specialized tissues. All tissues and organs arise from three germ layers: the endosperm, ectosperm, and mesoderm of the early embryo. Embryonic development requires the help of some embryonic membranes including the yolk sac, amnion, chorion, and allantois.

Organization, structures, and functions of systems in multicellular organisms

Categories of animal tissues

Animal tissues may be divided into seven categories:

1. **Epithelial** - Tissue in which cells are joined together tightly. Skin tissue is an example.
2. **Connective** - Connective tissue may be dense, loose or fatty. It protects and binds body parts.
3. **Cartilage** - Cushions and provides structural support for body parts. It has a jelly-like base and is fibrous.
4. **Blood** - Blood transports oxygen to cells and removes wastes. It also carries hormones and defends against disease.
5. **Bone** - Bone is a hard tissue that supports and protects softer tissues and organs. Its marrow produces red blood cells.
6. **Muscle** - Muscle tissue helps support and move the body. The three types of muscle tissue are smooth, cardiac, and skeletal.
7. **Nervous** - Cells called neurons form a network through the body that control responses to changes in the external and internal environment. Some send signals to muscles and glands to trigger responses.

Animal respiration

Animals consume large amounts of energy through their activity. The energy to fuel this activity comes from aerobic metabolism, which uses oxygen to produce carbon dioxide. The process of aerobic respiration allows animals to move oxygen into their bodies and to release carbon dioxide into the external environment. Respiration may occur at various sites including the skin, gills (in aquatic animals), trachea, and lungs. In animals with lungs, airways carry gas to and from one side of the respiratory surface of the lungs, and blood vessels carry gas to and

from the other side. Respiration in the lungs begins with air moving in and out of the organ. Gases then diffuse across the lung's respiratory surfaces. Pulmonary circulation (the flow of blood to and from lung tissues) facilitates the diffusion of dissolved gases into and out of the lungs' capillaries. Gases then continue to diffuse in the tissues, between blood and interstitial fluid, and between blood and cells.

Human respiration

Connected airways of the body (including the nasal cavities, pharynx, larynx, trachea, bronchi, and bronchioles) provide a transport highway for respiration. Alveoli at the end of this system serve as the gas exchange mechanism of the system. As air is inhaled, oxygen brought into the lungs diffuses from the alveoli into pulmonary capillaries. It then diffuses into red blood cells and fuses with hemoglobin. When the oxygen-rich blood reaches the body tissues, the hemoglobin releases its oxygen, which diffuses out of the capillaries, through the interstitial fluid, and into the cells. The hemoglobin releases oxygen in response to body signals. Carbon dioxide then diffuses from cells, through interstitial fluid, into the bloodstream, completing the cycle.

Obtaining and storing matter and energy

Autotrophs and heterotrophs

Autotrophic organisms process carbon and energy from the physical environment, making them capable of nourishing themselves. Their carbon source is carbon dioxide, a gas dispersed in the atmosphere and dissolved in water. Only photosynthetic autotrophy can obtain energy from sunlight. Chemosynthetic autotrophy obtains energy by stripping electrons from inorganic substances.

Heterotrophs do not nourish themselves; they feed on autotrophs, organic wastes, and even other heterotrophs. They must obtain carbon and energy from compounds already built by autotrophs. Carbon and energy enter the biosphere through photosynthesis and are stored in organic compounds. This energy is released by chemical reactions that begin with glycolysis, the release of sugars. Aerobic respiration also releases stored energy.

Photosynthesis

<u>Light-dependent reactions</u>

Light-dependent reactions, the first stage of photosynthesis, are made up of the following parts:

1. Photons, packages of light energy composed of different wave lengths, are absorbed by pigments. Leaves are green because they have chlorophyll pigments. Carotene

pigments are yellow, orange, and red. Pigments of chloroplasts are organized as photo systems that absorb sunlight.

2. ATP and NADPH are then formed by the transfer of energy from chlorophyll through electron transport systems. These chemical reactions result in the formation of ATP from ADP and can occur through cyclic and non-cyclic processes. Cyclic activity occurs through photophosphorylation, where ATP forms alone. Non-cyclic photophosphorylation produces both ATP and NADPH forms together.
3. Oxygen, a byproduct of the non-cyclic pathway, changed the earth's atmosphere and allowed aerobic respiration to occur.

Energy sources in the human body

Human cells need a steady source of carbohydrates, fats, and proteins for energy and building blocks. When a person eats more carbohydrates than is needed, the excess is stored as glycogen and fat. The body can draw on these stores for energy when needed.

Glucose is the main energy source for the body. When energy needs demand it, a body's cells tap their stores of complex carbohydrates to release glucose subunits. They utilize fats next, with proteins as a last option. Thus, in the absence of readily available quick energy, the body's storage capacity becomes a source of vital energy. Fats are stored in the body in the cells of adipose tissue. Stored fats and proteins are made available for energy through a series of chemical reactions including glycolysis and the Krebs Cycle, and are transferred into usable energy by electron transport phosphorylation.

Flowering plants

There are almost 290,000 species of plants in the world. Most are flowering plants. Although species have many differences, they all have commonalities, including patterns of structural organization. The following are features that flowering plants exhibit in their body plans:

- Shoot systems
- Root systems
- Ground tissues
- Vascular tissues
- Dermal tissues
- Meristems
- Monocots and dicots

<u>Root and shoot systems</u>

Root systems usually grow underground and have multiple functions. They anchor the plant to the ground and provide structural support. The root system serves to absorb water and nutrients from the soil and transfers water and solutes throughout the plant. It also serves as a storage facility for food. Types of root systems include taproots and fibrous roots.

Shoot systems consist of stems and leaves. The stems form a matrix for the upward growth of the plant. These growth tissues in leaves are exposed to sunlight and photosynthesis occurs. Plant flowers are favorably exposed to pollinators. Portions of the shoot system also store food. A major function of the shoot system is to transport water, minerals, and nutrients to roots, leaves, and other plant parts. Thus, the shoot system provides a series of critical functions necessary for plant life to prosper.

Plant tissues

Three main types of plant tissues are found in root and shoot systems:

1. Ground tissues form the bulk of plant tissues. The most common type, parenchyma, generally have thin walls and have important functions in photosynthesis, secretion, and food and water storage. Other ground tissues with thick walls provide structural support for plants.
2. Vascular tissue is either xylem or phloem. Xylem is a transporter of water, minerals, and vital nutrients. It does this by forming pipelines through stems, leaves, and roots. Xylem also aids in supporting the plant structurally. Phloem rapidly transports solutes and sugar through the plant and plays a role in photosynthesis.
3. Dermal tissues form the outer covering of the plant, known as the epidermis. A cuticle coats the outer layer of the epidermis with waxes and fats for protection and insulation.

All new tissue arises from bud-like masses of cells known as meristems.

Leaves and buds

Leaves are the main site on a plant where photosynthesis occurs. The point on a leaf's stem where one or more leaves are attached is called a node. Spaces between nodes are called internodes. A bud is a developing shoot that gives rise to leaves, flowers, or both. Leaves may be either stalked or unstalked. Leaves have a wide variety of shapes and qualities, including scales, hooks, or hairs which serve functional purposes. Leaves live only a short time, dropping away from the stem as winter approaches. Internally, photosynthetic cells are grouped near the surface of the leaf. Veins are vascular bundles that form a transport system in leaves. These veins move water and its solutes to assist photosynthesis and remove waste material produced in this process. Stomata are structures that exchange carbon dioxide, oxygen, and water vapor from leaves.

Nutritional requirements

Plants use oxygen, carbon, and hydrogen as their main building blocks. From these elements they produce fats, carbohydrates, proteins, and nucleic acids. An additional thirteen dissolved salts or mineral ions are also essential for plant life. Both macro and micro nutrients also play an important role

in plant health. Macronutrients means a significant amount of the ion is necessary; micronutrients only require a trace amount for optimal plant health. In the absence of any essential nutrient, a plant cannot grow well. In various geographical regions, an important element may be missing. In the production of crops, these elements may be added by fertilizers or other crop supporting elements; nitrogen is often the missing element.

Water absorption

Plants must obtain adequate water for root development, which in turn affects the growth of the whole plant. Abundant water and minerals spur root growth. Membrane transport mechanisms control the types of solutes that are dispersed through the plant. Root hairs are important specialized epidermal cells that promote water absorption. They provide additional surface area for the plant to absorb water and other nutrients. One root system may add millions of root hairs for this purpose. Mycorrhiza is another process that is important for plants to absorb nutrients. Mycorrhiza is a symbiotic relationship between a root and a fungus; the fungus extends filaments around the root system, which multiplies the water absorbing abilities of the root. In exchange, the fungus uses some of the root's sugar and nitrogen thus creating symbiosis, a relationship that is mutually beneficial to both organisms.

Water conservation and transport

Most of the water in a plant that moves from the roots through the stems and leaves will evaporate. Less than one percent is used by the plant for growth. Water evaporation from stems, leaves, and plants is called transpiration. Water moves from the roots to the plant body through the xylem, the water transport element of the plant. The cohesion theory of water transport explains that water is pulled upward by the drying power of air, the pressure that extends downward from leaves to roots, drawing the water upward. Translocation is the process that occurs in phloem and distributes water through the plant.

Stomas are the structures that control water loss by opening and closing. They open during daylight to allow photosynthesis to occur as water is lost and carbon dioxide enters the cells. They then close at night, accumulating carbon dioxide and conserving water.

Plant reproduction

Plants have complex reproductive systems and can reproduce both sexually and asexually. Asexual reproduction is by mitosis, resulting in a clone. Sexual reproduction requires sperm and egg cells. Female structures house the egg embryo and attract the pollinators that work to combine the eggs and sperm. Examples of pollinators include birds and insects, as well as air currents. A plant is a sporophyte, a body composed of diploid cells. The sporophyte produces flowers, which are reproductive

shoots. Flower cells divide by meiosis and produce gametophytes, made of haploid cells. Male gametophytes produce sperm while female gametophytes produce eggs. Pollen grains are released by the plant and travel to the eggs, where fertilization occurs. Sexual reproduction is the dominant feature of the life cycle of flowering plants.

Pollination, fertilization, and seeds

A flower has both male parts, known as stamens, and female parts, known as carpels. Pollen grains, which are male gametophytes, develop in the anther of each stamen. The ovary is located inside each carpel. It is in the ovary where eggs develop, fertilization occurs, and seeds grow. Pollination is the transfer of pollen grains to a carpel's stigma. This is facilitated by birds, insects, and other agents. As pollen tubes grow, two sperm cells develop within it. Fertilization occurs after a sperm nucleus joins with an egg nucleus to form a fertilized zygote. A nutritive tissue called endosperm is formed to nurture the zygote. Seeds are mature ovules that form within carpels and house eggs. After fertilization, the ovule expands and the endosperm forms the seed coat. The ovary develops into the fruit which protects and spreads the seeds. The next step is germination.

Plant germination

As a plant embryo absorbs water and nutrients, it grows until it breaks through the seed coating. When the first or primary root breaks through the seed coat, germination is achieved. The plant then enters a stage of rapid growth and increases dramatically in size. Specialized dermal, ground, and vascular tissues are produced during this stage. Later, flowers, fruit, and new seeds form. These processes are stimulated by hormones and enzymes as well as environmental conditions. There are five major types of plant hormones:

1. Auxin increases and hastens stem elongation.
2. Gibberellin increases and hastens stem elongation.
3. Ethylene fosters fruit ripening.
4. Abscisic acid promotes water conservation.
5. Cytotoxins are a stimulus to cell division and promote leaf expansion.

All of these hormones serve as signaling molecules that trigger cellular changes in plants.

Biological clocks

Plants have a variety of internal control systems called biological clocks. Some important ones include:

- Photoperiodism - A seasonal response that occurs as days and nights vary in length. Plants use a photoreceptor protein to monitor the changing conditions.
- Circadian rhythms - Plant activities that occur in cycles of 24 hours without regard for external conditions.

- Senescence - A group of processes that ultimately results in the death of the plant. Senescence is a response to biological and environmental cues.
- Dormancy - When a plant stops growing for no apparent reason it has entered a stage of dormancy. The plant will not resume growth during this time. Short days and long nights seem to trigger this dormancy.
- Flowering process - The flowering process is adjusted by the plant's control systems by measuring the lengths of days and nights and responding accordingly.

Human anatomy and physiology

Skeletal system

The skeletal system has an important role in the following body functions:

- **Movement** - The action of skeletal muscles on bones moves the body.
- **Mineral Storage** - Bones serve as storage facilities for essential mineral ions.
- **Support** - Bones act as a framework and support system for the organs.
- **Protection** - Bones surround and protect key organs in the body.
- **Blood Cell Formation** - Red blood cells are produced in the marrow of certain bones.

Bones are classified as long, short, flat, or irregular. They are a connective tissue with a base of pulp containing collagen and living cells. Red marrow, an important site of red blood cell production, fills the spongy tissue of many bones. Bone tissue is constantly regenerating itself as the mineral composition changes. This allows for special needs during growth periods and maintains calcium levels for the body. Bone turnover can deteriorate in old age, particularly among women, leading to osteoporosis.

Human body

The skeletal structure in humans contains both bones and cartilage. There are 206 bones in the human body, arranged in two parts:

1. **Axial skeleton** - Includes the skull, sternum, ribs, and vertebral column (the spine).
2. **Appendicular skeleton** - Includes the bones of the arms, feet, hands, legs, hips, and shoulders.

The flexible and curved backbone is supported by muscles and ligaments. Intervertebral discs are stacked one above another and provide cushioning for the backbone. Trauma or shock may cause these discs to herniate and cause pain. The sensitive spinal cord is enclosed in a cavity well protected by the bones of the vertebrae. Joints are areas of contact adjacent to bones. Synovial joints are the most common, and are freely moveable. These may be found at the shoulders and knees. Cartilaginous joints fill the spaces between some bones and restrict movement. Examples of

cartilaginous joints are those between vertebrae. Fibrous joints have fibrous tissue connecting bones and no cavity is present.

Muscular system

There are three types of muscle tissue: skeletal, cardiac, and smooth. There are over 600 muscles in the human body. All muscles have these three properties in common:

1. **Excitability** - All muscle tissues have an electric gradient which can reverse when stimulated.
2. **Contraction** - All muscle tissues have the ability to contract, or shorten.
3. **Elongate** - Muscle tissues share the capacity to elongate, or relax.

Only skeletal muscle interacts with the skeleton to move the body. When they contract, the muscles transmit force to the attached bones. Working together, the muscles and bones act as a system of levers which move around the joints. A small contraction of a muscle can produce a large movement. A limb can be extended and rotated around a joint due to the way the muscles are arranged.

Integumentary system

The skin and its associated structures are called the integumentary system. It provides the following key functions:

- Protection of the body from abrasion and bacterial attack.
- Serves as a control mechanism for internal temperature.
- Provides a reserve of blood vessels that can be used as necessary.
- Produces vitamin D for metabolic purposes.

The covering of the skin is the epidermis and the layer beneath that is the dermis. The dermis consists of dense connective tissue which protects the body. Skin structure varies widely among animals according to the needs of the particular species. Pigments determine skin color. The process of keratinization results in a new layer of top skin in humans every month or so. This process helps the skin heal itself after minor injuries and forms a barrier against toxic substances and bacterial infections.

Digestive system

Most digestive systems function by the following means:

- **Movement** - Movement mixes and passes nutrients through the system and eliminates waste.
- **Secretion** - Enzymes, hormones, and other substances necessary for digestion are secreted into the digestive tract.
- **Digestion** - Includes the chemical breakdown of nutrients into smaller units that enter the internal environment.

- **Absorption** - The passage of nutrients through plasma membranes into the blood or lymph and then to the body.

The human digestive system consists of the mouth, pharynx, esophagus, stomach, small and large intestine, rectum, and anus. Enzymes and other secretions are infused into the digestive system to assist the absorption and processing of nutrients. The nervous and endocrine systems control the digestive system. Smooth muscle moves the food by peristalsis, contracting and relaxing to move nutrients along.

Mouth and stomach

Digestion begins in the mouth with the chewing and mixing of nutrients with saliva. Only humans and other mammals actually chew their food. Salivary glands are stimulated and secrete saliva. Saliva contains enzymes that initiate the breakdown of starch in digestion. Once swallowed, the food moves down the pharynx into the esophagus en route to the stomach. The stomach is a flexible, muscular sac. It has three main functions:

1. Mixing and storing food
2. Dissolving and degrading food via secretions
3. Controlling passage of food into the small intestine

Protein digestion begins in the stomach. Stomach acidity helps break down the food and make nutrients available for absorption. Smooth muscle contractions move nutrients into the small intestine where the absorption process begins.

Small intestine

In the digestive process, most nutrients are absorbed in the small intestine. Enzymes from the pancreas, liver, and stomach are transported to the small intestine to aid digestion. These enzymes act on fats, carbohydrates, nucleic acids, and proteins. Bile is a secretion of the liver and is particularly useful in breaking down fats. It is stored in the gall bladder between meals. By the time food reaches the lining of the small intestine, it has been reduced to small molecules. The lining of the small intestine is covered with villi, tiny absorptive structures that greatly increase the surface area for interaction with chyme. Epithelial cells at the surface of the villi, called microvilli, further increase the ability of the small intestine to serve as the main absorption organ of the digestive tract.

Large intestine

Also called the colon, the large intestine concentrates, mixes, and stores waste material. A little over a meter in length, the colon ascends on the right side of the abdominal cavity, cuts across transversely to the left side, then descends and attaches to the rectum, a short tube for waste disposal. When the rectal wall is distended by waste material, the nervous system triggers an impulse in the body to expel the waste from the rectum. A muscle sphincter at the end of

the anus is stimulated to facilitate the expelling of waste matter. The speed at which waste moves through the colon is influenced by the volume of fiber and other undigested material present. Without adequate bulk in the diet, it takes longer to move waste along, sometimes with negative effects. Lack of bulk in the diet has been linked to a number of disorders.

Solute - water balance

Mammals usually take in as much water as they lose over a day's time. Water gains are affected by absorption of water from ingested substances and the process of metabolism which yields water as an end product. Water is lost by the body in five ways:

1. Excretion through the urinary system.
2. Evaporation from skin surfaces.
3. Evaporation from respiratory surfaces.
4. Sweating
5. Elimination through the gastrointestinal tract.

Solutes are also added to the body by secretions, waste products, and absorption from the gastrointestinal tract. Urine is formed through the process of filtration of fluid, reabsorption of fluid into the blood, secretion of substances into the kidney, and finally excretion through the urinary tract. Urine flows from each kidney into the ureters, which leads to the bladder. It leaves the bladder through a tube, the urethra, and is expelled from the body. The hormone ADH controls the body's need to retain or expel water.

Human nutrition

Energy from food supplies the body with the basic fuel necessary to function. Food energy is measured in the thousands of calories, or kilocalories. To maintain health and an appropriate weight, caloric intake must be balanced with energy output. This output varies due to differences in age, activity, genetic structure, metabolism, gender, and social and emotional environment. For most individuals, caloric intake and expenditure balance over long periods of time. Weight tends to remain stable in these situations. Obesity is an excess of fat in the body's adipose tissues, caused by an imbalance in caloric intake and output. There is much controversy over what should be considered an ideal weight. What is certain is that serious disorders are more likely to occur when an individual's weight is at one of the extremes of a weight range.

<u>Carbohydrate, lipid, and protein</u>
Carbohydrate - The body's main source of energy. Carbohydrate molecules are broken down into glucose molecules to fuel body tissues. Complex carbohydrates such as whole grains, fruits, peas, and beans are ideal energy sources as they burn at a slower rate and supply a steady flow of energy.

Lipid - Lipids or fats are used by the body as energy reserves, cushioning, and insulation. They are also components of cell membranes. Although the body can produce its own fats, essential fatty acids must be obtained from the diet.

Protein - When digested and absorbed, proteins provide amino acids for the body to use to build its own protein structures. There are eight essential amino acids (out of 20 total) which human cells cannot build and must come from the diet. A complete protein contains all the essential amino acids while an incomplete one does not. Net protein utilization measures the completeness of a protein.

Vitamins and minerals

Vitamins are organic substances essential to a normal metabolism. Vitamins must generally be obtained from food, as the body cannot produce most of them. Human beings need at least thirteen different vitamins, each serving a distinct metabolic function. Many chemical reactions depend on vitamins and an absence of one can have serious effects.

Minerals are inorganic substances essential to metabolic functioning. Many chemical reactions use minerals such as calcium, potassium, and magnesium. Iron is essential for the hemoglobin in red blood cells. The most sensible way to insure that the body gets appropriate and necessary vitamins and minerals is to eat a well rounded diet including carbohydrates, proteins, and fats. There is no clear evidence that supplementary vitamins and minerals are useful. Excessive vitamin doses are wasteful and, in some cases, even harmful.

Circulatory system

The circulatory system is responsible for the internal transport of substances to and from the cells. The circulatory system usually consists of the following three parts:

1. **Blood** - Blood is composed of water, solutes, and other elements in a fluid connective tissue.
2. **Blood Vessels** - Tubules of different sizes that transport blood.
3. **Heart** - The heart is a muscular pump providing the pressure necessary to keep blood flowing.

Circulatory systems can be either open or closed. Most animals have closed systems, where the heart and blood vessels are continually connected. As the blood moves through the system from larger tubules through smaller ones, the rate slows down. The flow of blood in the capillary beds, the smallest tubules, is quite slow. A supplementary system, the lymph vascular system, cleans up excess fluids and proteins and returns them to the circulatory system.

Blood

Blood helps maintain a healthy internal environment in animals by carrying raw materials to cells and removing waste

products. It helps stabilize internal pH and hosts various kinds of infection fighters. An adult human has about five quarts of blood. Blood is composed of red and white blood cells, platelets, and plasma. Plasma constitutes over half of the blood volume. It is mostly water and serves as a solvent. Plasma contains plasma proteins, ions, glucose, amino acids, hormones, and dissolved gases. Red blood cells transport oxygen to cells. Red blood cells form in the bone marrow and can live for about two months. These cells are constantly being replaced by fresh ones, keeping the total number relatively stable.

White blood cells defend the body against infection and remove various wastes. The types of white blood cells include lymphocytes, neutrophils, monocytes, eosinophils, and basophils. Platelets are fragments of stem cells which serve an important function in blood clotting.

Human heart

The heart is a muscular pump made of cardiac muscle tissue. It has four chambers; each half contains both an atrium and a ventricle, and the halves are separated by an AV valve. The valve is located between the ventricle and the artery leading away from the heart. Valves keep blood moving in a single direction and prevent any backwash into the chambers. The heart has its own circulatory system with its own coronary arteries. The heart functions by contracting and relaxing. Atrial contraction fills the ventricles and ventricular contraction empties them, forcing circulation. This sequence is called the cardiac cycle. Cardiac muscles are attached to each other and signals for contractions spread rapidly. A complex electrical system controls the heartbeat as cardiac muscle cells produce and conduct electric signals. These muscles are said to be self-exciting, needing no external stimuli.

Blood pressure

Blood pressure is the fluid pressure generated by the cardiac cycle. Arterial blood pressure functions by transporting oxygen-poor blood into the lungs and oxygen-rich blood to the body tissues. Arteries branch into smaller arterioles which contract and expand based on signals from the body. Arterioles are the site where adjustments are made in blood delivery to specific areas based on complex communication from body systems. Capillary beds are diffusion sites for exchanges between blood and interstitial fluid. A capillary has the thinnest wall of any blood vessel, consisting of a single layer of endothelial cells. Capillaries merge into venues which in turn merge with larger diameter tubules called veins. Veins transport blood from body tissues back to the heart. Valves inside the veins facilitate this transport. The walls of veins are thin and contain smooth muscle and also function as blood volume reserves.

Immune system

Nonspecific defense responses

The body's general immune defenses include:

- **Skin** - An intact epidermis and dermis forms a formidable barrier against bacteria.
- **Ciliated Mucous Membranes** - Cilia sweep pathogens out of the respiratory tract.
- **Glandular Secretions** - Secretions from exocrine glands destroy bacteria.
- **Gastric Secretions** - Gastric acid destroys pathogens.
- **Normal Bacterial Populations** - Compete with pathogens in the gut and vagina.

In addition, phagocytes and inflammation responses mobilize white blood cells and chemical reactions to stop infection. These include localized redness, tissue repair, and fluid-seeping healing agents. Additionally, plasma proteins act as the complement system to repel bacteria and pathogens.

Specific defense responses

Three types of white blood cells form the foundation of the body's immune system. They are:

1. **Macrophages** - Phagocytes that alert T cells to the presence of foreign substances.
2. **T Lymphocytes** - These directly attack cells infected by viruses and bacteria.
3. **B Lymphocytes** - These cells target specific bacteria for destruction.

Memory cells, suppressor T cells, and helper T cells also contribute to the body's defense. Immune responses can be anti-body mediated when the response is to an antigen, or cell-mediated when the response is to already infected cells. These responses are controlled and measured counter-attacks that recede when the foreign agents are destroyed. Once an invader has attacked the body, if it returns it is immediately recognized and a secondary immune response occurs. This secondary response is rapid and powerful, much more so than the original response. These memory lymphocytes circulate throughout the body for years, alert to a possible new attack.

Abnormal immune responses

Abnormal immune responses fall into three major categories:

1. **Autoimmune response** - This response occurs when lymphocytes attack the cells of the body. Sometimes, victims of these disorders display a high level of an anti-body that locks on the immune defense cells as if they were antigens. Rheumatoid arthritis is an example of such a disease. Joints become inflamed, fluid accumulates, and cycles of inflammation continue until the joint is badly damaged.
2. **Allergies** - These are secondary immune responses to a substance that would not usually cause harm. Exposure to certain foods, pollen, dust, medications, and insect venom

can all cause allergic reactions by triggering an abnormal response. Various factors, including genetic makeup, can dispose an individual to allergies. Some allergens can now be identified by tests and medications can be given to moderate their affects on the body.

3. **Deficient Human Responses** - Occasionally, cell-mediated response becomes weak and the organism becomes vulnerable to otherwise relatively mild diseases. AIDS (acquired immune deficiency syndrome) is just such a case. The AIDS virus may weaken the immune system's responses so much that diseases like pneumonia can become deadly.

Immunization

Immunization may be defined by deliberately invading a body with an antigen that causes an immune response and the production of memory lymphocytes. A vaccine, either oral or injectable, elicits a primary immune response. A booster may then be given that provokes a secondary response and starts the production of memory cells. These memory cells provide long lasting protection against bacteria. Genetically engineered vaccines have been used experimentally to immunize laboratory animals against rabies, hepatitis B, influenza, and other serious maladies. Genetically engineered vaccines are less dangerous than a weakened but still whole pathogen. If individuals have already been exposed to a disease, antibodies may be injected directly. This gives the person passive immunity, and though temporary, will help fight the immediate threat. This type of immunity may be used against diphtheria, botulism, and other deadly diseases.

Human nervous system

The human nervous system senses, interprets, and issues commands as a response to conditions in the body's environment. This process is made possible by a very complex communication system organized as a grid of neurons. Messages are sent across the plasma membrane of neurons through a process called action potential. These messages occur when a neuron is stimulated past a necessary threshold. These stimulations occur in a sequence from the stimulation point of one neuron to its contact with another neuron. At the point of contact, called a chemical synapse, a substance is released that stimulates or inhibits the action of the adjoining cell. This network fans out across the body and forms the framework for the nervous system. The direction the information flows depends on the specific organizations of nerve circuits and pathways.

Central nervous system

There are two primary components of the central nervous system:

1. **Spinal cord** - The spinal cord is encased in the bony structure of the vertebrae, which protects and supports it. Its nervous tissue functions mainly with respect to limb movement and internal organ activity. Major nerve tracts ascend and descend from the spinal cord to the brain.
2. **Brain** - The brain consists of the hindbrain, which includes the medulla oblongata, cerebellum, and pons. The midbrain integrates sensory signals and orchestrates responses to these signals. The forebrain includes the cerebrum, thalamus, and hypothalamus. The cerebral cortex is a thin layer of gray matter covering the cerebrum. The brain is divided into two hemispheres, with each responsible for multiple functions.

Peripheral nervous system

The peripheral nervous system consists of the nerves and ganglia throughout the body and includes sympathetic nerves which trigger the "fight or flight" response, and the parasympathetic nerves which control basic body function.

Endocrine system

The endocrine system is responsible for secreting the hormones and other molecules that help regulate the entire body in both the short and the long term. There is a close working relationship between the endocrine system and the nervous system. The hypothalamus and the pituitary gland coordinate to serve as a neuroendrocrine control center. Hormone secretion is triggered by a variety of signals, including hormonal signs, chemical reactions, and environmental cues. Only cells with particular receptors can benefit from hormonal influence. This is the "key in the lock" model for hormonal action. Steroid hormones trigger gene activation and protein synthesis in some target cells. Protein hormones change the activity of existing enzymes in target cells. Hormones such as insulin work quickly when the body signals an urgent need. Slower acting hormones afford longer, gradual, and sometimes permanent changes in the body.

Endocrine glands

- **Adrenal cortex** - Monitors blood sugar level; helps in lipid and protein metabolism.
- **Adrenal medulla** - Controls cardiac function; raises blood sugar and controls the size of blood vessels.
- **Thyroid gland** - Helps regulate metabolism and functions in growth and development.
- **Parathyroid** - Regulates calcium levels in the blood.
- **Pancreas islets** - Raises and lowers blood sugar; active in carbohydrate metabolism.
- **Thymus gland** - Plays a role in immune responses.

- **Pineal gland** - Has an influence on daily biorhythms and sexual activity.
- **Pituitary gland** - Plays an important role in growth and development.

Endocrine glands are intimately involved in a myriad of reactions, functions, and secretions that are crucial to the well-being of the body.

Lymphatic system

The main function of the lymphatic system is to return excess tissue fluid to the bloodstream. This system consists of transport vessels and lymphoid organs. The lymph vascular system consists of lymph capillaries, lymph vessels, and lymph ducts. The major functions of the lymph vascular system are:

- The return of excess fluid to the blood.
- The return of protein from the capillaries.
- The transport of fats from the digestive tract.
- The disposal of debris and cellular waste.

Lymphoid organs include the lymph nodes, spleen, appendix, adenoids, thymus, tonsils, and small patches of tissue in the small intestine. Lymph nodes are located at intervals throughout the lymph vessel system. Each node contains lymphocytes and plasma cells. The spleen filters blood stores of red blood cells and macrophages. The thymus secretes hormones and is the major site of lymphocyte production.

Cells and the Chemistry of Life

Cell structure and function

Prokaryotic cells

Prokaryotic cells are the smallest and the least complex of all cells. The word prokaryotic translates to "before the nucleus." Scientists think this means some prokaryotes existed on earth before a nucleus evolved. DNA is contained in the cytoplasm of prokaryotes rather than a nuclear envelope as seen in other cells. Bacteria are prokaryotic. They have a rigid cell wall protecting the plasma membrane. This wall gives the cell support and furnishes boundaries for the cell. It is formed by secretions from the bacteria. Under the wall, a plasma membrane controls passage of substances in and out of the cell. Bacteria cells have a small amount of protoplasm, which includes numerous ribosomes. A ribosome is composed of RNA and protein molecules. Ribosomes make new proteins and polypeptide chains are constructed on their surface.

Eukaryotic cells

Eukaryotic cells include all cells except bacteria. They contain a true nucleus and have several kinds of organelles (small organs). Eukaryotic cells also have a network of filaments and tubules called a cytoskeleton. The cytoskeleton gives shape to the cell and controls cellular movement. Multiple chemical reactions are continually occurring in eukaryotic cells. Each cell contains the following organelles:

1. Nucleus
2. Endoplasmic reticulum
3. Golgi bodies
4. Lysosomes
5. Transport vehicles
6. Mitochrondia
7. Vacuoles

Eukaryotic cells contain thousands of ribosomes which are attached to membranes or float freely in the cytoplasm. Photosynthetic eukaryotic cells also contain chloroplasts which are used for food production and storage.

Basic cell features

Basic cell theory states:

- All organisms are made of cells.
- The cell is the basic living unit of organization.
- All cells arise from preexisting cells.

Cellular details may be observed in great detail with electron microscopes. Basic cell structure and function may be understood as follows:

- The plasma membrane separates internal cellular metabolism from the external environment. The membrane is permeable and allows

substances to move across. It also has receptors for external molecules.
- The nucleus is contained in an envelope and has the genetic instructions to ensure characteristics are passed on from parent to offspring.
- The cytoplasm is located inside the plasma membrane and surrounds the nucleus. It has compartments where various metabolic processes occur. The cytoplasm contains particles and filaments floating in a semi-liquid substance. The filaments form a skeleton that gives the cell shape and allows for movement of cell structures.

Cell membranes

Cell membranes are composed mainly of lipids and proteins. A lipid bilayer is the structural basis of the cell membrane and serves as a barrier between fluids inside and outside of the cell. Proteins in this bilayer carry out most functions of the membrane. Cell transport functions to provide cells with necessary materials and to eliminate wastes. Transport across cell membranes is divided into five categories:

1. **Diffusion** is the process of molecules moving down the concentration gradient, from areas of greater concentration to areas of less concentration. If no other forces are active, diffusion is the method of transport.
2. **Osmosis** is the movement of water across membranes as a result of a concentration gradient, a pressure gradient, or both.
3. **Passive transport** is how fluids cross the membrane through proteins embedded in the bilayer.
4. **Active transport** occurs when a transport protein receives energy from adenosine triphosphate that allows it to move with or against the concentration gradient.
5. **Endocytosis and exocytosis** occur when cells create sacs or vesicles to transport or store substances within the cytoplasm.

Nucleus

The nucleus of a cell controls access to DNA and packages the DNA for cell division. The nucleus is composed of the following structures:

1. The nuclear envelope is the outermost part of the nucleus. It is composed of two lipid bilayers. The nuclear envelope is the boundary that allows exchanges of material between the nucleus and the cytoplasm.
2. The nucleolus is a dense mass formed inside the nucleus during cell growth. The nucleolus is where units of ribosomes are developed before being transported out of the nucleus.
3. Eukaryotic DNA is like a thread with beads of proteins attached to it. As a cell divides, DNA molecules are

duplicated and twisted into condensed structures. These condensed structures are called chromosomes, which means "colored bodies." DNA and its proteins are called chromosomes whether they are in a threadlike or condensed form.

Endoplasmic reticulum

The membrane of the endoplasmic reticulum (ER) has both smooth and rough portions, depending on whether or not ribosomes are present. Each type has particular functions and specialized sites.

- Smooth ER is free of ribosomes and curves throughout the cytoplasm like a series of tunnels. Although it is not involved in actual protein synthesis, it is the site where newly synthesized proteins and lipids are budded. Smooth ER is most developed in seeds and animal cells that secrete steroid hormones.
- By contrast, rough ER has a large number of ribosomes attached in stacks, much like pancakes. Polypeptide chains move through the rough ER to be secreted outside the cell or delivered to organelles. Rough ER is common in cells that produce secretions, such as those which produce digestive enzymes such as pepsin and resin.

Golgi bodies

Golgi bodies were first discovered by Nobel Prize winner Camillo Golgi, hence their name.
Golgi bodies are a stack of flat, bag-like membranes surrounded by storage units. Transport vesicles, in the form of tiny sacs, carry the products of the endoplasmic reticulum to the Golgi bodies. From there, many proteins and lipids are processed into their final products and packaged for their final destinations. Some secretory cells concentrate and store products in the Golgi bodies until the cells receive signals to release them. The Golgi bodies have the capacity to create vesicles for this storage purpose. The entire pathway from rough endoplasmic reticulum through the Golgi bodies is the major "highway" for moving materials out of the cell. This function is most important for the disposal of wastes as well as the transport of vital cellular material out of the cell.

Vacuoles

Although vacuoles appear to be empty sacs, they are actually filled with fluids and molecules used for many purposes. Vacuoles are of particular importance to single-celled organisms such as amoebae. The central vacuole, found most often in mature plants, occupies most of the cell interior. This leaves only a narrow slice of protoplasm between the vacuole and plasma membrane. This central vacuole serves as a

water reservoir, and as a storage site for sugars and proteins, as well as pigments that give plants and flowers bright colors. The fluid inside a plant vacuole contributes to the structural strength of the plant. During growth, plant cell walls enlarge from water pressure built up in the vacuole. The cell itself enlarges from this pressure and its increased surface area increases the ability of the plant to absorb nutrients. Thus, vacuoles play a major role in plant growth and development.

Cytoskeleton

The cytoskeleton is a complex system of intertwined fibers that extend from the nucleus to the plasma membrane. Each type of cell displays a unique shape and internal organization made possible by its cytoskeleton. The major components of the cytoskeleton are microtubules, microfilaments, and intermediate filaments. These are all made from units of protein. Some units of the cytoskeleton are transient, appearing and disappearing at different times during the life of a cell. For example, microtubules assemble when it is time to form a spindle for moving chromosomes during cell division, and then disappear after the task is completed. Other units of the cytoskeleton are permanent. For example, permanent filaments in the skeletal muscle cells are the basis of contraction. Flagella and cilia are other examples of other permanent structures.

Flagella and cilia

Flagella are constructed of microtubules and transport eukaryotic cells through their environment. They are fine whip-like organelles that undulate to move a cell forward or backward by propulsion. This propulsion is caused by tiny side "arms" that extend from the microtubules. Certain protistans have one or more flagella, as do sperm cells. Cilia are shorter than flagella, can number from a few to hundreds, and work together as a unit to propel materials. They are typically arrayed at the surface of the cell. Cells often use cilia for stirring up their environment. For example, cilia expel airborne bacteria and other particles from the lungs by coordinating their beating movements. Both flagella and cilia have the same organization, in which nine pairs of microtubules form a ring around two central tubules. This is called a "9+2 array."

Lysosomes

Lysosomes are the main digestion organelles of cells. Some vesicles extending from Golgi bodies become lysosomes. They are shaped as bags in the membrane. Various enzymes contained in these sacs break down polysaccharides, nucleic acids, and some lipids. Lysosomes often fuse with transport vesicles carrying a variety of substances. Lysosomes are helpful in clearing the cell of all types of waste materials. This is vital to cell life as an accumulation of waste products can be toxic to the cell. Lysosomes

clear the cell of worn out cell parts and destroy bacteria and foreign particles. Bacteria cells are destroyed by dismantling a sugar chain in a bacterium's cell wall. When enough sugar chains are broken, the bacterial cell is lysed and the invading cell dies.

Cell walls

Cell walls provide support and protection for cells. They have a carbohydrate framework. Two important elements of cell walls are:

1. The extracellular matrix is a meshwork that holds cells together. It is composed of collagen, fibrous proteins, and specialized substances that form a gel-like base. This matrix influences a cell's shape, how it will divide, and even its metabolism to some degree. Nutrients, hormones, enzymes, and other molecules diffuse from cell to cell through the extracellular matrix.
2. Cell junctions provide the means for multicellular organisms to interact with adjacent cells and the material surrounding the organism. At tissue surfaces, cells link closely together to protect the organism from exposure to external materials. In tissues, cells of the same type cling together. Cells sometimes share channels to exchange signals and nutrients. Multicelled organisms depend on linkage and communication between cells.

Chemical components of cells

Carbon compounds

The most common elements in the human body are carbon, oxygen, and hydrogen. Carbon is the most important structural element in the body. Carbon-based molecules are present in cells as organic compounds. These compounds link into chains or rings for structural utility. Organic compounds of less than 20 carbon atoms are grouped into four families: Simple sugars, fatty acids, amino acids and nucleotides. These compounds are usually dissolved in cellular fluids and are used as building blocks or energy sources for larger molecules including lipids, proteins, polysaccharides, and nucleic acids. These four play a critical role in cellular growth and reproduction; they have multiple functions in the life of a cell and the integrity of cellular life depends upon them.

Carbohydrates

Carbohydrates can be simple sugars or large molecules composed of simple sugar units. They are the most abundant molecules and cells use them as structural materials or as energy that can be stored or quickly used.

A monosaccharide is the simplest form of a carbohydrate. It is also the most readily available form of glucose, which is the main energy source for most organisms. An

oligosaccharide has two or more sugar units. Sucrose is an oligosaccharide and is the carbohydrate found in leafy plants. Table sugar is made by extracting it from beets and sugar cane. A polysaccharide is a chain of multiple sugar units. The most common polysaccharides are glycogen, starch, and cellulose. These store energy and cellulose serves as a material for the construction of plant cell walls. Cellulose has great structural strength and helps maintain the integrity of the cell.

Lipids

Lipids are compounds containing carbon and hydrogen. They serve as energy reserves and materials for cell membranes and other structures. Lipids with fatty acids include glycosides, phospholipids, and waxes. A glycoside molecule has one, two, or three fatty acid tails. The terms monoglyceride, diglyceride, and triglyceride refer to whether one, two, or three fatty acid tails are present. These molecules form fats and oils. Phospholipids are a major component of cell membranes. Waxes have many uses including skin and hair protection, and waterproofing animal fur and feathers. Lipids with no fatty acids include steroids. Cholesterol and many hormones are steroids. Hormones are essential to ensure proper body function, development, and reproduction. An excess of cholesterol or other hormones can disrupt the function of the body. Bodybuilders and athletes use steroid-like hormones to build muscle mass and improve performance. Use of these steroids can lead to serious physical and psychological problems.

Proteins

Proteins are large molecules composed of small organic molecules called amino acids. Proteins include enzymes and specialized cells used for structure, cell movement, storage, and transport. Enzymes are catalysts that facilitate chemical reactions. Protein formation begins with linking amino acids together by chemical bonding. Three or more linked amino acids are called polypeptide chains. The sequence of polypeptides determines the structure of the protein and how it will function. Protein structures can be disrupted by denaturation, which changes the shape of the protein molecule. The polypeptide chain unwinds or changes shape and the protein can no longer function. Exposure to high temperatures or chemical agents is the most common causes of denaturation. Some types of denaturation are reversible while others are permanent.

Nucleotides

Nucleotides are organic compounds composed of a five-carbon sugar, a nitrogen base, and a phosphate group. There are three types of nucleotides:

1. Adenosine phosphates are small molecules that serve as chemical messengers and energy carriers between cells. Adenosine

triphosphate (ATP) is the most important of these.
2. Nucleotide coenzymes transport hydrogen atoms and electrons necessary for metabolism.
3. Nucleic acids are single or double strands of nucleotide units. DNA and RNA are the most important of the nucleic acids. The genetic information is encoded in the sequence of bases in DNA. RNA molecules are used as genetic instructions in building proteins.

Nucleotides are responsible for the transfer of protons and electrons from one reaction site to another. They also function as storage units and transmitters of genetic information.

Acids, bases, and salts

Substances that release hydrogen ions when they dissolve in water are called acids, while substances that release ions that combine with hydrogen ions are called bases. The pH scale measures the concentration of hydrogen ions in various solutions. The pH scale ranges from 0, the most acidic, to 14, the most basic. The midpoint, 7, is a neutral solution.

Dissolved salts are ionic compounds formed when an acid reacts with a base. Many of these ionic compounds are important in human physiology. Ions in body fluids affect the movement of water and other solutions in the body. Buffers and other similar compounds keep the internal pH of most cells fairly constant. Carbonic acid is one of the body's main buffers. Buffers tend to offset metabolic reactions that could disturb the delicate pH balance of the body.

Elements and atoms

All living and nonliving matter is composed of elements. Elements are defined as substances that cannot be broken down into simpler substances. There are 92 chemical elements found in nature and 13 more have been created in the laboratory. Examples of elements include oxygen, hydrogen, and carbon. Elements are composed of tiny particles called atoms, the smallest units of matter. It has been postulated that there are more atoms in a human body than there are stars in the universe. In a typical living organism, 99% of the elements are carbon, nitrogen, oxygen, and hydrogen. The remaining 1%contains small amounts of sodium, calcium, phosphorus, sulphur, and traces of several other elements. Atomic architecture is the determinant of the properties of elements, and thus the properties of living organisms.

<u>Atomic structure</u>
Atoms are composed of subatomic particles called protons, neutrons, and electrons. Protons have a positive electric charged, neutrons are neutral, and electrons have a negative electric charge. Protons and neutrons are densely concentrated in the

center of an atom, which is known as the nucleus. Electrons orbit around the outer limits of the atom. Electrons, protons, and neutrons are themselves made up of smaller subatomic particles.

The number of protons in the nucleus is called the atomic number and is different for each element. The combined number of protons and neutrons in the nucleus is called the mass number. Knowing an atom's atomic number and mass number makes it possible to predict how it will interact with other atoms. These numbers determine whether an atom can acquire, surrender, or share electrons with other atoms. This electron activity is crucial to the flow of energy in life.

Chemical bonds

A union between the electron structures of atoms is called chemical bonding. An atom may gain, surrender, or share its electrons with another atom it bonds with. Listed below are three types of chemical bonding:

1. **Ionic bonding** - When an atom gains or loses electrons it becomes positively or negatively charged, turning it into an ion. An ionic bond is a relationship between two oppositely charged ions.
2. **Covalent bonding** - Atoms that share electrons have what is called a covalent bond. Electrons shared equally have a non-polar bond, while electrons shared unequally have a polar bond.
3. **Hydrogen bonding** - The atom of a molecule interacts with a hydrogen atom in the same area. Hydrogen bonds can also form between two different parts of the same molecule, as in the structure of DNA and other large molecules.

Molecular and structural formulas

Chemists have formulated various shorthand methods for showing the composition and formulation of molecules and compounds. A molecular formula shows the number and arrangement of atoms in a molecule. It also indicates if any of the atoms occur in common groups. A structural formula shows the approximate arrangement of the constituent atoms and the number of bonds between them.

Chemists use molecular formulas to write chemical equations. These equations show how molecules interact with each other to form new substances by chemical reactions. In chemical equations the total number of atoms remains the same but they can be distributed differently among the compounds by the chemical reactions.

Physiological processes of cells

Energy and metabolism

Energy is the capacity to do work, to make things occur, and to initiate change. Energy is necessary to maintain the complex functions of life. Cells must acquire and replace energy burned through cellular activity. The sun is the ultimate source of energy that cells utilize. A cell uses energy when it grows, making larger molecules from smaller ones. In looking at a cell through a microscope, it is obvious that the cell literally pulsates with energy. Accordingly, a body containing 65 trillion cells requires a great amount of energy. Metabolism is the sum of all chemical reactions by which cells obtain and utilize energy for combining substances, accumulating raw materials, breaking apart, and eliminating wastes. Cells have the capacity to locate energy, stockpile necessary materials, and dissolve and remove detritus in ways that contribute to the welfare of the cell.

Mitochondria

In mitochondria, energy that is stored as carbohydrates is released to form molecules such as adenosine triphosphate (ATP), which in turn supplies the energy to perform a variety of chemical reactions. Mitochondria are the most effective means a cell has to extract energy from carbohydrates. Oxygen is an important element in this process. When a person inhales, oxygen is supplied for the mitochondria to produce energy. The number of mitochondria in a given cell can range from a few to thousands. Each has an outer membrane facing the cytoplasm and an inner membrane with multiple deep folds or pockets that face inwards. This double membrane system creates two departments that function to produce ATP. This is vital to cell function as much of the energy a cell needs for normal functioning is provided by ATP.

Photosynthesis

Photosynthesis is actually a pair of chemical reactions.

1. In light-dependent reactions, sunlight energy is absorbed and converted to chemical energy. This chemical energy is then transferred to ATP and NAPDH.
2. In light-independent reactions, sugar and other substances are assembled with the help of ATP and NAPDH.

Glucose is the end product of these two reactions. The glucose is then converted to sucrose, starch, and other final products of this chain of reactions. Photosynthesis occurs in organelles called chloroplasts, which are present in plant cells. One small plant contains billions of chloroplasts, each a minuscule factory producing sugars and starch. Each chloroplast contains a

thylakoid membrane stacked in hollow discs. This space is used for ATP production. Surrounding these discs in the chloroplasts are the stoma, where the actual products of photosynthesis are made.

Light-independent reactions

Light-independent reactions do not absolutely require light. In these reactions, ATP provides energy while NADPH provides hydrogen atoms and electrons to synthesize light energy. The Calvin-Benson cycle is the heart of the light-independent reactions. In this cycle, the air around the photosynthetic cells provides carbon and oxygen in the form of carbon dioxide. A series of extremely complicated chemical reactions, with the help of ATP and NADPH, produce sugar and other compounds. The Calvin-Benson cycle also produces substances that begin the cycle again, assuring a constant source of energy for life. This energy takes the final form of sugar, starch, and other carbohydrates which provide the energy of life. These reactions take place in the stoma of the chloroplasts and are the last phase of photosynthesis converting light energy to chemical energy.

Adenosine triphosphate

The primary source of energy in life is the sun. Before the energy of the sun can be used for cellular life, it must first be converted to adenosine triphosphate (ATP). Cells must also convert the chemical energy of carbohydrates and other large molecules to ATP before it can be utilized for cellular activities. ATP is a combination of adenine, a nitrogen compound; ribose, a five carbon sugar; and a triphosphate, three linked phosphate groups. This unique combination delivers energy converted from the sun and stored carbohydrates.

ATP provides energy to or from almost all metabolic pathways in cells. This energy is used for biosynthesis, active transport across cell membranes, and molecular displacement (such as those used for muscular contraction). Without the conversion of multiple energy sources to ATP, cells would not have the ability to grow, develop, repair damage, or reproduce.

ATP/ADP cycle

Cells contain a high energy storage molecule, ATP, which can be split into adenosine diphosphate (ADP) and inorganic phosphate. In this reaction, heat and usable energy are released. This energy is used by cells to power multiple biological processes. This reaction is an ongoing process that drives life. This process of generating energy uses common intermediates as catalysts. In almost all biological reactions, common intermediates are the cell's means of transferring and utilizing the molecular energy of ATP. ATP's phosphate groups release so much free energy that they are called high energy groups and the bonds linking them together are called high energy phosphate bonds. Only about half the energy released in the cleaving of ATP is used to fuel cell function. The remaining energy is

wasted as heat loss. This freeing of energy and heat loss is an example of the second law of thermodynamics.

Electron transport systems

The production of ATP depends on a specialized series of reactions called electron transport systems. Electron transport systems are made up of enzymes and cofactors bonded together in a cell membrane. These transport systems transfer electrons in a particular organized sequence. Another term for these transport reactions is oxidation-reduction reactions. When atoms absorb enough energy, their electrons become "excited." Excited electrons return to their lowest energy levels available and, in doing so, release the excess energy. Electron transport systems intercept these excited electrons and use the energy they release. This is an extremely complex electro-chemical reaction that is important to the cell's work.

Aerobic energy releasing pathways

The prime energy carrier for all types of life is ATP. It is an active ingredient in almost all chemical reactions. Plants produce and use ATP during photosynthesis and also through degradative pathways that release carbohydrates, lipids, and proteins. The main degradative pathway is aerobic ("with oxygen") respiration, which requires oxygen for its operation. In the first stage of this reaction, glucose is degraded to pyruvate. In the second stage, which includes the Krebs Cycle, pyruvate is degraded to carbon dioxide and water. The third stage of this process is electron transport phosphorylation. The energy is released as electrons and is dispersed throughout the system, driving the production of glucose and ATP. At the end of this process, free oxygen combines with the electrons and positive hydrogen ions to form water. Over time, photosynthesis and aerobic respiration form a cycle to provide the supply of chemical energy to fuel life.

Anaerobic energy releasing pathways

Anaerobic ("without oxygen") respiration takes place in anaerobic pathways where something besides oxygen is the final electron acceptor. There are two main anaerobic pathways, both of which are fermentation processes:

1. In lactate fermentation, pyruvate from glycolysis is changed to lactate. One group of bacteria causes this fermentation. An example of this is when bacteria sours milk or cream. Muscle cells use lactate fermentation as a pathway. After vigorous exercise, oxygen levels in blood increase and lactate is converted to carbon dioxide and water.
2. In alcoholic fermentation, pyruate from glycolysis eventually produces ethanol. Yeasts are examples of cellular fungi that depend on alcoholic fermentation, as is seen in

the distillation of beer, wine, and whisky. Glucose is not completely degraded in a fermentation pathway, so some energy remains in the products. The relatively low energy release of fermentation is more than adequate for many microbes.

Enzymes

Enzymes are proteins with strong catalytic power. They greatly accelerate the speed at which specific reactions approach equilibrium. Although enzymes do not start chemical reactions that would not eventually occur by themselves, they do make these reactions happen faster and more often. This acceleration can be substantial, sometimes making reactions happen a million times faster. Each type of enzyme deals with reactants, also called substrates. Each enzyme is highly selective, only interacting with substrates that are a match for it at an active site on the enzyme. This is the "key in the lock" analogy: a certain enzyme only fits with certain substrates. Because of this selectivity, the fit is not always perfect. An unusual quality of enzymes is that they are not permanently consumed in the reactions they speed up. They can be used again and again, providing a constant source of energy accelerants for cells. This allows for a tremendous increase in the number and rate of reactions in cells.

Structure and function

The "lock and key" analogy for an enzyme and its substrates is not absolute. In the induced-fit model, an active site on the surface of the enzyme makes contact with its substrate and almost matches it, but not quite. When this happens, the bonding allows some changes in the active site and the substrate. When substrates fit more accurately in the active site on the enzyme it is called a transition state and the reaction proceeds much more quickly.

For any chemical action to occur, the minimum amount of energy needed to bring the reactant molecules to the transition state is required. This is called the activation energy. An enzyme increases the rate of a reaction by lowering the activation energy requirement, allowing a spontaneous reaction to occur with less energy. To summarize, the closer the fit between active enzyme sites and their substrates, the less energy is required to cause an accelerated chemical reaction.

Effects of pH and temperature

The ideal pH for enzymes is neutral, at or close to a pH of 7. If pH levels are much higher or lower than 7, the structure of the enzyme may be distorted and its function compromised. The higher the deviation from neutral, the higher the probability of impaired enzyme shape and function.

Enzyme function is optimal in a moderate temperature range. Generally, temperatures between 20 and 60 degrees Celsius are ideal for enzyme function. As temperatures fall

below or rise above this range, reaction rates decrease rapidly. This occurs because the active sites on the enzymes become damaged and substrates cannot adhere to them. Even a brief exposure to very high temperatures can destroy enzymes and adversely affect metabolism. For example, the human body can only survive up to temperatures of 44 degrees C (112 degrees F), at which point chemical reactions cease to occur at a rate sufficient to support human life.

Control of enzyme activity

Enzymes allow cells to control basic cellular function, including the flow of wastes, nutrients, and other necessary substances. Cells do this by controlling the number of enzyme molecules available. These controls may either speed up or slow down the production of enzymes. Other controls can affect the activity of existing enzymes. Inhibitors can bond with enzymes and decrease their ability to function. Other enzymes are guided by allosteric controls. Allosteric enzymes have unique sites where substances can bind and alter their activity. Feedback inhibition is another way cells govern the activity of enzymes. An enzyme may reverse its activity if it is producing too much of a substance. In this case, the end product, of which there is an excess, binds to the original substrate to inhibit additional production. Therefore, cells receive constant feedback in order to regulate chemical reactions. This process allows cells to maintain optimal concentrations of substances.

Cofactors in enzyme function

Most cofactors are actually coenzymes, small molecules associated with enzyme activity. Cofactors are non-protein substances that have two functions:

1. Helping enzymes catalyze reactions.
2. Briefly becoming transfer agents for enzymes.

Examples of major cofactors are NAD+ (nicotinamide adenine dinucleotide), which also is used in carbohydrate breakdown, and NADP+ (nicotinamide adenine dinucleotide phosphate), a cofactor that also plays a role in photosynthesis. Some metal ions also are cofactors. This includes ferrous iron, which is a component of cytochrome molecules. Cytochromes are electron transfer proteins found commonly in cell membranes such as mitochondria and chloroplasts. Enzymes involved in the transfer of functional groups, atoms, and electrons must be assisted by these cofactors to successfully accomplish their catalytic function.

Cell division, growth and differentiation

Cell division

Cell division is the means by which an organism sustains itself. It begins with the division of an individual cell. Each cell of a new generation must receive an exact

duplicate of all the parental DNA and enough cytoplasm to function independently. In multi-celled organisms, cell division begins with mitosis or meiosis, and ends with cytogenesis. Cytokinesis is the division of the cytoplasm, while mitosis and meiosis are the nuclear division mechanisms. In nuclear division, DNA is donated to offspring by the division of the nucleus. Mitosis is the basis of body growth through repeated cell divisions. It is also the means of asexual reproduction in many organisms. Meiosis occurs only in germ cells. Sexual reproduction begins with meiosis, continues with the production of gametes (sex cells including sperm and eggs), and ends at fertilization. During fertilization, a sperm and an egg nucleus combine into a zygote, the first stage of the offspring organism.

Mitosis

Mitosis proceeds through four stages:

1. Prophase is the first stage of mitosis, when chromosomes join together to form thread-like configurations. In the latter stages of prophase, each chromosome thickens to a rod-like width.
2. Metaphase is the second stage of mitosis, during which chromosomes are polarized away from each other in the cell. The chromosomes then align themselves halfway between the poles.
3. Anaphase is when sister chromosomes separate and move toward opposite poles. Once they separate, they become independent chromosomes.
4. Telophase is the final phase of mitosis. In this phase, chromosomes disassemble into thread-like forms. Patches of the membrane begin to fuse together to form a new nuclear envelope separating the genetic material from the cytoplasm. Once the nucleus of the new cell is completed, the final stage of mitosis is over and the process is complete.

Animal and plant cytokinesis

In animal cells, cytokenesis occurs in the latter stages of mitosis. During cytokinesis, the center of the cell develops a line down the middle, called a cleavage furrow. On the line of the furrow, contractile microfilaments pull the plasma membrane apart and divide the cell in two. Plants usually have a different type of cytokenesis called cell plate formation. Plant cells typically have more rigid walls that prevent the formation of cleavage furrows. Vesicles filled with cell wall material (often cellulose and other fibrous substances) form a cell plate. This plate forms into a disc-like shape, then cellulose deposits from the cell wall separate, creating new daughter cells.

The different structure and strength of animal and plant materials have caused each to adapt a unique method of division. This is

an example of organisms adapting to ensure reproduction and survival.

Meiosis

Meiosis is a nuclear division mechanism that occurs only in germ cells. Germ cells develop a wide variety of reproductive structures and organs. They commonly have two chromosomes, known as a diploid. Diploids are homologous chromosomes that are usually the same length, the same shape, and have the same genes. Meiosis splits the pair in half, with each gamete ending up with one pair of homologous chromosomes. Meiosis is similar in some respects to mitosis. When a germ cell is still in interphase, its chromosomes are duplicated by DNA. Each chromosome now has a duplicate of itself, called a sister chromatid. During meiosis, homologous chromosomes swap segments, and are mixed in ways that will give different combinations of maternal and paternal instructions for each trait. Unlike mitosis, meiosis has two divisions, Meiosis I and II. Each is divided into four phases:

- Prophase I and II
- Metaphase I and II
- Anaphase I and II
- Telophase I and II

Genetics and Evolution

Principles of heredity

Genetics/Heredity

Gregor Mendel

Gregor Mendel, the founder of modern genetics, was a monk with a classical education. Mendel tended the garden in his monestary and experimented with pea plants. Obtaining 34 distinct strains from local farmers, Mendel raised plants to select only true breeding plants, where each offspring is identical to the parent. Mendel focused on the inheritance of several distinct traits: flower color, seed color, pod shape and plant height, rather than on the entire appearance of the plant. Mendel chose seven characteristics, or pairs of traits, and studied only one trait at a time. Mendel's education in mathematics, chemistry, botany, and the new field of statistics gave him the tools necessary to discover modern genetics. His carefully planned experiments over the years demonstrated the particulate nature of heredity. In 1866, he presented his results to the Brunn Society of Natural History. However, his ideas were not well understood or accepted during his lifetime.

Mendel's experiments had three unusual and innovative qualities that pioneered modern genetics:

1. Mendel studied pea plants that demonstrated just two clear cut possibilities such as green or yellow seeds, tall or short plants, red or white flowers. This allowed him to concentrate on specific inherited traits with relative ease.
2. Crossbreeding hundreds of pea plants, he traced and recorded the characteristics of generations of plants produced from their parents. Applying his knowledge of science and statistics, he was able to cross-breed plants to observe the patterns of inheritance.
3. Perhaps most importantly, Mendel followed the results of his experiments for two generations rather than just one. This subtle but critical difference resulted in disproving the blended theory of inheritance, which was accepted at the time as valid.

Mendel concluded that when two alternative traits are present, but one masks the other, the visible trait is dominant and the hidden trait is recessive.

Genetic alleles

Modern geneticists know that a gene, a hereditary factor, determines specific aspects of an organism's appearance, behavior, and biochemistry. Every gene has a specific location on a chromosome. Two genes of a pair may deal with the same trait, but they may also carry different

information. The explanation for this is the nature of the allele. Each alternative form of a gene is called an allele. Each allele comes from one parent and is responsible for a dominant or recessive trait. True breeding parents are said to have homozygous, or matching, pairs. A homozygote is an organism that has two identical alleles for a particular trait. Geneticists differentiate between an organism's genotype and phenotype. A genotype is the genetic composition of a cell or organism. A phenotype is the physical appearance of the cell or organism. Although one may determine the other, it is important to use clear definitions in genetics to distinguish between an organism's genes and the characteristics they produce.

Segregation

Mendel first crossed monohybrids, parents that bred true for contrasting forms of a single trait. He was thus able to make predictions and test them in a controlled manner. By cross-testing different varieties of pea plants and examining the results, Mendel's experiments led him to formulate the principle of segregation. The principle theorized that diploid organisms inherit a pair of genes for each trait. The two genes segregate from each other during meiosis, with the result that each gamete formed will end up with one of the genes, but not both. The easiest method for determining the probable outcome of a cross between monohybrid crosses is the Punnett square method. This is a graphical presentation for predicting the probability of traits that will show up in the offspring of organisms with genes known to be heterogeneous for a given trait.

Mendel's law of independent assortment

In another series of experiments, Mendel crossed true breeding pea plants with contrasting forms of two traits. The results from these experiments led to the Mendel's law of independent assortment. This law states that each gene pair has a tendency to sort into gametes independently of other gene pairs located on nonhomologous chromosomes. Another way to state this principle is to assert that alleles of different genes are distributed randomly to the gametes, causing fertilization to occur at random. Mendel used cross-testing to demonstrate these results. This means he cross-tested by mating a plant of known phenotype (the physical appearance of a plant), but unknown genotype (genetic makeup of the plant) to a homozygous plant that was recessive for the trait being studied. He selected a homozygous, recessive trait so that the contribution of the unknown parent, either dominant or recessive, would be obvious in the phenotype of the offspring.

Exceptions to Mendelian theories

The phenotypes of many traits have exceptions to Mendelian principles. Some major exceptions are:

- Incomplete dominance - this occurs when the phenotype is intermediate between dominant and recessive traits.
- Co-dominance - a situation where a pair of non-identical alleles give rise to two different phenotypes. Neither allele is able to dominate the presentation of the other.
- Epistasis - one gene pair makes the expression of another and alters the appearance of the phenotype. Some expected phenotypes do not appear at all.
- Pleiotropy - a single gene can occasionally affect multiple and unrelated aspects of an individual's phenotype.
- Environmental effects altering gene expression - sunlight may produce freckles or darker pigmentation of the skin in some cases.
- Continuous variations in traits - this means that a relatively small degree of phenotypic variation occurs over a given range; for example, the variations from curly to straight hair.

Autosomes and sex chromosomes

Autosomes are chromosomes with the same number for each sex. Most chromosomes follow this pattern. One or two chromosomes are different in males and females. These are called sex chromosomes. Today, autosomes and sex chromosomes can be identified at metaphase, when they are in their most condensed form. The Y chromosome of humans carries a sex-determining gene. This indicates whether the individual will develop ovaries or testes. The hormones secreted by these organs determine the sexual development of the individual organism. Scientists now use precise designations for a sex-linked gene, labeling them X-linked or Y-linked genes. Research in the early part of the last century experimented with fruit flies. Their work led to the discovery of X-linked genes. This verified a major genetic theory, that each gene is located on a specific chromosome.

Genetic linkage

During experiments using fruit flies, researchers observed that many traits were inherited as a group from one parent or another. The concept of linkage is the tendency of genes located on the same chromosome to end up in the same gamete. Linkage is not an absolute rule, just a tendency.

Crossing over

Crossing over can disrupt linkage under certain circumstances. Crossing over occurs when there is breaking and exchange of segments between homologous chromosomes. The farther apart the genes are physically located on the chromosome, the more likely crossing over will occur and disrupt linkage. Two genes located close together on a chromosome usually end up in

the same gamete. Crossing over impacts evolution by introducing variations in genotypes (genetic makeup of an organism), which causes differences in phenotypes (physical appearance of an organism). Selected environmental agents favor genotypes that allow individuals to better adapt to the environment.

Tracking chromosome variations

Because human beings live in a wide range of variable conditions, randomly reproduce at their pleasure, and have relatively small families, the controlled and scientific study of chromosomes in humans is difficult. However, scientists have created standardized methods for studying family pedigrees, which chart genetic relationships of the individuals in families. As a result, scientists are now able to identify inheritance patterns and track genetic traits through generations. By studying identical traits in a large number of families, the statistical base for scientific analysis is increased. All of this has led to growth in the study of human genetics. Scientists are now able to use family pedigrees to identify inheritance patterns and track genetic variations, deviations, disorders, and abnormalities through several generations. Disorders refer to medical problems, while abnormalities are deviations from the average.

Molecular basis of genetics and genetic engineering

DNA

All things are composed of the same basic building blocks of matter—the atom. Atoms are bound in patterns to form molecules. Energy bonds are the key chemical reaction in the formation of all matter. Deoxyribonucleic acid (DNA) is a special type of molecule that occurs only in living organisms. DNA molecules contain the genetic code that allows an organism to reproduce from essentially lifeless matter. Molecules and energy combine following the instructions of DNA to reproduce new life, ensuring the survival of that life form. Both living and nonliving things arise from the same sources; the presence of DNA is the critical factor in determining living beings. In summary, DNA organizes energy and molecules to reproduce life. Without DNA, the raw materials of life remain disorganized and do not have the ability to reproduce themselves. Thus, DNA is the crucial element in life reproducing itself.

<u>History and discovery</u>

In 1868, Johann Miescher discovered an unknown substance in the cell nucleus that was later known as DNA. The function of this substance remained a mystery for over 75 years.

In the early 1950's, experiments with a class of viruses began providing evidence that DNA was the substance that determined

heredity. Later in that decade, James Watson and Francis Crick discovered the genetic code and accurately described DNA and its functions. Watson and Crick, armed with evidence from X-ray diffraction, which actually photographed crystallized DNA, began to try to build models of DNA. The breakthrough came when it was recognized that the structure of DNA was arranged in a double helix, with the phosphates and sugars positioned like the outer rungs of a ladder and the nitrogenous bases fitting perfectly between the rails with repeating features. The code was "broken," causing a historic breakthrough in scientific research.

Structure and function

A DNA molecule is composed of four kinds of nucleotides, the subunits of nucleic acid. A nucleotide consists of a five-carbon sugar (deoxribose), a phosphate group, and one of four nitrogen containing bases: adenine, guanine, thymine, and cytosine. The nucleotides in DNA are structurally similar to each other, but the four types of bases differ in relative amounts from species to species.

DNA consists of two strands of nucleotides twisted together into a double helix formation. Hydrogen bonds join the bases of each strand together. Adenine pairs with thymine and cytosine pairs with guanine for the entire length of the DNA molecule. The order and sequence of the bases differ greatly between species, but the base pairing between the two nucleotide stands of DNA is constant for all species. Thus, DNA mirrors both the unity and diversity of life.

DNA replication

Prior to cell division, the DNA must be duplicated to pass on to the offspring cell. The process by which this duplication occurs is called replication. In replication, the two nucleotide strands twisted together in the double helix structure unwind from each other and leave their bases exposed. This replication is aided by enzymes and other proteins called DNA polymerases. Stored supplies of free nucleotides then pair with the exposed bases of the relaxed strands. Each parent strand remains intact and a new strand is assembled on each one using the base-pairing mechanism. As replication proceeds, each parent strand twists into a new double helix with its newly made strand. The parent strand is conserved, and each new DNA molecule is half-new and half-old. The new complementary strand is assembled on the bases of the new parent according to the base-pairing rule contained in the genetic blueprint.

Protein synthesis

Each gene is a segment of nucleotides in the DNA that instructs the assembly of different amino acids into a polypeptide chain. These polypeptide chains are the basic structural unit of proteins. The pathway from genes to proteins is composed of two stages: transcription and translation.

In transcription, molecules of RNA (ribonucleic acid) are produced on templates of the DNA in the nucleus. In translation, RNA molecules transported from the nucleus into the protoplasm are used as the templates for making polypeptide chains. After translation, one or more of these chains fold into protein molecules. These proteins serve as enzymes in the production and synthesis of lipids, carbohydrates, and other essential elements for the structure and function of cells. Some of these proteins may be used as structural material in building cells. Protein synthesis thus serves multiple vital functions in cellular life.

DNA transcription and replication

During transcription, molecules of RNA are produced on the templates of the DNA in the nucleus. Strands of RNA and DNA are very similar but not exactly the same. RNA nucleotides are composed of a sugar (ribose), a phosphate group, and a nitrogen-containing base. Its bases are adenine, cytosine, guanine, and uracil. Like DNA's thymine, RNA's uracil pairs with adenine.

Transcription differs from DNA replication in two ways. First, only one segment of the DNA strand is used, rather than the whole strand. Second, different enzymes (RNA polymerases) are active. A promoter initiates transcription. Binding with RNA polymerase, it moves along the DNA template and joins nucleotides into an RNA transcript. When the enzyme reaches the gene region, the transcript is released from the template.

Translation of the genetic code

The genetic code consists of a sequence of nucleotide DNA and how it corresponds to the amino acid sequence of a polypeptide chain. Stages of translation of the code are as follows:

1. Initiation - an initiator able to start translation of the code binds to a small ribosomal subunit, which in turn binds to the transcript. Then, a large ribosomal unit bonds with a small unit. This creates a complete ribosome and an initiator.
2. Chain elongation - a start codon, a base triplet on RNA, defines the reading frame for assembling amino acids in the correct sequence. RNA then delivers amino acids to the ribosome, forming a polypeptide chain. A peptide bond then forms between the growing polypeptide chain and each added amino acid.
3. Chain termination - a stop codon is reached and the ribosome and polypeptide chains are detached from the RNA transcript. The chain joins the free proteins in the cytoplasm or enters the cytomembrane for further processing.

Mutation and protein synthesis

Although base sequences in DNA must be preserved from one generation to the next, changes do occur. Examples include changes caused by disjunction, crossing over, and other abnormal occurrences. Another type of change is called gene mutation. This is an addition, substitution, or deletion of one or more bases in the nucleotide sequence of the gene. The mutation rate for a gene is one in one million replications. Some environmental agents can attack a DNA molecule and alter its structure. These agents are called mutagens. Some viruses, types of chemicals, and radiation are all types of mutagens. If only one amino acid is substituted for another, the results can be huge. For example, sickle-cell anemia has been traced to a single mutation in DNA strand coding. Occasionally, DNA regions will change location in a DNA molecule. These transposable elements can result in spontaneous gene mutations.

Autosomal recessive inheritance

Autosomal recessive inheritance is a mutation caused by a recessive allele on an autosome. Features of this condition are:

1. The recessive allele may be carried on a chromosome other than a sex chromosome.
2. The condition does not occur in heterozygotes; only recessive homozygotes are affected.
3. If both parents are heterozygous, there is a fifty percent probability that the offspring born to them will also be heterozygous, and a twenty-five per cent probability that it will be homozygous recessive. If both parents are homozygous recessive, all of their offspring will be affected.

Examples of an autosomal recessive inheritance include a number of developmental impairments, tendencies toward certain diseases, and malformations. Scientists' rapidly increasing knowledge of human genetics is offering opportunities for early intervention in some of these cases.

Autosomal dominant inheritance

In autosomal dominant inheritance, a dominant allele on an autosome is always present to some extent. If its effects are serious enough to reduce the probability of survival and reproduction of the organism, its occurrence will decrease in successive generations.
There are only a few dominant alleles that cause major problems in populations. Some dominant alleles do not manifest until after the reproduction stage of life is over, making early intervention impossible.

Two very serious autosomal dominant disorders are achondroplasia, or dwarfism, which occurs in about 1 in 10,000 individuals. Affected persons are usually less than 52 inches tall. Huntington's

disease, a rare form of autosomal inheritance, is a progressive neurological disorder whose symptoms appear after age 40, most often after the affected individuals have stopped reproducing. Huntington's disease causes convulsive muscular movements, deteriorating brain function, and eventually death.

X–linked recessive inheritance

Some genetic disorders fall into the category of X-linked recessive inheritance which is characterized by the following features:

1. The mutated gene falls on the X, not the Y, chromosome.
2. Males are typically affected if they possess only one allele for the gene and it is recessive. Heterozygous females are normal; the nonmutated allele on their other X chromosome compensates and performs the necessary functions.
3. When a male is normal but the female is heterozygous, there is a 50 percent chance that each daughter will be a carrier of the gene, and a 50 percent chance that a son will be affected.

An example of an X-linked recessive inheritance is Hemophilia A. If a mutated gene participates in blood clot formation, the defective gene can cause several bleeding disorders. Although Hemophilia A affects only about one in 7,000 individuals, the frequency of the recessive allele was unusually high among the royal families of Europe. For example, Queen Victoria was a carrier who passed the gene to 69 of her descendents.

Changes in chromosome structure

Examples of changes in chromosome structure are rare, though they do occur and can have devastating effects. Types of changes in chromosome structure include:

- A deletion is a loss of a chromosome segment through a chemical reaction, viral attack, or the effects of radiation. Such a loss always causes grave problems as genes regulating a vital trait may be missing. Deletions of some chromosome segments may lead to cognitive developmental delays.
- A duplication is a chromosome segment in excess of its normal sequence. These duplicates could evolve through mutation and yield a variety of malfunctions or even new functions.
- An inversion occurs when a chromosome segment is structurally reversed, causing changes in the position and sequence of genetic activity.
- A translocation is a transfer of one part of a chromosome to a nonhomologous chromosome. This occurs in some types of cancer in humans.

Changes in chromosome number

Changes in chromosome numbers happen as a result of a cellular accident.

- Some types of changes in chromosome numbers occur with no disjunction, where one or more chromosomes fail to separate during meiosis. No disjunction often causes miscarriages and can also lead to Down syndrome and other human genetic disorders. This may be caused if a chromosome does not separate from its homologue at anaphase I. Sometimes sister chromatids do not separate at anaphase II; in these cases, some or all of the gametes can have one extra or one fewer chromosome than the parent.
- If a human gamete has an extra chromosome, the condition is called a trisomy. The most common of these is Down syndrome, or trisomy 21.
- A diploid cell without a homologue is called monotony. This gamete is missing a chromosome and the offspring will have an altered genetic makeup.

Common genetic disorders

Down syndrome - The cells of afflicted individuals have three copies of chromosome 21. A syndrome in this case refers to a set of symptoms occurring together and characterizing a certain disorder. About one in every 5,000 newborns have this disorder. Most victims have moderate to severe mental retardation, are shorter, and have distinguishing facial features.

Turner syndrome - Affects about one in every 5,000 newborn females. Caused by a non-disjunction, these individuals have a chromosome number of 45 rather than 46. The female phenotype of these newborns are altered. They are sterile, and secondary sexual characteristics fail to arise during puberty. They age prematurely and have a shortened life span.

XYY condition **-** Affects about one in every 1,000 males. These males tend to be taller and may show mild mental retardation. Many are normal and have genetically normal children.

Klinefelter syndrome - Caused by nondisjunction and affects males who it renders sterile and sometimes mentally retarded.

Phenotypic treatments

In a sense, genetic disorders cannot be permanently cured. However the phenotype effects may be treated by dietary changes, surgery, chemical modification of gene products, and changing of the external environment. Diet can be used as a therapeutic tool against such disorders as galactosemia and phenylketonuria (PKU),

allowing the affected individuals to lead normal lives. Surgical reconstruction can repair or minimize many phenotypic defects. A cleft lip is an example of such a defect that can be treated successfully with surgery. Chemical modifications of gene products are excellent interventions in some cases. For instance, Wilson's disease, which arises from an excess of copper in the body, is treated with drugs that bind with the copper and allow the body to eliminate the excess. Environmental adjustments such as avoiding sunlight are effective for albinos, whose photosensitivity is exaggerated.

Controlling gene activity

Gene activity is controlled by many interacting elements, including regulatory proteins, enzymes, DNA molecules, and hormones. These substances have control sites embedded in their structure to monitor gene activity. They govern which gene products appear, when they appear, and in what amounts they appear. Living cells control which genes are active, and how they determine cellular function. Each type of cell has specialized processes that control gene activity. These processes can control cell division, X chromosome inactivation, selective gene expression, cell differentiation, and multiple other cellular functions. Genes also control cell growth in ways that are not yet understood. For instance, sometimes a cell loses control over cell division, which causes a cancerous transformation in the body, sometimes with dire results.

Genes losing control

Occasionally, gene control over cell division is permanently altered. A cell divides again and again, eventually interfering with surrounding cells and tissues. This failure of cell control causes a tumor, a mass of tissue dividing at an abnormal rate. These tumor cells have lost the controls that limit their growth. Cancer cells have certain common characteristics:

1. They cause profound changes in the plasma membrane and cytoplasm of the cells, including enzyme dysfunction and the shrinking or disorganization of the cytoskeleton.
2. Cells multiply and increase to abnormally high densities while factors that inhibit the overcrowding of tissues fail to function.
3. Cells lose their ability to adhere to the parent tissue.
4. Cells become lethal. Unless the cancer cells are destroyed, the organism will die.

Any cell having the ability to induce cancerous growth is called an oncogene. Cancer seems to be a result of multiple failures of gene control.

Recombinant DNA technology

Genetic experiments have been occurring naturally in the physical world for billions of

years. Gene mutations, crossovers, displacements, and others have often caused dramatic changes in nature. Thanks to modern technology, these changes can now be initiated with human hands. Today, scientists are "engineering" changes through recombinant DNA technology. DNA from a variety of species can be cut, spliced together, and then inserted in other organisms that then multiply the number of recombinant DNA molecules. Applications of recombinant DNA technology have great potential in many fields, including medicine, industry, and agriculture. Despite the great potential for applications in these fields, recombinant DNA technology raises new questions and concerns about the social, ethical, ecological, and moral issues involved in recombinant DNA technology and testing.

Genetic fingerprinting

Restriction fragment length polymorphisms (RFLPs) refer to using restriction enzymes to cut human DNA into specific lengths. Each individual has a slightly different pattern of sites where the cuts occur. RLFPs have made a huge impact in criminal justice, since each individual has a human fingerprint. Criminals who leave a few drops of blood or strands of hair at a crime scene have left their genetic fingerprints. Courts have already ruled for convictions based on DNA evidence found at the scene of a crime. Many innocent individuals serving sentences for crimes they did not commit have been set free using DNA material to exonerate them. Paternity suits can now be resolved beyond a doubt by using DNA evidence comparing the genetic fingerprint of the child to that of the disputed parent. As techniques improve, the use of genetic fingerprinting will become more common and a valuable tool for society.

Cloned human genes

A DNA clone is any sequence of DNA that has been amplified in dividing cells. Cloned human genes are already having an impact in the practice of medicine. The following is a partial list of cloned proteins and their medical applications:

- Interferons used in cancer therapy.
- Insulin used in the treatment of diabetes.
- Factor IX as a treatment for hemophilia.
- Factor VIII as therapy for hemophilia.
- Somatotropin is used in the treatment of dwarfism.
- Monoclonal antibodies are used to combat infectious diseases.
- Tissue plasminogen activators factor in cardiac care.
- Erythropoietin is used to treat anemia.

This is only a beginning of the use of cloned materials as therapeutic tools. The raging debate over stem cell research is another example of the new issues being raised and considered in light of scientific advances.

Gene therapy

Gene therapy may be defined as inserting one or more normal genes into the body cells to correct a genetic defect. This concept has become accepted by large parts of society in cases of severe genetic disorders. This must be contrasted with inserting genes into a normal human being to change or improve a particular characteristic. This is called eugenic engineering and it raises serious questions about what traits are desirable and who is qualified to make such judgments. The long term impact of these questions is of much concern to thoughtful scientists and the general public. An extreme example of this could be seen in the totalitarian governments of Nazi Germany, which preached and practiced the concepts of racial purity, a possible use of eugenic engineering. Genetic manipulation in all of its forms will be the subject of impassioned debate in coming generations.

Genetic screening

As scientific knowledge of genetics has improved, genetic screening has become an important tool in interventions before symptoms can develop. In some cases, carriers without presenting symptoms can be identified before giving birth to affected children. Large scale programs have been initiated to educate and locate affected persons or carriers of genetic defects. For example, many hospitals in the United States routinely screen all newborns for PKU to reduce the number of individuals who show symptoms of the disorder. Populations at high risk for special disorders such as Tay-Sachs disease that primarily affects Jewish parents are encouraged to seek genetic screening. Vast strides have been made by scientists and physicians in combating and preventing genetic disorders.

Genetic counseling

Genetic counseling has become more common in recent years. If a couple has reason to believe they might produce an impaired child, or if an earlier child shows an abnormality, the couple may seek genetic counseling. In such cases, geneticists, doctors, social workers, and other health care professionals may be consulted. If an embryo is diagnosed with a severe disorder, the options are limited. There is no current cure for changes in chromosomes that trigger an embryonic disorder. Prospective parents may choose an induced abortion or elect to have the baby despite the disorder. This decision is usually made on moral, ethical, and religious grounds as much as medical evidence. The choice is usually consistent with their values and that of the society in which they live. Genetic counseling begins with an accurate genetic diagnosis based on available biochemical tests and medical imaging. Decisions are then made on a course consistent with the parents' (or parent's) values and beliefs.

Prenatal tests

Prenatal diagnosis has the ability to detect and predict almost 500 genetic disorders, from very mild to very severe. A major diagnostic tool is amniocentesis, the sampling and testing of the amniotic fluid in which the fetus is suspended. Between the fourteenth and sixteenth week of pregnancy, a syringe is inserted in the amnion and fluid containing embryonic cells is extracted. The cells are cultured and allowed to undergo mitosis. These cells can be analyzed and tested for multiple abnormalities. Biochemical defects such as those that cause sickle-cell anemia may also be discovered.

A newer test, chorionic villus sampling, using cells drawn from the chorion (a sac surrounding the amnion) is also available. This test carries a higher risk than amniocentesis, but may be performed much earlier in the pregnancy. Newer and more sophisticated tests are constantly being developed to make earlier and more precise prenatal diagnoses.

Taxonomy and classification in biology

Kingdoms of life

Biologists have divided all of life into five kingdoms:

- *Monera*—single cells with little internal complexity.
- *Protista*—single cells with much greater internal complexity than Monera.
- *Fungi*—multicellular life with considerable variation and complexity.
- *Plantae*—multicelled plants with great variation and complexity.
- *Animalia*—multicelled animals with much variation and complexity.

The diversity of life is further classified by using inclusive groups. Similar genera are placed together in a family. Like families are grouped with each other as classes. Classes that have similar characteristics are placed in a phylum. All phyla are part of the five kingdoms.

Many systems of classification have been invented and used by scientists over the centuries. The various classifications are an effort to organize the diversity of life in a useful manner. The five kingdoms represent the latest and most widely accepted system of classification, used and understood by scientists internationally.

Kingdom Monera

The kingdom Monera is composed entirely of bacteria, the most numerous of all organisms. They live in diverse environments; sometimes living on other organisms. Each human being harbors more bacteria than cells. Bacteria cells are much smaller than animal cells, so the volume of them is relatively low when measured by weight. Bacterial cells have no nucleus or

organelles and have semi-rigid cell walls and flagella for motility. Most bacteria are photosynthetic autotrophs, producing their own nourishment from substances using sunlight as energy. Some are chemosynthetic autotrophs and have the capacity to produce their own nourishment. Most bacterial cells reproduce by fission, dividing into two daughter cells after DNA replication.

Groups of bacteria

- **Archaebacteria** consists of methanogens, halophytes, and thermoacidophiles. They often live in inhospitable environments and are structurally and genetically different from all other bacteria.
- **Photosynthetic eubacteria** use sunlight energy and oxygen in photosynthetic reactions to produce ATP and nourish themselves. An example of photosynthetic eubacteria is blue-green algae that thrives on the surface of ponds.
- **Chemosynthetic eubacteria** are nitrifying bacteria that are active in nitrogen cycling, a key component of all proteins and amino acids.
- **Heterotrophic eubacteria** include some of the most deadly diseases known. They include syphilis and Lyme disease. Some form an endospore, a dormant body that can become active under certain conditions and multiply rapidly. These eubacteria also provide the enzymes to produce sour cream, yogurt, and cheese.

Protistans

Protistans are single-celled eukaryotic organisms that include:

- Slime Molds - live on decaying plant life. Cells of slime mold gather together and are able to creep around like animals.
- Euglenids - flagellated photosynthetic protistans that are very complex.
- Chrysophates - photosynthetic protistans that live in lakes, ponds, and rivers. They have silica as a major component of their structure.
- Dinoflagellates - photosynthetic members of marine plankton.
- Flagellated Protozoans - free-living parasitic organisms.
- Amoeboid Protozoans live in fresh and seawater and feed on -algae, bacteria, and other protozoans.
- Sporozoans - parasites with an infectious stage that causes malaria. Ciliated protozoans have cilia that beat in unison, moving the body through the water.

Kingdom of Fungi

Fungi are heterotrophs that live by decomposing organic or inorganic matter. Some fungi, such as saprobes, feed on inorganic matter. Others are parasites which nourish themselves from the bodies of

living hosts. Fungi rely on extracellular digestion and absorption, using enzymes to break down large organic molecules into smaller substances to be absorbed. Fungi serve an important function in life. They serve as consumers of waste products of other life forms. As decomposers, they prevent other organisms from being buried in their own waste. Fungi are multicellular. The food-absorbing part of the body is the mycelium, a mesh of filaments called hyphae which are composed of cell walls made of chitin, a polysaccharide containing nitrogen. The mycelium extends into the external environment to absorb vital nutrients.

Major groups of fungi

There are over 60,000 species of fungi. Major types include:

- Sac fungi - So named because their spores are shaped like sacs. Single cell yeasts are sac fungi.
- Imperfect fungi - All fungi that are asexual fall into this group. Penicillin is an imperfect fungi.
- Symbionts - These are fungi entering symbiotic relationships with photosynthesizers. Lichen is an example of a symbiont.
- Club fungi - These show a wide diversity with many forms. The mushroom is the most common club fungi.
- Chrytids - Chrytids live in swampy or watery environments and feed on decaying plants for nourishment.
- Zygospore-forming fungi - A type of fungi that reproduces sexually. Among these fungi are the common bread molds.

Most fungi spores are spread by air currents. Exceptions are chrytids and water molds which have motile spores.

Plant kingdom

Green plants are multicellular autotrophs that use minerals, light energy, and water to produce their own food. Plants nourish most of the earth either directly or indirectly. There are almost 300,000 species of plants existing in the biosphere. Most plants are vascular with an extensive root system that absorbs nutrients from the soil. They also have stems, leaves, and other structures composing a shoot system that helps with photosynthesis. Specialized transport tissues move water and its solutes through the roots, stems, and leaves. A wide variety of red, green, and brown algae are among the multicellular aquatic plant species. Bryophytes are nonvascular plants with simple transport systems. They have no true roots, stems, or leaves and their vascular systems provide all necessary functions. There are about 15,000 bryophytes, all of which live on land.

Sexual reproduction

Plant sexual reproduction on land involves the fusion of sperm and egg. Reproduction in aquatic plants is aided by currents

carrying motile sperm to the eggs. As plants made the transition to land, protection and nourishment of the gamete became more difficult. The result was a shift from haploid to diploid dominance. For land plants, a spore-producing body known as a sporophyte develops during the diploid phase, then a gametophyte develops during the haploid phase. Once a zygote forms, it grows into a sporophyte. These cells undergo meiosis and generate haploid cells. A plant spore is a haploid cell that develops into a gametophyte, producing gametes in its sex organs. The last phase of this process ends at fertilization. Simple aquatic plants spend most of their time reproducing, so the haploid phase dominates the life cycle.

Groupings of algae

The term algae originally referred to similar aquatic plants, but some varieties of algae are now grouped into different kingdoms. Only red, brown, and green algae are members of the plant kingdom.

- Red algae appear multi-colored, depending on the mixture of pigments present. They are the most numerous organisms in marine life. Some types of red algae are used to make agar, a common food additive.
- Brown algae often live in offshore areas, sometimes attached to submerged rocks or trees. Some species produce algin, a substance used as an emulsifier or thickening agent in a wide variety of products.
- Green algae are common in both salt and fresh water. They are similar to land plants, having an array of pigments and tough cell walls made of cellulose. Green algae store carbohydrates as starch, which can be converted to nourish the plant.

Seedless vascular plants

Seedless vascular plants were once the most numerous on the earth, but only a few species remain. They include:

- Horsetails - All horsetail spores form in the protective layer of shoots where they are then dispersed by the wind. They grow in disrupted environments such as vacant lots, highways and in moist, humid atmospheres.
- Lycophytes - Existing lycophytes are mosses that thrive on forest floors and in other shaded, humid areas. Millions of years ago lycophytes were large plants, some reaching the size of small trees.
- Ferns - Ferns prosper in tropical and subtropical habitats. There are over 10,000 species of ferns, many popular as nursery plants. Ferns range in size from very small to tropical tree ferns over 75 feet tall. Stems are almost always underground and the leaves of ferns are featherlike. Ferns show an extraordinary diversity and are extremely common plants.

Seed plants

Seed plants are among the most widespread vascular plants in number and distribution. The two major types of seed plants are angiosperms and gymnosperms. Angiosperms have vessels that surround and protect the seeds during development. There are almost a quarter of a million known species and more are discovered each year. Among the most diverse members of the plant kingdom, angiosperms range in size from microscopic to tall trees. They thrive in oceans, on dry land, and in wetlands. Although some are parasitic, most are free living and photosynthetic. Gymnosperms are primarily trees or shrubs. There are about 800 species of gymnosperms. The most familiar gymnosperms are conifers, which include pines, firs, hemlocks, redwoods, and many others. Most are evergreen, meaning they have leaves all year long, although they shed old leaves throughout the year.

Bryophytes

Byrophytes are non-vascular land plants. They have several distinctive characteristics:

- Above-ground parts have a protective cuticle.
- Reproductive cells are protected by insulating tissue layers to keep them moist.
- The embryo sporophyte begins its development inside the female gametophyte.

Bryophytes are small plants, with stems and roots, but do not have phloem or xylem. They require a moist environment to thrive. Bryophytes are unusual for land plants in that they have an independent gametophyte and an independent sporophyte. Bryophytes include liverworts, hornwarts, and mosses. Mosses are the most common byrophyte, living in most temperate and moist environments around the world.

Evolution among plants

The evolution from the sea to life on land gave rise to specialized plant parts (roots) to absorb water and nutrients from soil. Plant parts above the ground became specialized to use sunlight as an energy source. Complex vascular tissues evolved as root and shoot systems matured. Xylem and phloem, which are vascular tissues used for transporting water, minerals, and products of photosynthesis throughout a plant, are examples of evolved vascular systems. Plant surfaces are protected by a waxy coating that controls evaporation. Structural support tissue also evolved, allowing some plants to grow taller and have more access to sunlight. Much of this evolution was an adaptive response to changing environmental conditions. Plants became stronger, taller, more complex, and able to thrive under new and changing conditions. Today, flora displays an amazing diversity with complex internal systems.

Animals

Shared characteristics

The animal kingdom is has immense diversity, but all animals share a few key characteristics:

- Almost all animals are motile during some of their life cycle.
- Animals produce either sexually or asexually. They are all diploid organisms.
- Animals cannot produce their own food. They are heterotrophs that consume or absorb food produced by other organisms.
- Animals are multicellular and, except for sponges, their cells are organized into tissues. Tissues, in turn, are arranged into organs and organ systems.
- Animal life cycles are generally similar; cell divisions transform the zygote into a multicelled embryo. These cells arrange themselves in germ layers that give rise to tissues, organs, and organ systems.

Together there are more than 39 phyla of animals showing a wide range in diversity of appearance, function, and habitat.

Body features

Body features of animal groups can be categorized following their increasing complexity. They are:

- **Body Cavity** - Almost all bilateral animals have a body cavity between the gut and the body wall. A coelom, the most common type, has a lining called a peritoneum, which protects and anchors organs inside the animal. These organs were necessary for the evolution of large, complex animals.
- **Segmentation** - A segmented animal has body units that may not be alike. Insects are composed of three body segments (head, thorax, and abdomen), with each having a different function
- **Body Symmetry and Cephalization** - All animals have a bilateral or radial body blueprint. In bilateral animals the right and left sides are mirror images. In radial animals, body parts are arranged like spokes in a wheel.
- **Gut Type** - A gut is the region of the body where food is digested and absorbed. The volition of a complete gut made it possible for larger and more complex animals to evolve.

Sponges

Sponges are the simplest animals and one of the most abundant forms of aquatic life. They have no organs, no body symmetry, and vary in size from tiny to huge. An internal matrix composed of needles and fibers provide structural support. Sponges move large quantities of water through the pores in their body walls to trap food particles suspended in the water. Collar cells capture food on the microvillus and nourish the sponge by transferring the food to cells inside the matrix for digestion and

storage. Some sponges reproduce sexually; young sponges begin in larval form as sexually immature and free-living before attaining adulthood. Other sponges reproduce asexually by the process of fragmentation; small fragments break away from the sponge body and form new organisms.

Cnidarians

Aquatic animals such as coral, jellyfish, and sea anemones are cnidarians. Cnidarians exhibit two body styles, both radial in design. The medusa floats like a bell in the water while the polyp, a tube shaped structure, attaches to rocks. Both styles are designed for capturing prey. The main body cavity of the cnidarians is a gut with an attached mouth. This allows the cnidarians to eat larger, bacteria-sized structures. They have functional tissues, including a primitive nervous system called a nerve net. This system of nerve cells works with sensory and contractile cells to bring about movement, feeding, and changes in shape. Cnidarians produce nematocysts, which are sacs that emit prey-capturing toxins. Jellyfish stings are an example of nematocysts in action. Cnidarians' life cycles include both sexual and asexual reproduction. The zygote resulting from a sexual union develops into a planula, a creeping or swimming larvae.

Platyhelminthes

The phylum Platyhelminthes, also known as flatworms, includes turbellarians, fluke, and tapeworms. Flatworms are generally bilateral, cephalized, and have organ systems. They have a sac-like gut, with food entering through a pharynx. Three germ layers form in their embryos.

1. Turbellarians are generally sea plants. They feed on small animals or on the tissue of dead animals. Turbellarians have a complex organ system for regulating body fluids. They reproduce by dividing in half, with each part regenerating the missing portions.
2. Flukes are parasites that feed from a living host without killing it. Flukes suck in nutrients from the body surfaces or actually invade the host's body where they reside.
3. Tapeworms are intestinal parasites that will attach to the intestinal wall by a scolex, a structure with hooks or suckers. The tapeworm obtains soluble nourishment from the host.

Roundworms

Roundworms live in widely diverse environments, from tundras to arid areas. Any given square foot of soil contains hundreds of roundworms. They are parasites that feed on both plants and animals. Numerous species infect human beings, with often unpleasant results. Hookworms are an example of roundworms that invade humans and can cause significant medical problems, though they are rarely fatal. Pinworms are a species of roundworms that flourish in tropical or

semi-tropical climes. Roundworms have complete digestive systems, with a false coelom that contains their reproductive organs. They have a tough body covering called a cuticle that provides protection and insulation. Most roundworms, regardless of where they live, have the same basic body form, showing an unusual capacity to adapt to different habitats. They are very prolific, although most people have rarely seen one.

Rotifers

Rotifers are small animals that are less than a millimeter in length. They favor wet habitats such as lakes, ponds, rivers, and wetlands. Rotifers feed on bacteria and other animals eat them, making them an important link in the food chain. In many species of rotifers, males are unknown and are present only in a few varieties. Females produce diploid eggs that develop into other females, or they can produce haploid eggs that develop into haploid males. If the haploid eggs are fertilized by males, they develop into females. Male rotifers appear rarely and are usually dwarfs that have short lives. Rotifers, despite their small size, have great complexity in their anatomy and physiology. They contain organs and organ systems, and have brains, mouths, antennae, bladders, jaws, throats, and muscles among other structures.

Mollusks

Mollusks are soft-bodied animals encased in a calcified shell. They include such familiar creatures as snails, clams, and oysters. Mollusks have a tissue skirt that hangs around their body called a mantle. The mollusk has a mouth with sharp teeth that shred food before it enters the gut. They have a complex anatomy, including reproductive organs, a heart, excretory systems, and a breathing apparatus called gills. The more developed mollusks have a well developed head, eyes, and some have tentacles. Mollusks include the following groups:

- Gastropods - Snails and slugs make up the largest group of mollusks, the gastropods.
- Bivalves - Clams, scallops, and oysters are representative of bivalves.
- Cephalopods - These include squid, octopuses, and cuttlefish. The giant squid is the largest known invertebrate, sometimes measuring over 60 feet in diameter.

Annelids

Annelids are the segmented worm group that is composed of earthworms, leeches, and polychaetes.

- Earthworms are scavengers that live in moist soil or mud and feed on decomposing organic matter. Earthworms burrow through dirt, aerating the soil which benefits many organisms by making nutrients available to them. Earthworms have a complex body system along with other annelids.
- Leeches - Leeches live in both fresh and salt water. They nourish

themselves by swallowing or killing small animals and sucking out their juices. The gut of the leech has the capacity to store large amounts of food for future use.

- Polychaetes - Polychaetes are marine worms. They eat small animals and organic waste found in sediments. Varieties of these creatures can crawl, swim, and burrow as a means of motility. Some live in tubes they construct themselves and have tentacles near their mouths to facilitate feeding.

Arthropods

There are almost one million known species of arthropods. They display a wide range of diversity and include four different large groups.

1. Trilobites - No known members of this group are living today.
2. Chelicerae - Included in this group are ticks, mites, spiders, scorpions, and horseshoe crabs.
3. Crustaceans - Familiar members of this group are crabs, lobsters, shrimp, and barnacles.
4. Uniramians - Centipedes, millipedes, and insects are in this group.

Adaptations: Arthropods are very adaptable, and the following adaptations have been important in their success:

- Exoskeletons - The cuticle of existing arthropods is a tough, protective skeleton. Composed of protein and chitin, this exoskeleton (external skeleton) is flexible and provides support and insulation. The exoskeleton serves as a barrier against water loss and can support a dehydrated body. Arthropods shed or molt their old exoskeletons in order to grow.
- Division of labor - Metamorphosis is the transformation of arthropod larva into adults. During this process, a division of labor may occur between immature stages and adults. For example, a moth caterpillar specializes in feeding and growth, while a moth adult concentrates on reproduction.
- Jointed appendages – these became highly specialized to perform tasks such as swimming and flying
- Respiratory systems - The development of the tracheal tubes was an adaptation of great importance.
- Sensory structures - The development of the eye and other sensory organs was an important adaptation.

Chelicerae

Chelicerae include ticks, spiders, scorpions, and mites. These organisms have a bad reputation with some cause. Many ticks prey on domestic animals, feeding especially on blood. They often transmit serious diseases to human beings, such as Lyme disease and Rocky Mountain spotted fever.

Mites are parasites and scavengers. They cause minor infections in humans, but are a major problem in agricultural crops. Spiders are eight legged, multi-eyed predators. There are several poisonous species that can be deadly to humans and other animals. Most are harmless and provide a service by killing a host of insect pests. Small appendages spin out silk to construct cobwebs to catch prey and provide a food source. They also produce egg cases in the reproductive process.

Crustaceans

Familiar and common members of the crustacean family include lobsters, crabs, and crayfish. The species also includes pill bugs and copepods. The majority of crustaceans live in the sea, but there are some freshwater and land-dwelling examples. Many crustaceans serve as important food sources for humans, and all are of importance in food chains. Crustaceans are segmented animals and the segments perform many functions. Some serve as a shield for protection, as with crabs and lobsters. Crustaceans typically have strong claws, which they use for defense, food gathering, and tearing food. The head of the crustacean is well developed, with a pair of eyes, a jaw, and structures for handling food. Perhaps the oddest representative of crustaceans is the copepod, a poor swimming animal with a single eye in the middle of its head.

Insects, centipedes, and millipedes

There are more than 800,000 species of insects now identified, making them one of the most numerous invertebrates. This variety stems from their small size, as they can grow and reproduce in great numbers using a minimal amount of food. The addition of wings gives some insects great mobility and is an important adaptation. The typical insect has a head, thorax, and abdomen. Insects can reproduce in amazing numbers, insuring their survival. Although most people view most insects as pests, many serve important environmental and ecological purposes. Millipedes and centipedes are well known for having multiple pairs of legs. Millipedes are slower, and serve mainly as scavengers of decaying organisms. Centipedes are much faster and more aggressive, using fangs and venom glands to kill prey. They live under forest litter and rocks.

Echinoderms

Echinoderms are spiny-skinned animals and include sea urchins, sea stars, and sea cucumbers. They have a radial body plan and a unique water-vascular system allowing them to cling to stabilizing structures and capture food. Echinoderms have a primitive nervous system with no brain. Sea stars are a typical echinoderm with many unique features in their anatomy and physiology. Sea stars have tube feet for walking, burrowing, or clinging to debris. These feet can also be utilized for trapping and eating food. The tube feet have an

ampulla, a muscular structure that shortens or elongates the foot by forcing water through it. They may swallow their prey whole, and some actually push their stomach outside the mouth and begin digestion even before swallowing. The mouth serves as the major excretory organ.

Chordates

Chordates are bilateral animals, the vast majority of which are vertebrates. About 2,000 species are invertebrates. Chordates have the following features that distinguish them from other animals:

- **Notchord** - A cylinder of stiff tissues that provides support for the chordate body.
- **Nerve Cord** - A tubular nerve cord located above the notchcord and gut.
- **Pharynx** - The chordate's entrance to its digestive tract.

Invertebrate chordates include tunicates and lancelets. Tunicates are sea creatures that secrete a protective skirt around themselves. Lancelets are relatively rare fish-like organisms that bury themselves in land and mud for protection. A buried lancelet positions its mouth at the surface of the sand and mud, food is trapped by the pharynx and delivered to the gut.

Characteristics of fishes

Fishes are the most numerous and diverse vertebrates. The body of a fish is streamlined for ease of movement through water, and fins help propel and guide that movement. Most fishes have protective scales that provide them with a light but durable coat. Strong muscles give fishes excellent mobility in the water. Jawless fishes include lampreys and hagfish, both of which have snake-like bodies. Lampreys have an oval mouth with sharp, horny, tooth-like plates used for ripping the flesh from their prey. They can be very destructive, invading fresh water and decimating the populations of lake trout and other fishes used for human consumption. Hagfish are worm-shaped and have feelers around their mouths. They attack food crop fish and secrete a thick, slimy mucus.

Cartilaginous and bony fish

Cartilaginous fish are accomplished predators that have bodies adapted for speed and maneuverability. All have cartilage as their backbones, scales, and gills. They shed and replace their teeth regularly. Sharks, skates, and rays all belong to this group. Sharks can eat almost anything and have large, sharp rectangular teeth for killing and eating. Skates and rays dwell on sea bottoms and have flattened teeth with which they crush hard shell sea animals for use as nourishment. Bony fishes have diverged into four lineages: lungfish, crossopterygians, bichirs, and ray-finned fish. There are over 20,000 species of bony fishes, among them many that are familiar to people as seafood. Salmon, tuna, catfish, perch, and minnows are bony fishes. These fishes can move quickly due to light, flexible scales and maneuverable fins that propel

them through the water. Their respiratory systems have adapted to provide abundant oxygen even at their most active.

Amphibians

Amphibians today include frogs, toads, salamanders, and apodans. Amphibians eat everything they can catch. They all lay eggs in water or very wet environments. Amphibians probably evolved from lobe-finned fish. As they adapted to living on land, their brains became more complex and they gained the ability to process signals relating to vision and balance. For the amphibious water dweller, the gills and fins serve as aids for respiration. Land dwellers tend to rely on the lungs and skin for this purpose. Some amphibians produce toxins harmful to life and may be brightly colored as a warning to predators. Frogs and toads have powerful muscles that allow them to hop or jump great distances; they capture insects for food using a sticky tongue at the front of their mouth. Amphibians are of great use in the study of evolution, as scientists can chart their progress from the sea to land.

Reptiles

The important adaptation of insects on land and a burst of growth in the insect population may have triggered the evolution of reptiles from amphibians. The increase of the variety and number of insects provided an abundant food source for amphibians. The adaptation of the amphibian jaw for feeding on insects and the development of the amniotic egg were key points of this evolution. Today's reptiles include crocodiles, snakes, turtles, and lizards. These reptiles have a bony skeleton and tough protective scales. They have lungs for respiration and lay hard, leathery eggs. Reptiles show an unusual degree of social complexity, sometimes staying together as families for several years. Reptiles vary in size considerably, most are small but the Komodo dragon is large enough to hunt mammals. More than 90 percent of all reptiles are snakes and lizards.

Birds

Birds are thought to be descended from reptiles that were bipods. Birds still resemble reptiles in many of their internal structures and habit of laying eggs. Birds show an amazing diversity in size, color, ability to fly, and social behaviors. Their songs and calls have important behavioral meanings to other birds. The ostrich weighs nearly 350 pounds, while the hummingbird weighs less than an ounce. The two features that almost all birds share is low weight and great power, both of which allow them to fly. They feed on a wide variety of organic material. The most impressive adaptation of the bird is the wing, composed of feathers, bones, and muscles. Air cavities in bird bones make them light and enhance the bird’s ability to fly. It is the basis of the powerful down stroke that allows flight. All birds share an efficient oxygen delivery system and a strong, four-chambered heart.

Mammals

The three major groups of mammals include the egg-laying, pouched, and placental mammals. Examples are:

1. Egg Laying - The duck billed platypus. Also known as monotremes.
2. Pouched - The kangaroo and opossum. Also known as marsupials.
3. Placental - Humans and canines. Also known as eutherians.

All mammals have lungs, a four-chambered heart, and an advanced cerebral cortex. Embryos develop internally and newborns are nourished by milk produced by the mother. Most, but not all, mammals have hair or fur and adults usually have a permanent set of teeth. The evolution of modern mammals was signaled by the development of the complex brain. It expanded over time to include larger units of information processing systems. This led to the human ability to remember, reason, learn, and think creatively. All of these changes began at the beginning of the Cenozoic age and took eons to evolve.

Theory, evidence and mechanisms of evolution

Evolution

Theories of Darwin and Wallace

Charles Darwin and Charles Russell Wallace, working independently of each other, formulated their own theories of evolution by natural selection. Key features of both their theories are:

- Differences in related populations are caused by different adaptations to their environment. Adaptation may be defined as any genetically based feature that results in an organism being better suited to its environment.
- Differences in behavior, function, and form accumulate among separate groups; some of these differences may be adaptations.
- The heart of Darwin's theory, published in “On the Origin of Species,” is that organisms best adapted to their environment will have a greater chance to survive and reproduce.
- Darwin's own summary of his theory is “As more individuals are produced than can possibly survive, there must in every case be struggle for existence. The preservation of favorable variations and the rejection of injurious variations, I call natural selection."

Darwin’s theory of evolution

Darwin’s book *On the Origin of Species* gave us a unifying concept in science. Darwin offered two theories:

1. The *theory of evolution* states that all living things have evolved from common ancestors over millions of years. They diverged into multiple

species gradually through a process of change and variation.

2. The *theory of natural selection* concludes that changes in natural conditions select stronger organisms, while less-adaptable organisms tend not to survive and, therefore, fail to contribute to future generations. The key issue of survival is successful reproduction.

The theory of evolution explains both the unity and diversity of life: Many organisms share common traits yet show great diversity. The accumulated evidence for the theory of evolution is overwhelming: Almost all scientists consider evolution a scientific fact.

Evolutionary thought

Lamarck's contributions

Jean-Baptiste Lamarck accepted the concepts put forth by Buffon, Cuvier, Hutton, and others that life forms evolve. In 1809, he proposed that evolution is caused and driven by the inheritance of acquired characteristics. Lamarck also believed that organisms change as they struggle to meet their environmental demands. He thought changes were passed to future generations through elements called pan genes. Lamarck theorized that lower life forms moved to more complex forms through inherited changes. His classic example was the lengthening of the neck of the giraffe as it responded to the necessity of stretching in order to feed over long periods of time. He also felt body parts could be lost through disuse, as in the case of the loss of eyesight by the mole. Much of Lamarck's theories have been discarded because he failed to understand the role of cells, gametes, and heredity. Still, his focus on evolution was a breakthrough, stating that living things evolve because of natural laws.

Gene mutations

Mutations are the inherited changes in the chemical structure of genes. The actual alleles of the genes are altered and the equilibrium of the gene pool is upset. Mutations may be caused by abnormal gene duplication, gene relocation, or chromosomal changes in genes. Mutations are not inherently positive or negative. Mutations provide new alleles, which are a major cause of genetic variation. Every time an allele mutates to a different allele, the gene frequencies are changed, and evolution occurs. Although mutations are fairly rare, every human being probably has a mutated gene. Over a long period of time, any allele can eventually mutate. Mutations often arise by chance; this process has been observed through molecular research techniques.

Migration and gene flow

There are constant migrations into and out of populations. Gene flow occurs when organisms migrate to a new population and breed with the existing population. Gene

flow tends to lessen genetic differences between populations. It also tends to inhibit evolution by minimizing the diversity of genetic makeup in populations. The absence of gene flow may stimulate the origin of a new species.

Examples of migration and gene flow are everywhere. Mammals can invade new territories and breed with the new population. Pollen can be carried by the wind hundreds of miles and interact with different populations of plants. Wars or forced immigration can have a major impact on gene pools. For example, the Irish potato famine of the mid-19th century caused a tidal wave of immigration into the United States that influenced the country's genetic makeup.

Genetic drift

Probability and chance have an effect on gene frequency from generation to generation. This is called genetic drift and it tends to increase the diversity of populations. Genetic drift is subtle, particularly in large populations where its impact is minimal. In small populations, genetic drift can change gene frequencies dramatically and sometimes cause mutations relatively quickly. This is most obvious when a few members leave a large population to establish a new population. The new population will reflect gene patterns present in the founders of that community. This is called the "founder effect" and it is very common. A bottleneck effect happens when only a small number of a population survives a cataclysmic event. The survivors' gene pool may be very different than the original population. This "bottleneck effect" is often observed after a severe change decimates a population.

Nonrandom mating

Nonrandom mating is the breeding of two organisms and depends on their phenotypes and genotypes. Nonrandom mating is common in nature and is usually one of two types:

1. Inbreeding is the mating of relatives at a higher than normal frequency. An exaggerated form of inbreeding is self-fertilization found in relatively few plants and animals. Interestingly, Mendel's pea plants were capable of self-fertilization. Inbreeding can have positive or negative effects on a species.
2. Associative mating involves the breeding of unrelated organisms at an unusually high frequency. In modern society, certain ethnic groups tend to marry within their population, causing an obvious contradiction of the random mating requirement of the Hardy-Weinberg principle. This also happens frequently in the animal kingdom, where mating preferences are often based on nonrandom criterion.

Natural selection

Natural selection acts continually on an organism's phenotype and this activity affects the organism's genotype. Although there are multiple factors that affect gene pools, natural selection best explains the adaptations organisms make to survive in different environments. As Darwin recognized, natural selection is a key mechanism in evolution; it affects the phenotypes of microbes, plants, and animals over time and, in doing so, determines the way present day organisms look and behave. Major considerations in the understanding of natural selection include the following topics:

- The concept of fitness.
- How genotypes are affected by phenotypes.
- The varieties of natural selection.
- The mechanisms of evolution.

Influence of phenotype

Natural selection provides processes that tend to increase a population's adaptive abilities. The strongest phenotypes survive, prosper, and pass on their genetic code to the next generation. The new generation of phenotypes has a more fit genotype because they have inherited more adaptive characteristics. Thus, fitness thrives while the weak become extinct over time. This pattern, when repeated over many generations, develops strong, fit phenotypes that survive and reproduce offspring who are as fit or more fit than their parents.

Sometimes this apparently inexorable movement can be modified by drastic external conditions such as wide variations in climate. It is important to remember that all extinct species were once fit and adapted to their environments. Unforeseen circumstances always have the potential to cause chaos in the physical world.

Genetic fitness

Geneticists have a specialized definition of fitness. They use the term to denote an organism's capacity to survive, mate, and reproduce. This ultimately equates to the probability or likelihood that the organism will be able to pass on its genetic information to the next generation. Fitness does not mean the strongest, biggest, and most dangerous individual. A more subtle combination of anatomy, physiology, biochemistry, and behavior are factors that determine genetic fitness. Another way to understand genetic fitness is knowing that phenotypes affect survival and the ability to successfully reproduce. Phenotypes are genetically determined and genes contributing to fitness tend to increase over time. Thus, the "fittest" organisms survive and pass on their genetic makeup to the next generation. This is what Darwin meant by "survival of the fittest," which is the cornerstone of Darwin's theory of evolution.

Natural selection of genetic material

It is now clear that changes in phenotypes do not always reflect variations in genetic makeup. Even when the genotype affects the phenotype, it is often difficult to determine precisely the gene location and allele responsible for the variations. The difficulties of understanding the subtle differences in genotype as well as the more obvious changes in organisms have been partially solved by advances in molecular biology following the unraveling of the genetic code. Scientists can now explore genotype and phenotype relationships at a more sophisticated level and much more precisely understand the degree of protein and genetic variation in a variety of evolving organisms. Experts are now able to catalog genetic variations and their impact on phenotypes. These advances have arrived through better technology and equipment, and a clearer understanding of molecular genetics.

Gene pool

A population is a group of organisms that reproduce or have the potential to reproduce. All the alleles of all the genes in a population of organisms are called the gene pool for that population. There are two ways of understanding the genetic makeup of a gene pool. The first is to describe the types and approximate number of genotypes present in that pool. The second is to list the number and frequency of each allele present in the gene pool. There may be many alleles for any given gene depending on the number of mutations that have occurred. Geneticists sometimes define evolution as a change in gene frequencies. The relative frequency of different alleles is a method of measuring that population's evolution. Over time, these alleles will determine the phenotypes of a given population.

Hardy-Weinberg principle

The Hardy-Weinberg principle was formulated by two researchers, G.H. Hardy and Wilhelm Weinberg, working independently of each other. The principle describes the frequency of alleles in a hypothetical population meeting these requirements:

- There is random reproduction.
- The population is of a significant size.
- There are no mutations.
- The population is isolated from other populations.
- Natural selection does not occur.

When all of these requirements are met, the Hardy-Weinberg principle states that allele and genotype frequencies remain constant in large populations over time. In this case, the gene pool can be said to have reached genetic equilibrium. Since any change in a gene pool is evidence of evolution, the Hardy-Weinberg principle is a means of detecting evolution in a given population.

Implications

The implications of the Hardy-Weinberg principle are as follows:

- In populations with random mating, the frequency of the genetic alleles will determine the genotypic frequencies.
- If the frequency of alleles is the same for both males and females in a population, only one generation of reproducing will be needed to achieve equilibrium in genotype frequencies.
- Gene frequencies will remain constant from generation to generation unless external factors disrupt the genetic equilibrium.

Thus, there is a direct correlation between patterns of gene alleles and their genotype frequency. Gene frequencies will tend toward equilibrium if no external or internal events occur to disturb this frequency.

Upsetting gene pool equilibrium

In the physical world, the conditions for the Hardy-Weinberg gene equilibrium law never exist due to persistent change. In actual plant and animal populations, genes constantly mutate, animals migrate to different environments, and natural selection works continually to upset the equilibrium of the population's gene pool. This constant change is evidence that that evolution is occurring. The major factors causing the gene pool to evolve include the following:

- Genetic Drift
- Mutation
- Migration
- Natural selection
- Nonrandom mating.

As these factors impact the population's gene pool, evolution occurs. Thus, the actual proof of evolution is that the Hardy-Weinberg gene equilibrium never exists in the physical world.

Electrophoresis

Electrophoresis is a technique that traces the movement of electrically charged particles through a fluid medium. The development of this technique has dramatically improved the ability to survey a gene and its proteins among members of a population. Using electrophoresis, scientists can differentiate between enzymes, proteins, and other charged molecules extracted from tissues. This gives scientists a clearer view of the genetic characteristics of a population. Electrophoresis is carried out by placing a protein sample on a slice of starch, gel, or paper. Then, an electric current running from a positive electrode to a negative electrode is applied. An electrophoresis gel is then able to analyze protein differences. Researchers are making great strides in understanding genetic makeup using electrophoresis and other new techniques.

Evolutionary change

Major selective processes

There are four major selective processes which may produce evolutionary change or preserve existing adaptive traits. They are:

1. Normalizing or stabilizing selection simply protects and preserves a fit existing phenotype. This type of selection is strongest in environments that have remained stable for long periods of time. Examples include arid desert areas and Antarctic glaciers.
2. Directional variation occurs when an environment favors a genetic variant which grows in frequency over a period of time.
3. Disrupting or diversifying selection occurs when a population is confronted with extreme new conditions that are so diverse that no one phenotype can prosper without the expense of others. This selective process can lead to two or more phenotypes adapting to a different extreme condition of the environment.
4. Balanced selection is when a heterozygote has a higher fitness level than either homozygote. This is also called hybrid advantage, such as when mongrel dogs are heartier than purebred dogs.

Adaptation

The debate on the nature of adaptation is ongoing. The neutralist position is that although many variations of phenotypes are certainly driven by natural selection, many others are not. Neutralists argue that many variations are the result of mutations caused by many factors, including chance. They feel most of the mutations in genes are randomly neutral and do not affect the fitness of the organism carrying the mutation. The selectionists believe that natural selection drives every adaptation of the phenotype. They feel every structure, behavior, color, and shape of an organism is a result of selective pressure. Both of these positions have strong advocates and molecular research is being conducted to explore the merits of each side. Because the results of this research will not be known for some time, the question remains unanswered.

Isolating mechanisms in genetics

There are two broad categories of isolating mechanisms that prevent gene exchange between individuals.

1. **Pre-zygotic isolating mechanisms** block the formation of zygotes. It prohibits the fertilization between a male and female gamete. These may be ecological or behavioral and affect processes that determine the timing and physiology of reproduction.

2. **Post-zygotic isolating mechanisms** prevent gene transfer between species. When individuals from different species breed, hybrids may result but usually do not survive or cannot reproduce. These phenomena are respectively known as hybrid inviability and hybrid sterility.

For example, sheep and goats may breed, but the fertilized egg dies at an early stage of development. Hybrid plants may interbreed but the seeds usually grow into a sterile plant.

Crosses between members of genetically distant populations can sometimes result in hybrid vigor but more often result in hybrid breakdown.

Species

In the early days of scientific investigation, an individual's morphological identity or physical correspondence with other organisms qualified it for membership in a particular group. Darwin advanced the concept that physical similarity was the result of common ancestry. Population genetics presented the theory of a shared gene pool as the basis for joining a species. This theory defines species as a group of interbreeding populations. Today the accepted definition of species is reproductive isolation, meaning that members of a species can interbreed with each other but not with organisms belonging to another species. This definition is only valid for organisms that reproduce sexually. For asexually reproducing organisms, physical similarity and like biochemical processes are the determining standards for inclusion in a species.

Origin of new species

Allopathic model

Gene pools must become very isolated for a new species to develop. The allopathic, or geographic isolation, model of speciation posits one hypothesis for new species creation. If particular segments of a population are isolated, the gene flow is halted for the populations and more genetic differences will accumulate between the separated populations. Differences become so significant that post-zygotic isolation will occur. Afterward, even if the populations were reunited and attempted to breed, their offspring would either not survive or be sterile. Over time, the two populations will function as new, separate species.
Simply stated, this allopathic model states that physically separate populations diverge genetically and eventually become a fully distinct species by natural selection. There is much scientific evidence to support his theory.

Genetic basis of speciation

New molecular research has found that relatively small changes in genetic structure may lead to more dramatic physical changes and in fact be responsible for the beginning

of a new species. Mutations were once thought to be the most important factor in the emergence of a new species, which would emerge from many generations of mutation and natural selection. However, new evidence suggests that mechanisms other than mutation can split populations much more quickly. Chromosomal changes such as the multiplication of an entire set of chromosomes can alter genetic makeup significantly in a short period of time. For example, chromosomal rearrangement was proven to be the catalyst for the evolution of the giant panda from the bear lineage. To summarize, species can originate in a variety of ways, some taking thousands of years and others occurring in a single generation or two.

Macroevolution and microevolution

Macroevolution may be defined as the major phenotypic changes that occur over long periods of time and that finally result in a new taxonomic level above species. Macroevolutionary affects include major changes in anatomy and physiology and basic changes in body design. An example of such a change is the evolution of stomata and cell guards in plants that allowed them to regulate gas exchange. In animals, an example would be the evolution of the reptilian foreleg into the wing of a bird. In general, macroevolution causes major changes in the appearance and functions of plants and animals and results in new taxonomic levels of a high order.

By contrast, microevolution works on a much smaller scale. Microevolution refers to small-scale changes in gene frequencies that generate new species, rather than a higher taxonomic order.

Phylogeny

Phylogeny is the process of tracing the lines of descent of plants and animals as they lived from one era to the next. Incomplete fossil records make it difficult to build complete lineage charts for many plants and animals. However, if many descendents still survive, scientists can project likely phylogenies by comparing physical and behavioral features and analyzing genes and proteins of the living organisms. An example of a well-traced phylogeny is the horse. Early horses of the genus Hyracotherium were about the size of large dogs and had toes instead of hoofs. Scientists have constructed a complex evolutionary lineage for the modern horse, with more than 20 genera of the horse family represented. The only surviving genus of the horse family is Equus; all other genera in the family are extinct.

Evolutionary patterns

In building a phylogeny, scientists use similarities in anatomy, physiology, biochemistry, and behavior to trace common lines of descent. Three broad classes of evolutionary patterns are:

1. **Parallel evolution** - Occurs when two populations develop similarly in different geographical areas. For example, some species of rodents developed independently, but with similar characteristics.
2. **Convergent evolution** - A pattern in which two or more distantly related lineages grow more alike by evolving similar adaptations.
3. **Divergent evolution** - The splitting off of variations from a common ancestral organism. Homology is the derivation from a single ancestor, while analogy is the independent evolution of features with similar functions.

Most modern species and genera are the result of divergent evolution.

Punctuated equilibrium

For most of recorded scientific history, scientists have believed that major evolutionary changes took place over vast periods of time. However, a new theory called punctuated equilibrium suggests that evolution takes place in radical changes in a short period of time, followed by longer periods of stability. The proponents of this theory state that a lineage of organisms arise because of some drastic change, followed by a period of stability when only minor changes occur. Punctuated equilibrium is a hotly debated theory among evolutionists. The equilibrium of some lineages may be "punctuated" by dramatic environmental events or other factors, but gradualism characterizes the history of many species.

Commonalities and diversities of life

Billions of organisms have existed on Earth. All of life shares certain qualities:

- DNA and biological organization arise from the basic elements of energy and matter.
- All organisms depend on homeostatic and metabolic processes.
- All organisms have the ability to grow, develop, and reproduce.
- All organisms have genetic characteristics encoded in their DNA.

Millions of different organisms have led scientists to classify them based on similarities and differences. Each unique type of organism is called a species; species resembling each other are grouped into one genus, and so on through groupings of family, order, class, phylum, and kingdom. Diversity among life forms occurs through mutations that cause changes in DNA. These mutations cause changes in the behavior, structure, and functioning of new generations. Individuals in a group vary in their genetic makeup. Certain traits survive through adaptation while others disappear. This fluid state of genetic change causes the population to evolve over time. This is the basis of natural selection, a core concept in the theory of evolution.

Modern view of origin of life

It is believed that complex chemicals generated by the heat of the sun and other factors caused the creation of simple atoms and molecules. These chemicals are thought to have caused the bonding of simple structures into primitive, organized systems able to reproduce themselves. These were the first cells—the beginning of life on Earth. Mutations in the genetic code of cells resulted in variations of new cells that ultimately created a huge variety of species, becoming more complex and specialized over a long span of time.

Big Bang theory

The *Big Bang theory* has captured the attention of society and scientists alike. The term big bang is actually used in two different but related senses: It refers to the event that marked the origin of the universe; it also refers to the expansion and cooling of the universe that has happened since then. The big bang theory describes the temperature of the universe and the collision rates of particles within it. It can therefore predict the proportions of light nuclei that were created at the dawn of the universe. Recent research has shown that melding the big bang theory with the modern theory of elementary particles provides many answers to the structure of the universe. Many mysteries still remain. We do not understand the very beginning of the universe, nor is it certain that our current laws of physics applied at that time. Despite these questions, there is ample and persuasive evidence that the big bang theory is valid.

Fossils

Fossils are the hardened body parts of plants and animals which remain after an organism dies. They include bone, shells, and impressions made in soft sediment. Fossil evidence may be used to track some lines of descent very well, but many lineages are difficult to trace using fossils. Fossil evidence is an incomplete record of the earth's evolution of life, but it provides a great deal of information that can be useful in the study of evolution. Problems with fossils as a tool in tracing evolution are the following:

- The majority of organisms that ever lived left no fossils.
- Only a tiny percentage of organisms with hard parts would have been preserved as fossils.
- Fossils that did form were often altered or destroyed by geologic changes of the earth or by chemical reactions which dissolved them.

Radioisotope dating

The most accurate method of determining the age of fossils is radioisotope dating. In this method, radioactive isotopes are used as biological clocks for measuring time. To use radioisotopes effectively in fossil dating, the scientist must know the isotope's half-life: the amount of time it takes for one half of the

isotope to decay. The scientist must first determine how much of the isotope was originally present in the fossil and then how much of the isotope is left. When all these factors are known, a scientist can calculate the age of the fossil with about 98 percent accuracy. The older the fossil, the longer the half-life of the isotope must be to accurately date the fossil. Uranium-235, with a half-life of 713 million years, or uranium-238, with a half-life of 4.5 billion years, are both very useful in dating more ancient fossils. Isotopes with shorter half-lives may be used to date relatively recent fossils.

Although fossils provide a window into the process of evolution, they provide only a partial picture at best.

Extinction

Extinction may be defined as the permanent loss of a species. Extinction has been the eventual result for almost all species: of the 4 billion species to have lived on earth, only 30 million or less survive today. Extinction can be mass extinction, which results in massive species lost, or individual extinction, where only a single species is lost. Scientists believe that there have been five mass extinctions in history, two of which resulted in huge species loss. In the past 600 million years, an average of about one species has become extinct each year. Today's rate of extinction is at least 1,000 species a year. One of history's great mass extinctions is currently in progress: the loss accorded by destroying the species-rich tropics and rainforests. The best remedy for extinction is habitat preservation.

Scientific Processes and Inquiry

Principles and procedures of scientific investigation

Science

Science is a method of acquiring and obtaining knowledge. It is the process of gaining reliable information about the real world, including the explanation of phenomena. It is the development of a body of knowledge about observable phenomena, using the best capabilities humans have at their disposal. The process of organizing and classifying knowledge, through objective observation and evaluation, is a major goal of science.

Science can be considered reliable, but it is not infallible. The limits of human knowledge are constantly growing, often making yesterday's science obsolete and simplistic. Science is thus never fixed; it is always subject to change as new information is gained and synthesized with existing knowledge. Ultimately, science is the sum total of knowledge in any period of time, based on the current abilities of man to understand the world of phenomena, verifiable by observable data.

Basic and applied science

Basic science and applied science share many attributes but are generally motivated by different influences:

- Basic science is spurred on by scientific inquiry, the human need to explain the observed physical world. It may have no specific goal, but is man's response to questions that arise from human curiosity and interest. It is usually an attempt to explain the laws of nature by using the scientific method.
- Applied science has a specific practical goal or application: It is designed to solve a problem. Industry and government are institutions that use applied science regularly.

Thus, basic and applied science share many qualities, including scientific inquiry and the scientific method. The goals of each can be very different. It should be pointed out that basic science very often provides results that have uses in applied science.

Benefits of basic science

Although basic science may have no stated goal or target, it provides many benefits to society:

1. Basic science contributes greatly to human understanding and culture, enriching society in many ways.
2. Basic science has been responsible for major breakthroughs that have great social and economic impact.
3. Basic science provides derivative solutions that can be used in applied science. For example, basic science was critical to the development of the space program, from which countless valuable applications have been derived.
4. Basic science contributes to education and research across the broad spectrum of society.

Limits of science

There are clear limits on what science can explain. The demand for objectivity both strengthens knowledge we gain from scientific experiments and limits what we can explore. Beyond the realm of scientific inquiry are such questions as "Why does anything exist?" or "What is the meaning of life?" These are subjective questions that do not lend themselves easily to scientific inquiry. These questions, and others like them, come from within, and their conclusions, not validated by science, shape the very fabric of a society. They attempt to give meaning to what may be viewed as chaos. Periodically, science will impact these subjective conclusions with new evidence. For example, the theory of evolution is regarded as blasphemy by many religious fundamentalists. These conflicts may cause great upheavals in society, leaving many to wonder how science and religious belief can be reconciled. Ultimately, observation of the external world must stand as the true test of science.

Scientific inquiry

Scientific inquiry is the impetus and catalyst for all scientific research and experimentation. It grows from questions about the observed world and gives us a template with which to apply the scientific method. Steps in scientific inquiry include the following principles:

1. Determination and scope of the questions to be investigated are the first step. These may range from simple to extremely complex questions to be explored by scientists.
2. The design, strategy, and method of the inquiry are then carefully considered, and a model for the inquiry is constructed.
3. The formulation of theories and models based on the careful observation of objective, unbiased data then follows. This formulation is derived from the scope of the scientific inquiry and the questions to be investigated.
4. Analysis of possible alternative conclusions drawn from the models and results of experimentation follows.
5. Postulating a theory or constructing a scientific statement based on conclusions is the next logical step.
6. Defending the scientific statement against alternative hypotheses is a critical function of scientific inquiry.
7. Defense of the theory or conclusion against critical analysis is the final step in the process.

Scientific method

The steps of the scientific method are as follows:

1. The scientific method begins with, and absolutely depends upon, the observation of objective, unbiased data. Any prejudice or bias in the observed data nullifies its validity. Thus the basic input from the observations must be rigorously screened to ensure objectivity.
2. The development of a theory or hypotheses based on objective data is the next step in the scientific method. These theories or hypotheses pose logical expectations that the experiment may yield.
3. Construction of a rigorous and valid experimental method designed to test the theories is the next phase of the scientific method. This experimental method must be carefully constructed to give objective, unbiased conclusions based on the hypotheses posited.
4. Careful and statistically correct analysis and evaluation of the experimental results make up the next stage.
5. Modification and replication of the experiment must then follow to provide a statistically accurate

demonstration of the validity of the hypotheses. Equivalent results must be shown from a number of repetitions of the experiment.

Deductive model

The deductive model of the scientific method has the following criticisms:

1. The deductive model fails to make logical distinctions among explanations, predictions, and descriptions of things to be explained.
2. The deductive model is restrictive: It excludes most scientific examples.
3. The deductive model is too inclusive: It admits data that cannot be explained.
4. The deductive model requires an account of cause, law, and probability, which are basically unsound.
5. The deductive model leaves out the elements of context, judgment, and understanding.

Hypothetico-deductive process

The hypothetico-deductive process states that to have an idea and then formulate a hypothesis are essentially creative processes, driven by eons of human experience. Statements about reality are the logical conclusions of observed experience. Such creative propositions are the basis for scientific inquiry. Empirical evidence must then validate these hypotheses. Creative inspiration and scientific validation are interdependent aspects of scientific inquiry. New observations often are the catalyst for creative new theories. Science thus proceeds through creative thinking and scientific validation. There are criticisms of the hypothetico-deductive process: The problem of deduction points out that the original hypothesis may be proved wrong in the future, thus invalidating all subsequent conclusions. The problem of induction, building a theory from generalizations, is that any generalization may be proved wrong by future objective observations. This hypothetico-deductive process, and its problems, is a fascinating subject to philosophers of science.

Forming a hypothesis

It is important to form a hypothesis in order to make a tentative explanation that accounts for an unbiased observation. To be scientific, the hypothesis must be testable through experimentation. Careful construction of the experiment provides that predictions derived from the hypothesis are valid. The hypothesis must be formulated in a manner designed to provide a framework for evaluating the results of an experiment. In many scientific experiments, a hypothesis is posited in negative terms because scientists may accept logically plausible ideas until they are proven false. It is more difficult to prove that a hypothesis is true because its validity must be proven in all possible situations under endless variable conditions. Scientists tend to construct hypotheses for testing by creating

experiments that might prove them false. If they succeed, the hypothesis must be modified or discarded.

Prediction

These are the two widely accepted definitions of scientific prediction:
In the language of science, prediction is stating in advance the outcome from testing a theory or hypothesis in a controlled experiment. Based on objective observation of data, scientists move from observation of facts to a general explanation, or hypothesis, which must be confirmed by testing through experimentation.

Another definition of prediction favored by scientific philosophers is the ability of a hypothesis to lead to deductions of scientific statements that could not be anticipated when the hypothesis was posited. In this sense, prediction means what the scientist can verify from what he or she has deduced from the hypothesis.

Testing a hypothesis

Testing a hypothesis is the key to both scientific inquiry and the scientific method. While testing, all variables of the experiment must be strictly controlled except the one being studied. Variables, by their definition, are the processes subject to change. Examples of this in a typical experiment would be the degree of heat or light. In an experiment there are three types of variables:

1. The variable to be tested. Known as the independent variable.
2. Dependent variables. These are dynamic conditions that may change because of the independent variable.
3. Controlled variables. These are conditions that are held constant so they do not affect the independent variable.

A well-constructed experiment changes one independent variable at a time, observing the effects it may have on dependent variables. Only one independent variable at a time may be manipulated, so the experiment will yield a clear cause and effect result. If more than one independent variable were applied, the experimenter could not be sure which variable caused the result. This would invalidate the conclusions of the experiment.

Measuring, organizing, and classifying data

- Measuring data is a crucial part of the scientific process. Measurements are most useful if they are quantified—expressed in numbers. Measuring is the process of determining variables such as time, space, and temperature of objects and processes in precise numbers. The metric system is the universal standard of measurement in science.
- Data must be organized in a practical, useful manner to be valuable.

Scientists use graphs, charts, tables, and other organizational tools to make data more useful.
- Data must then be classified—grouped into organizational schemes for easy access and use. These schemes attempt to organize the maximum amount of useful data in a format that scientists can use.

Although these steps may be less glamorous than other areas of science, they are essential.

Analyzing and communicating scientific data and information

Verifying data

A critical distinction should be made between confirmation and verification of scientific data. Verification establishes once and for all the truth of the statement. Confirmation is the testing of claims to see how true they are. For a claim to be testable, an experiment must be devised to ensure the validity of the results. A claim can only be confirmed when we know the conditions for verification. A claim confirmation is always relative to the testing procedures. Test results must always be objective and observable. Actually, no factual claim can ever be verified because there is always the possibility of new evidence appearing that proves the claim false. A scientific law must also be confirmed by making predictions based on unbiased, observable data.

Scientific laws

1. Scientific laws must be true, not just probable. A highly probable principle may still be proven false.
2. Laws are statements of patterns found in nature.
3. Laws may have a universal form but be stated conditionally. For example, the statement "All living human beings breathe," may be restated "If a thing is a living human being it must breathe."
4. Laws refer to a general, not a particular, class.
5. Laws have purely qualitative predicates.
6. Laws must have a formal language of expression to be fully understood. Such a language does not exist now.
7. Laws may be probabilistic. For example, a law may state "Eight percent of all dogs are terriers."

Scientific tools, instruments, materials, and safety

Laboratory safety

The following basic rules should be supplemented by standards appropriate to individual laboratories:

1. Hazardous areas must be identified and warnings posted regarding risks.
2. A hazard containment plan must be in effect and readily available.

3. Safe control of airflow must be maintained at all times.
4. Safe work practices must be taught to all who work in the lab.
5. Proper maintenance of laboratory equipment must be enforced.
6. Safe storage of hazardous material must be implemented.
7. Procedures for safe disposal of hazardous wastes must be followed at all times.
8. An updated emergency procedure manual must be available.
9. A complete emergency first aid kit should be accessible at all times.
10. Regular education on the basics of lab safety should be implemented.

Unifying principles of science and relationships among science, technology, and society

Major scientific theories

Scientific theories have many different structures that may be applied in various realms of science. Some major scientific theories include:

- The once widely accepted *received view theory* is based on an analysis of theories empirically devised from deductive axiomatic systems. This theory has been widely criticized.
- The *model theory* states that a model may be constructed to correlate to a real system of relationships, and it can be used to simulate real systems. This allows the model to be manipulated and controlled and be able to predict the dynamics of the real system.
- *Mechanistic theories* do not attempt to fit phenomena into a set of inferential patterns but focus on the mechanism by which data is produced or realized.

Science and ethics

Debates over issues paramount to science and ethics are rarely resolved unambiguously. Ethical conclusions should be based on reason, logic, and accepted principles that represent a consensus of current thinking on a question. Education and debate are important in clarifying issues and allowing intelligent participation in a democratic process. Deciding issues of science and society usually requires an examination of individual cases. Generalizations in these areas tend to lead to extreme positions that exclude mainstream opinions. Both intrinsic and consequential arguments for or against any question may be advanced. There are no blanket solutions to most problems involving science, technology, and societal ethics.

Value neutrality of science

Science may be regarded as value neutral by society. This scientific neutrality is supported by the following arguments:

- Science provides us with knowledge of how the world works and the consequences of our interventions in it, but it does not indicate whether or when such interventions should be made. Science is like a map that can tell us how to get to many places but does not tell us where to go.
- Although scientists may welcome applications of their work, the primary focus is on the advancement of knowledge for its own sake.
- The applications of scientific knowledge are for society to decide. The scientist is the servant of the people, using his or her expertise to attain goals others have set.

All three of these arguments are open to challenge and debate, and many exceptions can be found for each.

Motivation for doing science

The motivation for doing science has fascinated society since the beginnings of scientific inquiry. Motives internal to the process of scientific research include scientific curiosity and the pleasure of doing pure research. Motives generated by the scientific community are the desire for a scientific reputation and corresponding influence in a scientific field. External influences on scientific research are the attractions of public fame, the desire to provide useful applications for society, the need for funding, and the ambition of influencing public and private policy. The desire to profit financially is an additional incentive. Although most scientists do earn a living from their work, there is a clear sense that scientific curiosity is the primary motive. No activity can count as scientific unless it answers the desire to know and understand the truth about some aspect of the physical or psychological world. Thus, multiple motives inspire scientists, and the common factor for all is scientific inquiry.

Good and evil effects of science

The applications of science have produced countless benefits for society, and the potential exists for many more benefits. However, science has been put to many negative and destructive ends in warfare and weaponry and in the less-obvious examples of pollution and the effects of radiation. The cost-benefit equation will be debated endlessly, with few real general conclusions drawn. We must live with the fact that science is used for both beneficial and destructive purposes by society, and, more alarmingly, it is often difficult to predict which are which. We must welcome the benefits that science provides, while understanding that these benefits may have hidden costs, and that even the best-planned technologies have unforeseen consequences. It must be acknowledged that there will always be forces in society using science for their own ends and not necessarily for the benefit of society. Science is neither a demon

nor panacea; it should be considered on the merits of individual research.

Science as a guide to decision making

Science has had an impact on the way in which people think and how personal and societal decisions are made. Science has given us a blueprint for rational decision making:

1. Identify a problem and formulate goals.
2. Specify a set of alternative plans of action.
3. Assign risk factors to the outcomes.
4. Assign values to each outcome in a systematic way.
5. Calculate the result of each course of action based on a cost-benefit analysis.
6. Choose the course of action with the best probable outcome.

This scientific approach to making decisions urges us to consider the benefits and risks of any decision. The institutionalization of science has encouraged the use of risk-cost-benefit analysis in policymaking. The risk-cost-benefit model has many critics, among them leading scientists and philosophers. Still, it provides us with a powerful tool to use in making decisions affecting the welfare of society.

Objectivity of science

The standard view of science is that it is objective above all. Science has a methodology that ensures against bias and prejudices and is testable by any qualified observer. The most obvious criticism of this tenet is that nothing can be viewed objectively because of the nature of the senses and their ability to distort observations. Other criticisms have arisen, led by Paul Feyerabend, Herbert Marcuse, and Nicholas Maxwell. Each has posited a different paradigm, in which science is viewed as one tradition among many. These radical thinkers (among many others) have challenged the objectivity of science on philosophical grounds. However, their arguments, while raising good questions, supply few rewarding answers. The most valid challenge to the objectivity of science is the difficulty of knowing if any observation is valid because of the inherent subjectivity of the observer. Quantum mechanics has provided new fuel for the question of an individual's ability to observe objectively.

Arguments against science

The reasons usually given to do science include intellectual curiosity, theoretical interest, and the potential usefulness to society. But what are the arguments about not doing science? They may be summarized as follows:

1. Any scientific inquiry uses someone's time and effort. The opportunity cost

of this time and effort must be evaluated: What other activities must be ignored if time and energy are used in scientific endeavors?
2. Resource allocation is the other argument against scientific research. When a project demands significant funds, questions can obviously be raised about the relative value of using the funds on one project rather than another. We are currently engaged in a national debate about allocating huge sums for scientific projects such as space exploration or the Human Genome Project. The billions of dollars needed to fund these projects could be used in a variety of less-costly projects that may benefit society more.

These objections are raised about large national projects, but they may be equally applicable to any proposal for a scientific investigation.

Nobel Prize

Alfred Nobel amassed a fortune, through inventions such as dynamite, which he used to found an endowment for the Nobel Prizes—now the standard measurement for scientific excellence among the public and the scientific community alike. Although Nobel cannot be counted as a scientist, because he did not contribute to scientific research per se, he did gain considerable knowledge in chemistry, which he used to practical effect as well as personal gain. Making money appeared to be his strongest motivation, and his primary business was the development and use of armaments. Nobel did take a strong interest in the technical aspects of his work. In later life his experiments contributed to the development of synthetic leather, silk, and rubber. At the end of his life, Nobel established a foundation that awarded prizes to persons who had contributed the most toward the ideal of peace in Europe. He set up five prizes in all, including the Nobel Peace Prize, for which he is most remembered.

Sexism

Two examples from the recent history of science illustrate the ongoing concern of sexism:

1. Rosalind Franklin was not given appropriate credit for developing a great deal of important data leading to the discovery of the structure of DNA. James Watson, the father of DNA discovery, has been accused of downplaying the contributions made by Ms. Franklin. This case is complex and appears to involve much more than gender-based discrimination, but there is little doubt sexism played a role.
2. A more obvious case of sex discrimination can be made for Jocelyn Bell in the discovery of stars known as pulsars. Bell, a member of a team headed by Antony Hewish at

Cambridge University, made initial observations that eventually led to the discovery of pulsars (a type of tiny neutron stars). Hewish received the Nobel Prize for this discovery, but Bell was not included in the honors. Hewish later commented "Jocelyn was a jolly good girl, but she was just doing her job." This statement would be understood as blatant sexism today.

Despite the increased number of prominent female scientists today, there still remains a concern that they do not always share in the credit deserved.

Biotechnical innovations

There are many biotechnical innovations that are beneficial to specific individuals in society that may be harmful to society as a whole. An example is the ability of parents to choose the sex of their offspring. This choice offers appealing benefits to individuals who may prefer one sex over another for a variety of reasons. However, if these choices lead to an 80/20 ratio of the sexes, it will be harmful to the population as a whole. An outcome of multiple individual choices would then amount to a net harm to society. Society moves to counter collective action problems by social pressure, legislation, and control. These countermeasures have the potential for altering society in unforeseen ways. The new power of institutions seeking to solve scientific problems that impact society may be the most alarming result of the meeting of science and technology.

Practical technology

A famous example of a practical technological breakthrough with vast industrial applications, which also stimulated the development of theoretical science, is the invention of the steam engine. James Watt, the developer of the steam engine, was an engineer more than a scientist. Watt's contribution was a modification of existing principles that led to a much more efficient steam engine. This had a huge impact on technology, economics, and science. Watt's research led to fundamental research in the theory of heat and the science of thermodynamics, with its general equations of the transfer of energy. Thus, though Watt did not directly contribute to pure science, his work formed the foundation for important pure research. We may speculate, had social and educational conditions been different, that Watt would have pursued a scientific career rather than an engineering career. Science history provides many more examples of similar cases, indicating that pure and applied science often go hand in hand in advancing human knowledge.

Environmental debate

The two extremes of the environmental debate serve to illustrate the diversity of thought in this area:

1. The *technocratic cornucopianism theory*—This position claims there is no shortage of resources on Earth. Humans must develop more-sophisticated technologies to harvest these resources. Earth provides an infinite well of resources for those clever and industrious enough to tap them.
2. The *deep ecology movement*—The principles of diversity and symbiosis are the key themes in this view. This movement argues for a biocentric approach, insisting on the equality of all species. This position sees man as a part of the biosphere rather than apart and distinct from the world. It posits a relational, total-field image.

Between these two extremes is the mainstream of environmental concern and the issues that face society in light of our increasing technological power.

Formulating environmental policy

Many principles are used in planning environmental policy:

- *Free-market economics*—In this principle, the nonhuman world has no intrinsic value, and decisions are based solely on economic concerns. The weakness of this policy is that many natural resources are not owned (e.g., the oceans) and have no financial value.
- 2 The *polluter pays principle*—This policy states that the environment may be exploited for economic gain, but the consumer must return the environment to its original condition. This overlooks the fact that much environmental damage is unseen and permanent.
- *Radical biocentrism*—In this principle, all organisms are equal and cannot be exploited for another's gain. This is an impractical solution, particularly in underdeveloped countries.
- *Environmental economics*—In this scheme, all factors are weighed, and decisions are based on the principles of common good for society. This involves giving a value to the environment—a valid concept that is subject to social, political, and economic pressures.

Environmental ethics

<u>Rainforest conservation</u>

The harvesting of the natural resources found within the rain forest comes at a steep price. For this reason, many environmentalists advocate rainforest conservation despite its adverse effects on the global economy. They argue that economic controls should be placed on the resources found in the rainforest, so that there will be less of an incentive for plunder. They also argue that the rapid deforestation of these areas will ultimately destroy local

economies and extirpate thousands of species. However, environmentalists know that the economic incentive to tap the resources of the rainforest is immense. They hope to encourage rainforest conservation by offering people debt forgiveness and economic aid in exchange for a moratorium on timber-harvesting and deforestation.

Malaria and DDT

It is now scientifically possible to eradicate or substantially reduce the scourge of malaria in the world through the use of DDT. Although at first glance this seems an easy decision, there are complicating factors involved. Countries with endemic malaria are poor and can only afford cheap, effective pesticides. DDT fits this description: cost-effective, easy to apply, and with lasting effects. The savings in human suffering would be significant. However, mosquitoes, the cause of malaria, are an important part of tropical ecosystems, providing an important link in the food chain. Also, DDT is not species-specific and affects a large range of organisms from insects to mammals. This problem raises ethical questions:

- What value is placed on the lives of the affected people and animals?
- What value can be assigned to affected ecosystems and the biosphere?
- How can both the ecological concerns and the health needs of a country be satisfied?

The difficulties of answering these questions and formulating policy are apparent. Environmental ethics is a source of much debate and discussion and will be for years to come.

Reproductive technology

The scientific advances of reproductive technology have raised a number of ethical issues:

- Artificial insemination separates sexual intercourse from procreation.
- Donor insemination breaks the link between the genetic parent and the nurturing parent.
- Confidentiality of participants in gamete donation may be breached.
- Questions concerning the moral status of embryos and when life begins are of central importance.
- Questions about the use of medical funding and its distribution among the population are raised.
- Harm may outweigh benefit in some reproductive technologies.

Clearly these issues touch on sensitive topics in ethics, religion, social policy, medicine, and politics. There are no easy or definitive answers, but there is ample room for discussion, education, and argument.

Environmental movement

Rachel Carson is described as the mother of the environmental movement that began in

the 1960s. Her book *Silent Spring* awakened public concern about the hazards of pesticides, and it spurred an awareness of environmental problems. The agricultural chemicals industry branded Carson as a hysterical woman without professional credentials at war with the agricultural economy. They claimed Carson had grossly distorted the actual facts and provided no scientific evidence for her conclusions. Carson's specific arguments were never refuted, although her rhetoric has been called inflammatory. Carson never called for a ban on pesticides, but she was concerned about their indiscriminate use and its effects on ecosystems. Her legacy includes the myriad environmental groups formed after her book and the establishment of the Environment Protection Agency. Her work raised public awareness of the protection of natural habitats, and it remains a milestone in the science of ecology.

Animal experimentation

Few areas in bioethics are as controversial as biomedical research on mammals. Legitimate questions regarding animal research include:

- What kind of animals will be used in biomedical research?
- What type of research will be conducted using animals?
- Are there alternatives to animal research?
- Are the results of animal research relevant to humans?

Some guiding principles in animal research include reducing animal suffering, replacing animal research with nonanimal substitutes, and the reduction in the number of animals used for biomedical research. In the final analysis, decisions on using animals in research are highly personal, often based on the perceived relationship between an individual and animals. As we learn more about the lives of animals, this debate will doubtless continue and accelerate.

Use of genetic information

New technologies have provided a large amount of genetic information that may be used by society. Criminal justice has benefited by solving crimes and freeing innocent individuals. Genetic counseling, interventions, and screening have opened a new specialty in medicine. These are only a few examples that advances in genetics have made possible. There are several primary questions and issues that arise out of the proliferation of genetic information:

- Confidentiality and the right to privacy must be preserved.
- Discrimination on the basis of genetic information must be avoided.
- Responsible and reasonable use of genetic information must be safeguarded and ensured.

Genetics is a growing science with vast potential for good and for abuse. Current and future ethical questions will continue to stimulate debate and controversy.

Genetic technology

Human genetic research has brought enormous changes to clinical medicine and promises many more in the future. Individuals, families, and couples are benefiting from prenatal screening, genetic interventions, and new tools being used by physicians. Genetic manipulation is an area of much controversy, posing both ethical dilemmas and new and exciting possibilities. In the foreseeable future the focus will be on patient-clients to whom genetic manipulation offers some benefits. Over time, great moral, ethical, social, and political forces will align themselves on different sides of these issues as the potential impact on society increases. The challenge will be to translate and communicate potential benefits and health improvements to the public while protecting society from the misuse and abuse of the technology. A stormy and uncertain future awaits the new frontiers of genetic technology and its applications in clinical medicine.

Human embryonic stem cell research

There are a number of common diseases that are caused by a failure of one of the 200 or so cell types in the human body. Type I diabetes, Parkinson's disease, and long-term effects of stroke and heart disease are all caused or exacerbated by failure of one or more of these cell types. Currently, the injection of healthy cells to replace defective ones has yielded potentially dramatic results. Controversial research on embryonic human stem cells has shown great promise worldwide for treating a number of serious diseases. At the heart of the conflict is the question of when human life begins. The Catholic Church and other pro-life groups argue that human life begins at conception and that any research on embryos is wrong. Many countries currently allow research on embryonic stem cells, but the situation in the United States is more confused: The issue is becoming a major political controversy transcending traditional party lines and affiliations.

Human Genome Project

The *Human Genome Project* was conceived by scientists in the nuclear weapons lab at Los Alamos National Laboratory, presumably to ensure the future of their jobs and to do more-positive research. The project plans to map out all human genes. Controversy swirls around this project: Many feel it is a misuse of vitally needed research funds. Others have concerns about the possible uses of such knowledge of human genetics. At the heart of these questions is whether we want to develop the science of genetic engineering, and if so, to what extent. Information gleaned from the project could give us the power to tinker with human nature itself. There is a sharp division of opinion on this matter. On the one hand, scientific curiosity, technological pressures, and the drive for adventure make this an appealing project. Yet, on the other hand, critics say the project will raise new

and difficult medical and ethical issues that will create division and acrimony.

Voluntary euthanasia

There are three main arguments for making euthanasia legal:

- **Autonomy** - The key ethical argument for voluntary euthanasia is autonomy: Do individuals have the right to decide when and how to end their lives? The argument that an intolerable life allows an individual to choose death is gaining favor worldwide.
- **Necessity** - The prospect of living a life clouded by pain and helplessness is a terrible dilemma. This brings the powerful emotions of compassion and empathy into play. Who is willing to sentence an individual to such an existence?
- **Openness** - There is a great deal of anecdotal evidence that euthanasia is practiced widely. It is clearly difficult to garner evidence of an illegal activity, although polls and confidential surveys indicate the practice is widespread.

A famous case of euthanasia occurred when King George V's life was terminated by his physician in 1936; this was made public 48 years later by the publication of his physician's diary.

Opposition

Those who oppose euthanasia raise two important arguments:

1. Although individuals should be able to make decisions about their own lives, their human responsibilities extend beyond self to others and the community. Individuals should not make decisions that infringe on the rights of others without adequate grounds. Does the right to die infringe upon the rights of others to live? Studies indicate that occasionally physicians may act to terminate life without the clear assent of the patient. What may be considered voluntary by some could be justified as the best course of action without patients' expressed consent.
2. Is voluntary euthanasia necessary? Studies have shown that the pain and distress of terminal illness can be controlled in the vast majority of cases. Medical strategies have evolved that give dying patients a reasonable quality of life and also ensure freedom from a painful death. As pressure increases to legalize euthanasia, many see this as a threat to weak, vulnerable, and incompetent patients.

Nuclear weapons

The development of atomic weapons was one of the greatest (or most notorious) scientific feats of the twentieth century. The

construction of the first atomic bomb and subsequent development of more-sophisticated weapons remain among the most controversial issues in science. Scientists such as A.O.C. Nier, Leo Szilard, Niels Bohr, Robert Oppenheimer, Edward Teller, and a score of other brilliant physicists contributed to the Manhattan Project—the crash program to develop an atomic weapon to end World War II. The success of this and subsequent projects had both beneficial and negative effects for the world and for mankind. Many of the scientists involved had grave second thoughts about the use of these weapons. One moral of this fascinating and complex story is that scientists who develop powerful scientific applications can never be sure that the science will be used in ways of which they will approve.

Practice Test One

Molecular and Cellular Biology Test Practice Questions

1. The hydrogen bonds in a water molecule make water a good
   a. Solvent for lipids
   b. Participant in replacement reactions
   c. Surface for small particles and living organisms to move across
   d. Solvent for polysaccharides such as cellulose
   e. Example of an acid

2. The breakdown of a disaccharide releases energy which is stored as ATP. This is an example of a(n)
   a. Combination reaction
   b. Replacement reaction
   c. Endothermic reaction
   d. Exothermic reaction
   e. Thermodynamic reaction

3. Which of the following metabolic compounds is composed of only carbon, oxygen, and hydrogen?
   a. Phospholipids
   b. Glycogen
   c. Peptides
   d. RNA
   e. Vitamins

4. When an animal takes in more energy that it uses over an extended time, the extra chemical energy is stored as:
   a. Fat
   b. Starch
   c. Protein
   d. Enzymes
   e. Cholesterol

5. Which of the following molecules is thought to have acted as the first enzyme in early life on earth?
   a. Protein
   b. RNA
   c. DNA
   d. Triglycerides
   e. Phospholipids

6. Which of the following organelles is/are formed when the plasma membrane surrounds a particle outside of the cell?

a. Golgi bodies
b. Rough endoplasmic reticulum
c. Lysosomes
d. Secretory vesicles
e. Endocytic vesicles

7. Which of the following plant organelles contain(s) pigment that give leaves their color?

a. Centrioles
b. Cell walls
c. Chloroplasts
d. Central vacuole
e. Golgi apparatus

8. All but which of the following processes are ways of moving solutes across a plasma membrane?

a. Osmosis
b. Passive transport
c. Active transport
d. Facilitated diffusion
e. Endocytosis

9. Prokaryotic and eukaryotic cells are similar in having which of the following?

a. Membrane-bound organelles
b. Protein-studded DNA
c. Presence of a nucleus
d. Integral membrane proteins in the plasma membrane
e. Flagella composed of microtubules

10. Which of the following cell types has a peptidoglycan cell wall?

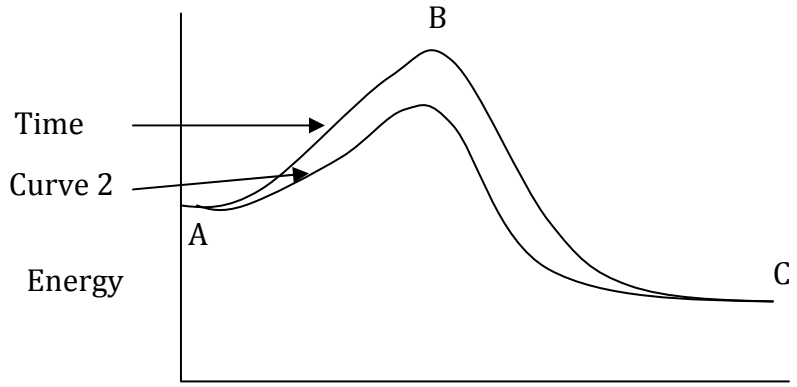
a. Algae
b. Bacteria
c. Fungi
d. Land plants
e. Protists

11. Enzymes catalyze biochemical reactions by

a. Lowering the potential energy of the products
b. Separating inhibitors from products
c. Forming a complex with the products
d. Lowering the activation energy of the reaction
e. Providing energy to the reaction

12. Which of the following is an example of a cofactor?
    a. Zinc
    b. Actin
    c. Cholesterol
    d. GTP
    e. Chlorophyll

13 Cyanide is a poison that binds to the active site of the enzyme cytochrome c and prevents its activity. Cyanide is a(n)
    a. Prosthetic group
    b. Cofactor
    c. Coenzyme
    d. Inhibitor
    e. Reverse regulator



14. The graph above shows the potential energy of molecules during the process of a chemical reaction. All of the following may be true EXCEPT
    a. This is an endergonic reaction
    b. The activation energy in curve 2 is less than the activation energy in curve 1
    c. The energy of the products is less than the energy of the substrate
    d. Curve 2 shows the reaction in the presence of an enzyme
    e. The reaction required ATP

15. Which of the following is not a characteristic of enzymes?
    a. They change shape when they bind their substrates
    b. They can catalyze reactions in both forward and reverse directions
    c. Their activity is sensitive to changes in temperature
    d. They are always active on more than one kind of substrate
    e. They may have more than one binding site

16. In a strenuously exercising muscle, NADH begins to accumulate in high concentration. Which of the following metabolic process will be activated to reduce the concentration of NADH?
    a. Glycolysis
    b. The Krebs cycle
    c. Lactic acid fermentation
    d. Oxidative phosphorylation
    e. Acetyl CoA synthesis

17. Which of the following statements regarding chemiosmosis in mitochondria is not correct?
    a. ATP synthase is powered by protons flowing through membrane channels
    b. Energy from ATP is used to transport protons to the intermembrane space
    c. Energy from the electron transport chain is used to transport protons to the intermembrane space
    d. An electrical gradient and a pH gradient both exist across the inner membrane
    e. The waste product of chemosmosis is water

18. In photosynthesis, high-energy electrons move through electron transport chains to produce ATP and NADPH. Which of the following provides the energy to create high energy electrons?
    a. NADH
    b. NADP+
    c. O2
    d. Water
    e. Light

19. Which of the following kinds of plants is most likely to perform CAM photosynthesis?
    a. Mosses
    b. Grasses
    c. Deciduous trees
    d. Cacti
    e. Legumes

20. The combination of DNA with histones is called
    a. A centromere
    b. Chromatin
    c. A chromatid
    d. Nucleoli
    e. A plasmid

21. How many chromosomes does a human cell have after meiosis I?
    a. 92
    b. 46
    c. 23
    d. 22
    e. 12

22. In plants and animals, genetic variation is introduced during
    a. Crossing over in mitosis
    b. Chromosome segregation in mitosis
    c. Cytokinesis of meiosis
    d. Anaphase I of meiosis
    e. Anaphase II of meiosis

23. DNA replication occurs during which of the following phases?
    a. Prophase I
    b. Prophase II
    c. Interphase I
    d. Interphase II
    e. Telophase I

24. The synaptonemal complex is present in which of the following phases of the cell cycle?
    a. Metaphase of mitosis
    b. Metaphase of meiosis I
    c. Telophase of meiosis I
    d. Metaphase of meiosis II
    e. Telophase of meiosis II

25. A length of DNA coding for a particular protein is called a(n)
    a. Allele
    b. Genome
    c. Gene
    d. Transcript
    e. Codon

26. In DNA replication, which of the following enzymes is required for separating the DNA molecule into two strands?
    a. DNA polymerase
    b. Single strand binding protein
    c. DNA gyrase
    d. Helicase
    e. Primase

27. Which of the following chemical moieties forms the backbone of DNA?
    a. Nitrogenous bases
    b. Glycerol
    c. Amino groups
    d. Pentose and phosphate
    e. Glucose and phosphate

28. Required for the activity of DNA polymerase
    a. Okazaki fragments
    b. RNA primer
    c. Single-strand binding protein
    d. Leading strand
    e. Replication fork

29. Substrate for DNA ligase
    a. Okazaki fragments
    b. RNA primer
    c. Single-strand binding protein
    d. Leading strand
    e. Replication fork

30. Which of the following is true of the enzyme telomerase?
    a. It is active on the leading strand during DNA synthesis
    b. It requires a chromosomal DNA template
    c. It acts in the $3' \rightarrow 5'$ direction
    d. It adds a repetitive DNA sequence to the end of chromosomes
    e. It takes the place of primase at the ends of chromosomes

31. Which enzyme in DNA replication is a potential source of new mutations?
    a. DNA ligase
    b. Primase
    c. DNA gyrase
    d. DNA polymerase
    e. Topoisomerase

32. Which of the following mutations is most likely to have a dramatic effect on the sequence of a protein?
    a. A point mutation
    b. A missense mutation
    c. A deletion
    d. A silent mutation
    e. A proofreading mutation

    d. snRNP
    e. Amino acids

34. The *lac* operon controls
    a. Conjugation between bacteria
    b. Chromatin organization
    c. Gene transcription
    d. Excision repair
    e. Termination of translation

35. All of the following are examples ways of controlling eukaryotic gene expression EXCEPT
    a. Regulatory proteins
    b. Nucleosome packing
    c. Methylation of DNA
    d. RNA interference
    e. Operons

36. Transfer of DNA between bacteria using a narrow tube called a pilus is called
    a. Transformation
    b. Transduction
    c. Operation
    d. Conjugation
    e. Conformation

37. A virus that has incorporated into the DNA of its host
    a. Lysogenic cycle
    b. Lytic cycle
    c. Retrovirus
    d. Provirus
    e. Bacteriophage

38. A virus in this stage is actively replicating DNA
    a. Lysogenic cycle
    b. Lytic cycle
    c. Retrovirus
    d. Provirus
    e. Bacteriophage

39. A bacterial mini-chromosome used in recombinant DNA technology is called a
    a. Centromere
    b. Telomere
    c. Plasmid
    d. Transposon
    e. cDNA

40. Which of the following parts of an angiosperm give rise to the fruit?
    a. Pedicel
    b. Filament
    c. Sepal
    d. Ovary
    e. Meristem

41. Which of the following structures is NOT present in gymnosperms?
    a. Leaves
    b. Pollen
    c. Flowers
    d. Stomata
    e. Roots

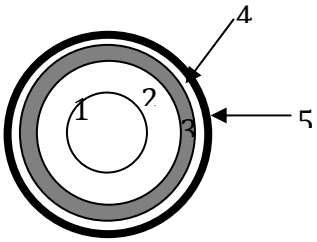
42. Which of the following plant structures allows for gas exchange?
    a. Xylem
    b. Phloem
    c. Cuticle
    d. Meristem
    e. Stomata

43. Leaves have parallel veins
    a. Monocots
    b. Dicots
    c. Angiosperms
    d. Gymnosperms
    e. Nonvascular plants

44. Do not produce fruits
    a. Monocots
    b. Dicots
    c. Angiosperms
    d. Gymnosperms
    e. Nonvascular plants

45. Produce seeds that are housed inside a fruit
    a. Monocots
    b. Dicots
    c. Angiosperms
    d. Gymnosperms
    e. Nonvascular plants

Questions 46 and 47 pertains to the following diagram representing a cross section of a tree trunk



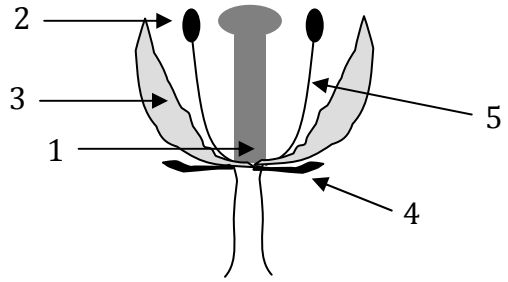
46. Which structure contains tissue that is dead at maturity?
    a. 1
    b. 2
    c. 3
    d. 4
    e. 5

47. Which structure transports carbohydrates to the roots?
    a. 1
    b. 2
    c. 3
    d. 4
    e. 5

48. In ferns, the joining of egg and sperm produces a zygote, which will grow into the
    a. Gametophyte
    b. Sporophyte
    c. Spore
    d. Sporangium
    e. Seedling

49. Which of the following is an example of the alternation of generations life cycle?
    a. Asexual reproduction of strawberries by runners
    b. Annual plants that live through a single growing season
    c. Ferns that have a large diploid and a diminutive haploid stage
    d. Insects that have distinct larval and adult stages
    e. Reptiles that have long periods of dormancy and metabolic inactivity

Questions 50 and 51 pertains to the following diagram of a complete, perfect flower



50. The structure in which microspores are produced.
    a. 1
    b. 2
    c. 3
    d. 4
    e. 5

51. The structures composed solely of diploid cells
    a. 1, 2, and 3
    b. 2, 3, and 4
    c. 3, 4, and 5
    d. 1, 4, and 5
    e. 1, 2, and 4

52. Auxins are plant hormones that are involved in all but which of the following processes?
    a. Fruit ripening
    b. Gravitropism
    c. Growth
    d. Phototropism
    e. Seed germination

53. Which of the following plant hormones is most likely to delay aging when sprayed on cut flowers and fruit?
    a. Ethylene
    b. Gibberellins
    c. Cytokinins
    d. Abscisic acid
    e. Jasmonic acid

54. Which of the following would most likely be disruptive to the flowering time of a day-neutral plant?
    a. Daylight interrupted by a brief dark period
    b. Daylight interrupted by a long dark period
    c. High daytime temperatures
    d. Night interrupted by a brief exposure to red light
    e. Night interrupted by a long exposure to red light

55. Animals exchange gases with the environment in all of the following ways EXCEPT
    a. Direct exchange through the skin
    b. Exchange through gills
    c. Stomata
    d. Tracheae
    e. Lungs

56. Which of the following blood components is involved in blood clotting?
    a. Red blood cells
    b. Platelets
    c. White blood cells
    d. Leukocytes
    e. Plasma

57. Which section of the digestive system is responsible for water reabsorption?
    a. The large intestine
    b. The duodenum
    c. The small intestine
    d. The gallbladder
    e. The stomach

58. When Ca^{2+} channels open in a presynaptic cell (doesn't the cell also depolarize?)
    a. The cell depolarizes
    b. The cell hyperpolarizes
    c. An action potential is propagated
    d. Synaptic vesicles release neurotransmitter
    e. The nerve signal is propagated by salutatory conduction

59. Which of the following processes is an example of positive feedback?
    a. High CO2 blood levels stimulate respiration which decreases blood CO2 levels
    b. High blood glucose levels stimulate insulin release, which makes muscle and liver cells take in glucose
    c. Increased nursing stimulates increased milk production in mammary glands
    d. Low blood oxygen levels stimulate erythropoietin production which increases red blood cell production by bone marrow
    e. Low blood calcium levels stimulate parathyroid hormone release from the parathyroid gland. Parathyroid hormone stimulates calcium release from bones.

60. Which of the following would be the most likely means of thermoregulation for a mammal in a cold environment?
    a. Adjusting body surface area
    b. Sweating
    c. Countercurrent exchange
    d. Muscle contractions
    e. Increased blood flow to extremities

61. Which hormone is *not* secreted by a gland in the brain?
    a. Human chorionic gonadotropin (HCG)
    b. Gonadotropin releasing hormone (GnRH)
    c. Luteinizing hormone (LH)
    d. Follicle stimulating hormone (FSH)
    e. None of these

62. Which hormone is secreted by the placenta throughout pregnancy?
    a. Human chorionic gonadotropin (HCG)
    b. Gonadotropin releasing hormone (GnRH)
    c. Luteinizing hormone (LH)
    d. Follicle stimulating hormone (FSH)
    e. None of these

63. Polar bodies are a by-product of
    a. Meiosis I
    b. Meiosis II
    c. Both meiosis I and II
    d. Zygote formation
    e. Mitosis of the morula

64. Which of the following hormones triggers ovulation in females?
    a. Estrogen
    b. Progesterone
    c. Serotonin
    d. Luteinizing hormone
    e. Testosterone

65. Spermatogenesis occurs in the
    a. Prostate gland
    b. Vas deferens
    c. Seminal vesicles
    d. Penis
    e. Seminiferous tubules

66. In which of the following stages of embryo development are the three primary germ layers first present?
    a. Zygote
    b. Gastrula
    c. Morula
    c. Blastula
    e. Coelomate

67. Which of the following extraembryonic membranes is an important source of nutrition in many non-human animal species but NOT in humans?
    a. Amnion
    b. Allantois
    c. Yolk sac
    d. Chorion
    e. Placenta

68. Which of the following is not a mechanism that contributes to cell differentiation and development in embryos?

a. Asymmetrical cell division
b. Asymmetrical cytoplasm distribution
c. Organizer cells
d. Location of cells on the lineage map
e. Homeotic genes

69. Which of the following is true of the gastrula?

a. It is a solid ball of cells
b. It has three germ layers
c. It is an extraembryonic membrane
d. It gives rise to the blastula
e. It derives from the zona pellucida

70. In birds, gastrulation occurs along the

a. Dorsal lip of the embryo
b. Embryonic disc
c. Primitive streak
d. Circular blastopore
e. Inner cell mass

71. In snapdragons, the red (*R*) allele is incompletely dominant to the white (*r*) allele. If you saw a pink snapdragon, you would know

a. Its phenotypes for both parents
b. Its genotypes for both parents
c. Its genotype for one parent
d. Its genotype
e. Its phenotype but not its genotype

72. In peas, purple flower color (*P*) is dominant to white (*p*) and tall stature (*T*) is dominant to dwarf (*t*). If the genes are unlinked, how many tall plants will be purple in the progeny of a *PpTt* x *PpTT* cross?

a. 0
b. ¼
c. ½
d. ¾
e. 1

73. Which of the following does not obey the law of independent assortment?

a. Two genes on opposite ends of a chromosome
b. Flower color and height in snapdragons
c. Two genes on separate chromosomes
d. Seed color and flower color in peas
e. Two genes next to each other on a chromosome

74. In a dihybrid cross between bean plants with red (*R*) wrinkled (*w*) seeds and white (*r*) smooth (*W*) seeds, the F1 progeny is all red and smooth. If the F1 plants are selfed, what proportion of the F2 will also be red and smooth if the genes are linked?

a. All of them
b. ¼
c. 1/2
d. 9/16
e. None of them

75. Red-green color blindness is an X-linked trait. What is the probability that a mother that is heterozygous for this trait and a father with this trait will have affected children?

a. 0
b. ¼
c. ½
d. ¾
e. 1

76. An individual with an AB blood type needs a blood transfusion. Which of the following types could NOT be a donor?

a. O
b. AB
c. A
d. B
e. All can be donors

77. In humans, more than one gene contributes to the trait of hair color. This is an example of

a. Pleiotropy
b. Polygenic inheritance
c. Codominance
d. Linkage
e. Epistasis

78. A child is born with type A blood and his mother has type A. Which of the following is NOT a possible combination of genotypes for the mother and father?

a. IAIB and ii
b. IAi and ii
c. IA i and IB i
d. IAi and IBIB
e. IAIB and IBi

79. On a standard biomass pyramid, level 3 corresponds to which trophic level?
    a. Producers
    b. Decomposers
    c. Primary consumers
    d. Primary carnivores
    e. Secondary carnivores

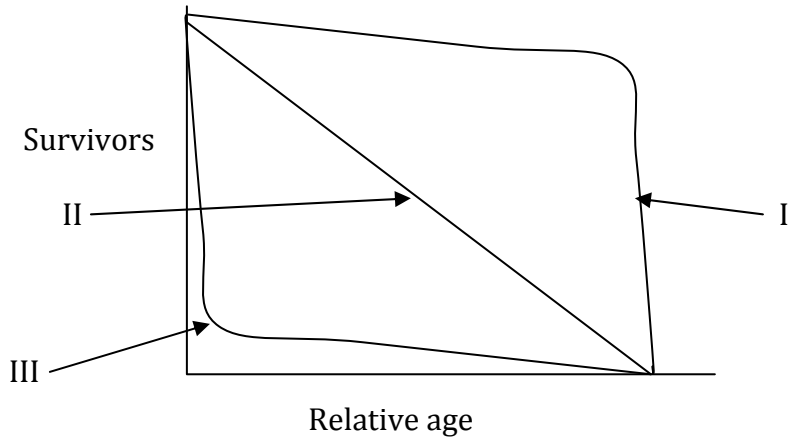
    grass → cow → wolf → vulture

80. In the food chain above, vultures represent
    a. Scavengers
    b. Detritivores
    c. Primary carnivores
    d. Herbivores
    e. Secondary consumers

81. Which of the following is the major way in which carbon is released into the environment?
    a. Transpiration
    b. Respiration
    c. Fixation
    d. Sedimentation
    e. Absorption

82. What is the largest reservoir of nitrogen on the planet?
    a. The ocean
    b. Plants
    c. Soil
    d. The atmosphere
    e. Sediments, including fossil fuels

83. The diagram below represents the three types of survivorship curves, describing how mortality varies as species age. Which of the following species is most likely to exhibit Type I survivorship?



a. Frogs
b. Oysters
c. Salmon
d. Dolphins
e. Shrimp

84. A population of 1000 individuals has 110 births and 10 deaths in a year. Its growth rate (r) is equal to

a. 0.01 per year
b. 0.1 per year
c. 0.09 per year
d. 0.11 per year
e. 0.009 per year

85. During primary succession, which species would most likely be a pioneer species?

a. Lichens
b. Fir trees
c. Mosquitoes
d. Dragonflies
e. Mushrooms

86. Which of the following habitats would provide an opportunity for secondary succession?

a. A retreating glacier
b. Burned cropland
c. A newly formed volcanic island
d. A 500 year old forest
e. A sand dune

87. Which biome is most likely to support the growth of epiphytes?
a. Deserts
b. Tropical rain forests
c. Temperate deciduous forests
d. Taigas
e. Savannas

88. Which of the following is NOT a natural dispersal process that would lead to species colonization on an island?
a. Mussels carried into a lake on the hull of a ship
b. Drought connecting an island to other land
c. Floating seeds
d. Animals swimming long distances
e. Birds adapted to flying long distances

89. When a population reaches its carrying capacity
a. Other populations will be forced out of the habitat
b. Density-dependent factors no longer play a role
c. Density-independent factors no longer play a role
d. The population growth rate approaches zero
e. The population size begins to decrease

90. Which of the following is an example of a density-dependent limiting factor?
a. Air pollution by a factory
b. The toxic effect of waste products
c. Nearby volcanic eruptions
d. Frosts
e. Fires

91. Two species of finches are able to utilize the same food supply, but their beaks are different. They are able to coexist on an island because of
a. Niche overlap
b. Character displacement
c. Resource partitioning
d. Competitive exclusion
e. Realized niches

92. Lichens consist of fungi and algae. The algae supply sugars through performing photosynthesis while the fungi provide minerals and a place to attach. This is an example of
a. Mutualism
b. Commensalism
c. Parasitism
d. Coevolution
e. Resource partitioning

93. Which of the following of Lamarck's evolutionary ideas turned out to be true?
    a. Natural selection
    b. Organisms naturally transform into increasingly complex organisms
    c. Inheritance of acquired characters
    d. Body parts develop with increased usage and weaken with disuse
    e. Genes are the basic units of inheritance

94. The weight of adult wolves is within a fairly narrow range, even if they are well-fed in zoos. This is an example of
    a. Stabilizing selection
    b. Directional selection
    c. Disruptive selection
    d. Sexual selection
    e. Artificial selection

95. Which of the following is a trait that results from disruptive selection?
    a. Insecticide resistance
    b. Male peacocks have colorful plumage while females do not
    c. Within the same species, some birds have large bills, while others have small bills.
    d. Human height
    e. Various varieties of wheat

96. Which of the following conditions would promote evolutionary change?
    a. Neutral selection
    b. Random mating
    c. A large population
    d. An isolated population
    e. Gene flow

97. Which of the following would create the greatest amount of genetic variation for a diploid species in a single generation?
    a. Crossing over
    b. Mutation
    c. Hybridization
    d. Independent assortment of homologs
    e. Random joining of gametes

98. A population of pea plants has 25% dwarf plants and 75% tall. The tall allele, *T* is dominant to dwarf (*t*). What is the frequency of the *T* allele?
    a. 0.75
    b. 0.67
    c. 0.5
    d. 0.25
    e. 0.16

99. Darwin's idea that evolution occurs by the gradual accumulation of small changes can be summarized as

a. Punctuated equilibrium
b. Phyletic gradualism
c. Convergent evolution
d. Adaptive radiation
e. Sympatric speciation

100. Which of the following processes of speciation would most likely occur if a species of bird were introduced into a group of islands that were previously uninhabited by animals?

a. Allopatric speciation
b. Adaptive radiation
c. Sympatric speciation
d. Artificial speciation
e. Hybridizing speciation

101. Hummingbirds drink nectar from *Ipomopsis* flowers. *Ipomopsis* are trumpet-shaped, and hummingbirds have long narrow beaks to access the nectar. These adaptations could best be described as

a. Divergent evolution
b. Convergent evolution
c. Parallel evolution
d. Coevolution
e. Macroevolution

102. All of the following are homologous structures EXCEPT

a. Bird feathers
b. Elephant eyelashes
c. Human fingernails
d. Dog fur
e. Insect exoskeleton

103. Human predation has cause the population of cheetahs to decline dramatically.
Changes in allele frequencies in the remaining population of cheetahs would most likely be due to

a. Mutation
b. The bottleneck effect
c. The founder effect
d. Gene flow
e. Natural selection

104. The first living cells on earth were most likely

a. Heterotrophs
b. Autotrophs
c. Aerobic
d. Eukaryotes
e. Photosynthetic

105. Evidence that humans share a common ancestor with other primates includes all of the following EXCEPT

a. DNA sequence
b. Fossil evidence of intermediate species
c. Analogous structures
d. Homologous structures
e. Radiometric dating of fossils

For questions 106 – 108, match the sentence(s) with the choice below that most closely matches it. Each lettered choice may be used more than once or not at all.

a. Associative learning
b. Imprinting
c. Habituation
d. Chemical communication
e. Territoriality

106. Sea anemones pull food into their mouths by withdrawing their tentacles. If the tentacles are stimulated with a non-food item, they will ignore the stimulus after a few futile attempts to capture the food.

107. Queen bees secrete pheromones that are eaten by workers and prevent the workers from being able to reproduce.

108. Salmon hatch in freshwater streams and then migrate to the ocean to mature. When they are mature, they swim upstream to their birthplace to spawn.

109. The species *Homo sapiens* first appeared in the fossil record approximately

a. 10 million years ago
b. 1 million years ago
c. 100,000 years ago
d. 10,000 years ago
e. 6,000 years ago

110. Which of the following demographic changes would lead to a population with an older age composition?

a. Increased birth rate
b. Environmental pollution
c. Increased availability of food
d. Medical advancements that increase life expectancy
e. Introduction of contraceptives

111. Which of the following factors has the greatest impact on birth rate in humans?

a. The carrying capacity of the earth
b. Age at reproductive maturity
c. Reproductive lifetime
d. Survivorship of offspring to reproductive maturity
e. Socioeconomic factors

112. Which of the following organisms would be most likely to have mercury in their bodies?
a. Mosquitoes
b. Carnivorous insects
c. Frogs
d. Filter-feeding fish
e. Fish-eating birds

113. Clear-cutting of rain forests leads to all of the following consequences EXCEPT
a. Climate change
b. Erosion
c. Reduction in species diversity
d. Air pollution
e. Desertification

114. Burning fossil fuels releases sulfur dioxide and nitrogen dioxide. These pollutants lead to which environmental problem?
a. Denitrification
b. Acid rain
c. Global climate change
d. Ozone depletion
e. Eutrophication

115. Genetic engineering
a. Is a form of human reproduction
b. Involves introducing new proteins to a cell
c. Involves transient expression of genes
d. Can have no environmental affects
e. Requires using restriction enzymes to cut DNA

Answers and Explanations

1. C: The hydrogen bonds between water molecules cause water molecules to attract each other (negative pole to positive pole. and "stick" together. This gives water a high surface tension, which allows small living organisms, such as water striders, to move across its surface. Since water is a polar molecule, it readily dissolves other polar and ionic molecules such as carbohydrates and amino acids. Polarity alone is not sufficient to make something soluble in water, however; for example, cellulose is polar but its molecular weight is so large that it is not soluble in water.

2. D: An exothermic reaction releases energy, whereas an endothermic reaction requires energy. The breakdown of a chemical compound is an example of a decomposition reaction (AB → A + B.. A combination reaction (A + B →AB. is the reverse of a decomposition reaction, and a replacement (displacement) reaction is one where compound breaks apart and forms a new compound plus a free reactant (AB + C →AC + B or AB + CD → AD + CB.

3. B: Glycogen is a polysaccharide, a molecule composed of many bonded glucose molecules. Glucose is a carbohydrate, and all carbohydrates are composed of only carbon, oxygen, and hydrogen. Most other metabolic compounds contain other atoms, particularly nitrogen, phosphorous, and sulfur.

4. A: Long term energy storage in animals takes the form of fat. Animals also store energy as glycogen, and plants store energy as starch. , but these substances are for shorter-term use. Fats are a good storage form for chemical energy because fatty acids bond to glycerol in a condensation reaction to form fats (triglycerides). This reaction, which releases water, allows for the compacting of high-energy fatty acids in a concentrated form.

5. B: Some RNA molecules in extant organisms have enzymatic activity; for example the formation of peptide bonds on ribosomes is catalyzed by an RNA molecule. This and other information has led scientists to believe that the most likely molecules to first demonstrate enzymatic activity were RNA molecules.

6. E: Endocytosis is a process by which cells absorb larger molecules or even tiny organisms, such as bacteria, than would be able to pass through the plasma membrane. Endocytic vesicles containing molecules from the extracellular environment often undergo further processing once they enter the cell.

7. C: Chloroplasts contain the light-absorbing compound chlorophyll, which is essential in photosynthesis. This gives leaves their green color. Chloroplasts also contain yellow and red carotenoid pigments, which give leaves red and yellow colors in the fall as chloroplasts lose their chlorophyll.

8. A: Osmosis is the movement of water molecules (not solutes) across a semi-permeable membrane. Water moves from a region of higher concentration to a region of lower concentration. Osmosis occurs when the concentrations of a solute differ on either side of a semi-permeable membrane. For example, a cell (containing a higher concentration of water) in a salty solution (containing a lower concentration of water) will lose water as water leaves the cell. This continues until the solution outside the cell has the same salt concentration as the cytoplasm.

9. D: Both prokaryotes and eukaryotes interact with the extracellular environment and use membrane-bound or membrane-associated proteins to achieve this. They both use diffusion and active transport to

move materials in and out of their cells. Prokaryotes have very few proteins associated with their DNA, whereas eukaryotes' DNA is richly studded with proteins. Both types of living things can have flagella, although with different structural characteristics in the two groups. The most important differences between prokaryotes and eukaryotes are the lack of a nucleus and membrane-bound organelles in prokaryotes.

10. B: Bacteria and cyanobacteria have cell walls constructed from peptidoglycans – a polysaccharide and protein molecule. Other types of organisms with cell walls, for instance, plants and fungi, have cell walls composed of different polysaccharides. Plant cell walls are composed of cellulose, and fungal cell walls are composed of chitin.

11. D: Enzymes act as catalysts for biochemical reactions. A catalyst is not consumed in a reaction, but, rather, lowers the activation energy for that reaction. The potential energy of the substrate and the product remain the same, but the activation energy—the energy needed to make the reaction progress—can be lowered with the help of an enzyme.

12. A: A cofactor is an inorganic substance that is required for an enzymatic reaction to occur. Cofactors bind to the active site of the enzyme and enable the substrate to fit properly. Many cofactors are metal ions, such as zinc, iron, and copper.

13. D: Enzyme inhibitors attach to an enzyme and block substrates from entering the active site, thereby preventing enzyme activity. As stated in the question, cyanide is a poison that irreversibly binds to an enzyme and blocks its active site, thus fitting the definition of an enzyme inhibitor.

14. A: Because the energy of the products is less than the energy of the substrate, the reaction releases energy and is an exergonic reaction.

15. D: Enzymes are substrate-specific. Most enzymes catalyze only one biochemical reaction. Their active sites are specific for a certain type of substrate and do not bind to other substrates and catalyze other reactions.

16. C: Lactic acid fermentation converts pyruvate into lactate using high-energy electrons from NADH. This process allows ATP production to continue in anaerobic conditions by providing NAD^+ so that ATP can be made in glycolysis.

17. B: Proteins in the inner membrane of the mitochondrion accept high-energy electrons from NAD and $FADH_2$, and in turn transport protons from the matrix to the intermembrane space. The high proton concentration in the intermembrane space creates a gradient which is harnessed by ATP synthase to produce ATP.

18. E: Electrons trapped by the chlorophyll P680 molecule in photosystem II are energized by light. They are then transferred to electron acceptors in an electron transport chain.

19. D: CAM photosynthesis occurs in plants that grow where water loss must be minimized, such as cacti. These plants open their stomata and fix CO_2 at night. During the day, stomata are closed, reducing water loss. Thus, photosynthesis can proceed without water loss.

20. B: DNA wrapped around histone proteins is called chromatin. In a eukaryotic cell, DNA is always associated with protein; it is not "naked" as with prokaryotic cells.

21. B: The diploid chromosome number for humans is 46. After DNA duplication but before the first cell division of meiosis, there are 92 chromosomes (46 pairs). After meiosis I is completed, the chromosome number is halved and equals 46. Each daughter cell is haploid, but the chromosomes are still paired (sister chromatids). During meiosis II, the two sister chromatids of each chromosome separate, resulting in 23 haploid chromosomes per germ cell.

22. D: In anaphase I, homologous chromosome pairs segregate randomly into daughter cells. This means that each daughter cell contains a unique combination of chromosomes that is different from the mother cell and different from its cognate daughter cell.

23. C: Although there are two cell divisions in meiosis, DNA replication occurs only once. It occurs in interphase I, before M phase begins.

24. C: The synaptonemal complex is the point of contact between homologous chromatids. It is formed when nonsister chromatids exchange genetic material through crossing over. Once meiosis I has completed, crossovers have resolved and the synaptonemal complex no longer exists. Rather, sister chromatids are held together at their centromeres prior to separation in anaphase II.

25. C: Genes code for proteins, and genes are discrete lengths of DNA on chromosomes. An allele is a variant of a gene (different DNA sequence.. In diploid organisms, there may be two versions of each gene.

26. D: The enzyme helicase unwinds DNA. It depends on several other proteins to make the unwinding run smoothly, however. Single-strand binding protein holds the single stranded DNA in place, and topoisomerase helps relieve tension at the replication fork.

27. D: DNA is composed of nucleotides joined together in long chains. Nucleotides are composed of a pentose sugar, a phosphate group, and a nitrogenous base. The bases form the “rungs” of the ladder at the core of the DNA helix and the pentose-phosphates are on its outside, or backbone.
28. B: DNA replication begins with a short segment of RNA (not DNA.. DNA polymerase cannot begin adding nucleotides without an existing piece of DNA (a primer).

29. A: DNA synthesis on the lagging strand forms short segments called Okazaki fragments. Because DNA polymerase can only add nucleotides in the 5□ □ 3□ direction, lagging strand synthesis is discontinuous. The final product is formed when DNA ligase joins Okazaki fragments together.

30. D: Each time a cell divides; a few base pairs of DNA at the end of each chromosome are lost. Telomerase is an enzyme that uses a built-in template to add a short sequence of DNA over and over at the end of chromosomes—a sort of protective “cap”. This prevents the loss of genetic material with each round of DNA replication.

31. D: DNA polymerase does not match base pairs with 100% fidelity. Some level of mismatching is present for all DNA polymerases, and this is a source of mutation in nature. Cells have mechanisms of correcting base pair mismatches, but they do not fix all of them.

32. C: Insertions and deletions cause frameshift mutations. These mutations cause all subsequent nucleotides to be displaced by one position, and thereby cause all the amino acids to be different than they would have been if the mutation had not occurred.

33. A: Transcription is the process of creating an RNA strand from a DNA template. All forms of RNA, for example mRNA, tRNA, and rRNA, are products of transcription.

34. C: The *lac* operon controls transcription of the gene that allows bacteria to metabolize lactose. It codes for both structural and regulatory proteins and includes promoter and operator sequences.

35. E: Operons are common to prokaryotes. They are units of DNA that control the transcription of DNA and code for their own regulatory proteins as well as structural proteins.

36. D: Conjugation is direct transfer of plasmid DNA between bacteria through a pilus. The F plasmid contains genes that enable bacteria to produce pili and is often the DNA that is transferred between bacteria.

37. D: In the lysogenic cycle, viral DNA gets incorporated into the DNA of the host. A virus in this dormant stage is called a provirus. Eventually, an external cue may trigger the virus to excise itself and begin the lytic cycle.

38. B: In the lytic cycle, viruses use host resources to produce viral DNA and proteins in order to create new viruses. They destroy the host cell in the process by lysing it. For this reason, actively replicating viruses are said to be in the lytic cycle.

39. C: Plasmids are small circular pieces of DNA found in bacteria that are widely used in recombinant DNA technology. They are cut with restriction enzymes and DNA of interest is ligated to them. They can then easily be used to transform bacteria.
40. D: The ovary houses the ovules in a flower. Pollen grains fertilize ovules to create seeds, and the ovary matures into a fruit.

41. C: Gymnosperms reproduce by producing pollen and ovules, but they do not have flowers. Instead, their reproductive structures are cones or cone-like structures.

42. E: Stomata are openings on leaves that allow for gas exchange, which is essential for photosynthesis. Stomata are formed by guard cells, which open and close based on their turgidity.

43. A: Monocots differ from dicots in that they have one cotyledon, or embryonic leaf in their embryos. They also have parallel veination, fibrous roots, petals in multiples of three, and a random arrangement of vascular bundles in their stems.

44. E: Nonvascular plants do not produce fruits like angiosperms and gymnosperms do. They generally reproduce sexually, but produce spores instead of seeds.

45. C: Angiosperms produce flowers, with ovules inside of ovaries. The ovaries become a fruit, with seeds inside. Gymnosperms have naked seeds that are produced in cones or cone like structures.

46. A: The actual wood of a tree trunk is made of dead xylem tissue. It does not function in the transport of water, but rather functions only in support.

47. C: The phloem transports carbohydrates from the shoot to the roots. Phloem tissue is living and is located outside the xylem.

48. B: In ferns, the mature diploid plant is called a sporophyte. Sporophytes undergo meiosis to produce spores, which develop into gametophytes, which produce gametes.

49. C: Alternation of generations means the alternation between the diploid and haploid phases in plants.

50. B: Anthers produce microspores (the male gametophytes of flowering plants), which undergo meiosis to produce pollen grains.

51. C: In flowering plants, the anthers house the male gametophytes (which produce sperm) and the pistils house the female gametophytes (which produce eggs). Eggs and sperm are haploid. All other tissues are solely diploid.

52. A: The plant hormone ethylene is responsible for fruit ripening. Auxins are involved in a range of processes involving growth and development.

53. C: Cytokinins stimulate cell division (cytokinesis) and have been found to delay senescence (aging). They are often sprayed on cut flowers and fruit to prolong their shelf life.

54. C: Day-neutral plants are not affected by day length in their flowering times. Rather, they respond to other environmental cues like temperature and water.
55. C: Plants exchange gases with the environment through pores in their leaves called stomata. Animals exchange gases with the environment in many different ways: small animals like flatworms exchange gases through their skin; insects use tracheae; and many species use lungs.

56. B: Platelets are cell fragments that are involved in blood clotting. Platelets are the site for the blood coagulation cascade. Its final steps are the formation of fibrinogen which, when cleaved, forms fibrin, the "skeleton" of the blood clot.

57. A: The large intestine's main function is the reabsorption of water into the body to form solid waste. It also allows for the absorption of vitamin K produced by microbes living inside the large intestine.

58. D: When Ca^{2+} channels open, calcium enters the axon terminal and causes synaptic vesicles to release neurotransmitter into the synaptic cleft.

59. C: In a positive feedback loop, an action intensifies a chain of events that, in turn, intensify the conditions that caused the action beyond normal limits. Nursing stimulates lactation, which promotes nursing. Contractions during childbirth, psychological hysteria, and sexual orgasm are all examples of positive feedback.

60. D: Mammals often warm themselves by altering their metabolism. Shivering warms animals due to the heat generated by contractions in trunk muscles.

61. A: HCG is secreted by the trophoblast, part of the early embryo, following implantation in the uterus. GnRH (gonadotropin-releasing hormone. is secreted by the hypothalamus, while LH (luteinizing hormone. and FSH (follicle-stimulating hormone. are secreted by the pituitary gland. GnRH stimulates the production of LH and FSH. LH stimulates ovulation and the production of estrogen and progesterone by the ovary in females, and testosterone production in males. FSH stimulates maturation of the ovarian follicle and estrogen production in females and sperm production in males.

62. E: The placenta secretes progesterone and estrogen once a pregnancy is established. Early in pregnancy, the placenta secretes hCG.

63. C: In oogenesis, meiosis I produces a secondary oocyte and a polar body. Both the first polar body and the secondary oocyte undergo meiosis II. The secondary oocyte divides to produce the ovum and the second polar body.

64. D: Positive feedback from rising levels of estrogen in the menstrual cycle produces a sudden surge of luteinizing hormone (LH). This high level triggers ovulation.

65. E: The testes contain hundreds of seminiferous tubules for the production of sperm, or spermatogenesis. This requires 64-72 days. Leydig cells surround the seminiferous tubules and produce male sex hormones called androgens, the most important of which is testosterone. Semen is made in the seminal vesicles, prostate gland, and other glands. Sperm are transferred to the penis via the epididymis, where they become motile, and thence through the vas deferens.
66. B: The gastrula is formed from the blastocyst, which contains a bilayered embryonic disc. One layer of this disc's inner cell mass further subdivides into the epiblast and the hypoblast, resulting in the three primary germ layers (endoderm, mesoderm, ectoderm).

67. C: In birds and reptiles, the yolk sac contains the yolk, the main source of nutrients for the embryo. In humans, the yolk sac is empty and embryos receive nutrition through the placenta. However, the yolk sac forms part of the digestive system and is where the earliest blood cells and blood vessels are formed.

68. D: A lineage map describes the fates of cells in the early embryo: in other words, it tells which germ layer different cells will occupy. In some small organisms such as the nematode *Caenorhabditis elegans*, all of the adult cells can be traced back to the egg. A lineage map is not a mechanism of embryo development, but rather a tool for describing it.

69. B: The gastrula is the first three-layered stage of the embryo, containing ectoderm, mesoderm, and endoderm

70. C: In birds, the invagination of gastrulation occurs along a line called a primitive streak. Cells migrate to the primitive streak, and the embryo becomes elongated.

71. D: You would know the snapdragon has an *Rr* genotype, but you would not know whether its parents had an *Rr* genotype or a combination of Rr and *rr* or *RR* and *rr*.

72. D: All the plants will be tall, and flower color will assort independently of stature. In a *Pp* x *Pp* cross, ¾ of the progeny will be purple.

73. E: Two genes next to, or within a specified close distance of, each other, are said to be linked. Linked genes do not follow the law of independent assortment because they are too close together to be segregated from each other in meiosis.

74. C: If the genes are linked, there would be only two kinds of alleles produced by the F1 plants: *Rw* and *rW*. A Punnet square with these alleles reveals that half the progeny will have both an *R* and a *W* allele.

75. C: Half of the boys will receive the color-blind allele from the mother, and the other half will receive the normal one. All the girls will receive the color-blind allele from the father; half of them will also get one from the mother, while the other half will get the normal one. Therefore, half the children will be colorblind.

76. E: An individual with AB blood is tolerant to both the A carbohydrate on red blood cells and the B carbohydrate as "self" and can therefore accept any of the 4 different blood types.

77. B: When more than one gene contributes to a trait, inheritance of that trait is said to be polygenic. This type of inheritance does not follow the rules of Mendelian genetics.

78. D: The parents in D could only have offspring with AB or B blood types, not the A blood type.
79. D: At the lowest trophic level are the producers, followed by primary consumers. Primary carnivores follow consumers, followed by secondary carnivores.

80 A: Vultures eat carrion, or dead animals, so they are considered scavengers. Detritivores are heterotrophs that eat decomposing organic matter such as leaf litter. They are usually small.

81. B: Carbon is released in the form of CO_2 through respiration, burning, and decomposition.

82. D: Most nitrogen is in the atmosphere in the form of N_2. In order for it to be used by living things, it must be fixed by nitrogen-fixing bacteria. These microorganisms convert N_2 to ammonia, which then forms NH_4^+ (ammonium).

83. D: Type I curves describe species in which most individuals survive to middle age, after which deaths increase. Dolphins have few offspring, provide extended care to the young, and live a long time.

84. B: The growth rate is equal to the difference between births and deaths divided by population size.

85. A: Pioneer species colonize vacant habitats, and the first such species in a habitat demonstrate primary succession. Succession on rock or lava often begins with lichens. Lichens need very little organic material and can erode rock into soil to provide a growth substrate for other organisms.

86. B: Secondary succession occurs when a habitat has been entirely or partially disturbed or destroyed by abandonment, burning, storms, etc.

87. B: Epiphytes are plants that grow in the canopy of trees, and the tropical rain forest has a rich canopy because of its density and extensive moisture.

88. A: Transportation by humans or human-associated means is not considered a natural dispersal process.

89. D: Within a habitat, there is a maximum number of individuals that can continue to thrive, known as the habitat's carrying capacity. When the population size approaches this number, population growth will stop.

90. B: Density-dependent limiting factors on population growth are factors that vary with population density. Pollution from a factory, volcanic eruptions, frosts, and fires do not vary as a function of

population size. Waste products, however, increase with population density and could limit further population increases.

91. B: Character displacement means that, although similar, species in the same habitat have evolved characteristics that reduce competition between them. It occurs as a result of resource partitioning.

92. A: Because both species benefit, lichens constitute an example of mutualism.
93. D: Natural selection was Darwin's idea, not Lamarck's. Mendel discovered that genes are the basic units of inheritance. Lamarck's observation about use and disuse is true, although he did not connect it with the underlying mechanism of natural selection.

94. A: Stabilizing selection is a form of selection in which a particular trait, such as weight, becomes stable within a population. It results in reduced genetic variability, and the disappearance of alleles for extreme traits. Over time, the most common phenotypes survive.

95. C: Disruptive selection occurs when the environment favors alleles for extreme traits. In the example, seasonal changes can make different types of food available at different times of the year, favoring the large or short bills, respectively.

96. E: Options A-D all describe conditions that would lead to genetic equilibrium, where no evolution would occur. Gene flow, which is the introduction or removal of alleles from a population, would allow natural selection to work and could promote evolutionary change.

97. C: Hybridization between two different species would result in more genetic variation than sexual reproduction within a species.

98. C: According to Hardy-Weinberg equilibrium, $p + q = 1$ and $p^2 + 2pq + q^2 = 1$. In this scenario, $q^2 = 0.25$, so $q = 0.5$. p must also be 0.5.

99. B: Phyletic gradualism is the view that evolution occurs at a more or less constant rate. Contrary to this view, punctuated equilibrium holds that evolutionary history consists of long periods of stasis punctuated by geologically short periods of evolution. This theory predicts that there will be few fossils revealing intermediate stages of evolution, whereas phyletic gradualism views the lack of intermediate-stage fossils as a deficit in the fossil record that will resolve when enough specimens are collected.

100. B: Adaptive radiation is the evolution of several species from a single ancestor. It occurs when a species colonizes a new area and members diverge geographically as they adapt to somewhat different conditions.

101. D: In coevolution, one species responds to new adaptations in another. Coevolution occurs between predator and prey, pathogens and the immune systems of animals, and plants and their pollinators.

102 E: Structures are homologous because they derive from a common ancestor. Insects do not share a common ancestor with birds and mammals. Birds and mammals share a reptile ancestor.

103. B: The bottleneck effect occurs when populations undergo a dramatic decrease in size. It could be due to natural or artificial causes.

104. A: The first living organisms probably had not yet evolved the ability to synthesize their own organic molecules for food. They were probably heterotrophs that consumed nutrition from the "organic soup."
105. C: Analogous structures do not reveal anything about common ancestors between species. They are simply features that arise due to adapting to similar ecological conditions.

106. C: Habituation is a learned behavior that teaches an animal to ignore meaningless or neutral stimuli.

107. D: Pheromones are chemicals used by animals for communication. They are released by certain individuals and elicit behavioral changes in other individuals.

108. B: Imprinting is a program for acquiring a behavior if an appropriate stimulus is given during a critical time period early in life. Salmon are imprinted with the odors of their birthplace after hatching.

109. C: *Homo sapiens* are thought to have evolved in Africa approximately 100,000 years ago.

110. D: Prolonging the life of individuals in a current population will lead to an older age composition. An increased birth rate will cause population growth, but a greater proportion will be younger, not older.

111. E: With many species, factors like food, space, and predation have large effects on reproduction. Humans are able to control or at least affect many of these challenges, as well as the reproductive process itself, so other factors like education, religion, wealth, and access to health care are more significant factors in birth rates.

112. E: Mercury is a fat-soluble pollutant and can be stored in body tissues. Animals higher up the food chain that eat other animals are most likely to accumulate mercury in their bodies.

113. D: Air pollution would not be a direct result of clear-cutting forests. It would result in increased atmospheric CO_2, however, as well as localized climate change. Transpiration from trees in the tropical rain forest contributes largely to cloud formation and rain, so rainfall decreases because of clear-cutting, resulting in desertification.

114. B: When sulfur dioxide and nitrogen dioxide mix with water and other substances in the atmosphere, they produce sulfuric acid and nitric acid. These acids kill plants and animals when they reach the surface of the earth.

115. E: Genetic engineering is a general term to describe altering DNA sequences through adding or removing pieces of DNA from a native sequence. Restriction enzymes perform this "clipping" function.

Practice Test Two

Molecular and Cellular Biology Practice Questions

1. The chemical bonds between hydrogen and oxygen in an H_2O molecule are an example of?
   a. Nonpolar covalent bonds
   b. Polar covalent bonds
   c. Ionic bonds
   d. Hydrogen bonds
   e. Van der Waals bonds

Questions 2 and 3 pertain to the following: From choices A-E, choose the property of water that best explains the biological phenomenon described

2. When a molecule of water evaporates from a leaf on a tree, another water molecule immediately fills its place.
   a. High heat capacity
   b. Properties of solid water
   c. Surface tension
   d. Solvent for polar and ionic molecules
   e. Capillary action

3. The temperature of a deep lake at a depth of a few hundred feet is nearly constant.
   a. High heat capacity
   b. Properties of solid water
   c. Surface tension
   d. Solvent for polar and ionic molecules
   e. Capillary action

4. Which of the following carbohydrate polymers serves as an energy storage molecule in plants?
   a. Chitin
   b. Cellulose
   c. Starch
   d. Glycogen
   e. Phospholipids

5. Which of the following is not a function of protein in a cell?
   a. Encoding genetic information
   b. Storage of energy
   c. Structural support
   d. Transport of materials
   e. Catalysis of chemical reactions

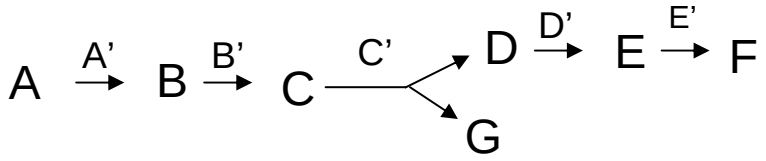
6. DNA and RNA are similar in which of the following ways?
   a. Both contain the sugar ribose
   b. Both grow in the 5□ □ 3□ direction during replication or transcription
   c. Both are usually double-stranded
   d. Both contain the base thymine
   e. Both can serve as a template for translation

7. Phosphate, PO3-, is a chemical moiety found in all but which of the following metabolic compounds?
   a. Amino acids
   b. DNA
   c. RNA
   d. Phospholipids
   e. Nucleotides

8. All of the following molecules are soluble in water except:
   a. Polysaccharides
   b. Hydroxyl groups
   c. Carboxylic acids
   d. Polypeptides
   e. Triglycerides

9. Biochemical reactions take place in an enzyme's?
   a. Cofactor site
   b. Active site
   c. Prosthetic group
   d. Substrate complex
   e. Endothermic site

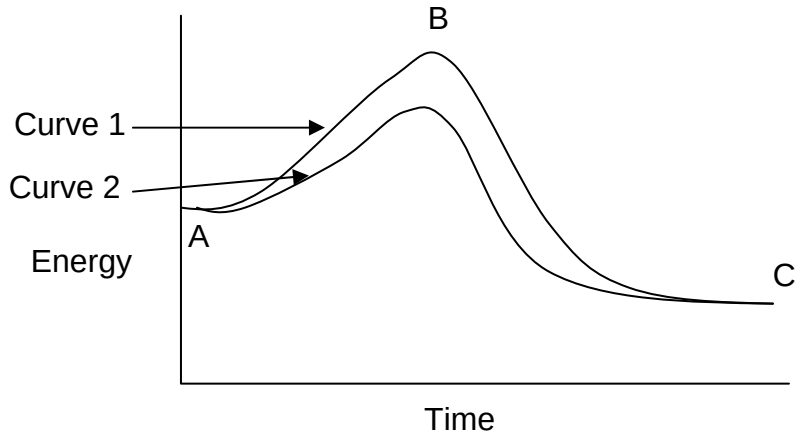
10. An example of a coenzyme is:
   a. Iron
   b. Catalase
   c. Vitamin B1
   d. Glucose
   e. ATP



11. The diagram above depicts a metabolic pathway. When product D accumulates, the production of product C decreases, D is an inhibitor of which enzyme?
   a. A□
   b. B□
   c. C□
   d. D□
   e. E□

12. Cyanide is a poison that binds to the active site of the enzyme cytochrome c and prevents its activity. This kind of inhibition is called:

a. Feedback inhibition
b. Allosteric inhibition
c. Competitive inhibition
d. Noncompetitive inhibition
e. Cooperativity



13. The graph above shows the potential energy of molecules during a chemical reaction. Which of the following statements about the reaction is true?

a. An enzyme could have increased the potential energy at point C
b. An enzyme was probably present in curve 2
c. This is an exergonic reaction
d. The curves show the potential energy of the enzyme
e. The energy of the substrate is less than the energy of the products

14. Which of the following is a characteristic of an enzyme cofactor?

a. It binds to an enzyme's active site
b. It is consumed in the enzymatic reaction
c. It inhibits the enzymatic reaction
d. It binds to an allosteric site
e. It is covalently bound to the enzyme

15. Which of the following is a characteristic of enzymes?

a. They often catalyze more than one kind of reaction
b. They are sensitive to denaturation by heat
c. They catalyze reactions in only one direction
d. They are primarily regulated by gene transcription
e. They all require ATP

16. Which of the following metabolic processes does not require oxygen?
    a. Glycolysis
    b. Photosynthesis
    c. Cellular respiration
    d. Oxidative phosphorylation
    e. Aerobic respiration

17. In oxidative phosphorylation, high-energy electrons are passed from NAD and $FADH_2$ down the electron transport chain to a final electron acceptor. Which of the following is that electron acceptor?
    a. CO2
    b. NAD+
    c. Pyruvate
    d. O2
    e. ATP

18. In photosynthesis, high-energy electrons in Photosystem II are transferred along an electron transport chain and eventually end up in high-energy molecules used in the Calvin Cycle. Which molecule provides electrons to replace those lost by Photosystem II after light stimulation?
    a. NADPH
    b. H2O
    c. ATP
    d. CO2
    e. FADH2

19. Which of the following photosynthetic reactions can only take place in the presence of light?
    a. Chemosmosis
    b. Photorespiration
    c. The Calvin Cycle
    d. Carbon fixation
    e. C4 photosynthesis

20. Centromeres function primarily to
    a. Contain genes that code for proteins
    b. Hold homologous chromosomes together in meiosis I
    c. Provide a point of attachment for kinetochore microtubules
    d. Anchor chromosomes to the cell membrane during cytokinesis
    e. Provide a starting point for DNA replication enzymes

21. In mitosis, how many DNA strands does each chromosome contain prior to anaphase?
    a. 1
    b. 2
    c. 3
    d. 4
    e. 5

22. Which of the following is NOT true of homologous pairs of chromosomes in meiosis I?
    a. They contain four DNA strands
    b. They are held together by centromeres
    c. They are composed of two genetically identical chromatids
    d. They exchange DNA through forming chiasmata
    e. They are known as tetrads

23. In cell division, microtubules function to
    a. Form the cleavage furrow between the two hemispheres of a dividing cell
    b. Form the centromere of chromosomes
    c. Package DNA into a highly condensed form
    d. Form the cell plate in a dividing nucleus
    e. Pull chromosomes apart at the beginning of anaphase

24. How many chromosomes does a human cell have at the metaphase stage of mitosis?
    a. 92
    b. 46
    c. 23
    d. 22
    e. 184

25. In DNA replication, which enzyme is responsible for relieving tension at the replication fork?
    a. Helicase
    b. Primase
    c. Topoisomerase
    d. DNA ligase
    e. DNA polymerase

26. Which of the following is NOT true of the enzyme telomerase?
    a. It requires a chromosomal DNA template
    b. It adds a repetitive DNA sequence to the end of chromosomes
    c. Without its activity, chromosomes would get shorter with every round of DNA duplication
    d. It is active on the lagging strand
    e. It solves the problem of not having enough DNA templates for primase to attach at the end of a DNA strand

27. After a DNA double helix has been replicated, each new strand contains a single strand of old DNA and a single strand of newly synthesized DNA. This form of replication is known as:
    a. Conservative replication
    b. Semiconservative replication
    c. Dispersive replication
    d. Divisive replication
    e. Transformative replication

28. All of the following elements are involved in DNA synthesis on the leading strand except:
    a. DNA polymerase
    b. Primase
    c. Helicase
    d. Single strand binding protein
    e. DNA ligase

29. Which of the following is a common source of genetic mutations?
    a. Exposure to UV light
    b. Errors in DNA replication
    c. Errors in transcription
    d. Exposure to chemicals
    e. Exposure to radiation

Questions 30 – 32, match the statement with the answer that best matches it

30. Assists in mRNA attachment to the ribosome
    a. TATA
    b. AAAAAAA
    c. Intron
    d. 5′ cap
    e. tRNA

31. Point of initiation for RNA polymerase
    a. TATA
    b. AAAAAAA
    c. Intron
    d. 5′ cap
    e. tRNA

32. Substrate for small nuclear ribonucleoproteins
    a. TATA
    b. AAAAAAA
    c. Intron
    d. 5′ cap
    e. tRNA

33. Which of the following could be an end product of translation?
    a. Chromatin
    b. tRNA
    c. Histones
    d. DNA
    e. Okazaki fragments

34. In the *lac* operon, a gene that codes for the protein that blocks RNA polymerase form acting is a
    a. Promoter
    b. Regulatory gene
    c. Structural gene
    d. Operator gene
    e. Inducible gene

35. A segment of DNA that can block the action of RNA polymerase when occupied by a repressor protein is called
    a. A promoter
    b. A telomere
    c. A centromere
    d. A nucleosome
    e. An operator

36. Transfer of DNA between bacteria through viral infection is called
    a. Conjugation
    b. Transformation
    c. Transduction
    d. Binary fission
    e. Excision

37. The genetic material of retroviruses like HIV
    a. Capsid
    b. Envelope
    c. Prophage
    d. DNA
    e. RNA

38. The protein coat that surrounds the genetic material of a virus
    a. Capsid
    b. Envelope
    c. Prophage
    d. DNA
    e. RNA

39. Which of the following enzymes cleaves DNA at a particular sequence?
    a. Exonuclease
    b. Restriction endonuclease
    c. Ligase
    d. Polymerase
    e. Phosphatase

40. Transports food made in leaves to the rest of the plant
    a. Cuticle
    b. Guard cells
    c. Xylem
    d. Phloem
    e. Parenchyma

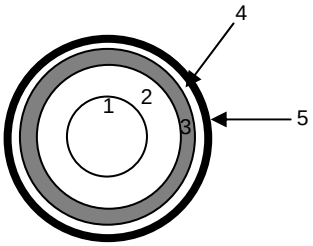
41. Protects the plant from desiccation
    a. Cuticle
    b. Guard cells
    c. Xylem
    d. Phloem
    e. Parenchyma

42. Transports water from the roots to the leaves
    a. Cuticle
    b. Guard cells
    c. Xylem
    d. Phloem
    e. Parenchyma

43. Which part of a plant embryo gives rise to the roots?
    a. Epicotyl
    b. Hypocotyl
    c. Cotyledon
    d. Radicle
    e. Coleoptile

44. In many plants, growth of the shoots and roots only originates from the
    a. Apical meristem
    b. Lateral meristem
    c. Vascular cambium
    d. Peridium
    e. Root cap

Questions 45 and 46 pertain to the following diagram representing a cross section of a tree trunk:



45. Which structure transports water from the roots to the shoots?
    a. 1
    b. 2
    c. 3
    d. 4
    e. 5

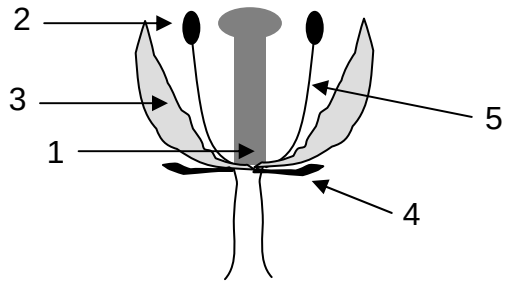
46. Which structure contains meristem cells that give rise to new tissue?
    a. 1
    b. 2
    c. 3
    d. 4
    e. 5

47. Which of the following contributes most to the movement of water from soil into roots?
    a. Capillary action
    b. Transpiration
    c. Bulk flow
    d. Osmosis
    e. Adhesion

48. In mosses, eggs and sperm are produced by:
    a. Spores
    b. Sporophytes
    c. Gametophytes
    d. Zygotes
    e. Flowers

49. Which of the following is true of the alternation of generations life cycle of plants?
    a. The diploid stage is always more prominent than the haploid cells
    b. Flowering plants do not have alternation of generations
    c. Gymnosperms do not have alternation of generations
    d. The sporophyte and gametophyte can exist in the same individual at the same time
    e. Gametophytes eventually mature into sporophytes

Questions 50 and 51pertains to the following diagram of a complete perfect flower:



50. The structures containing haploid cells are:
    a. 1 and 2
    b. 2 and 3
    c. 3 and 4
    d. 4 and 5
    e. 1 and 5

51. The structure in which a zygote is formed is:
    a. 1
    b. 2
    c. 3
    d. 4
    e. 5

52. Plant shoots demonstrate negative gravitropism, whereas roots demonstrate positive gravitropism. Which of the following plant hormones mediates this response?
    a. Ethylene
    b. Abscisic acid
    c. Jasmonic acid
    d. Gibberellins
    e. Auxin

53. Auxin stimulates stem elongation and is involved in the process of phototropism. If plants bend toward a light source, in which region of the plant is auxin most likely to be found?
    a. The sunny side of a stem
    b. The shaded side of a stem
    c. The top of a shoot
    d. The bottom of a shoot
    e. The top side of leaves

54. Which of the following would be most disruptive to the flowering time of a short-day plant?
    a. Daylight interrupted by a brief dark period
    b. Daylight interrupted by a long dark period
    c. High daytime temperatures
    d. Watering only at night
    e. Night interrupted by a brief exposure to red light

55. Most of the CO_2 in blood is converted to carbonic acid in red blood cells. When a body is active, CO_2 production increases. Which of the following changes in pH would stimulate increased respiratory rate?
a. A drop in pH
b. A return to normal pH after a drop in pH
c. A rise in pH
d. A return to normal pH after a rise in pH
e. No change in pH is needed to stimulate increased respiratory rate

56. Which of the following organisms has a circulatory system in which blood circulates in an internal cavity called a hemocoel?
a. Earthworms
b. Cats
c. Birds
d. Centipedes
e. Eels

57. The digestion of starches begins in which part of the digestive system?
a. The mouth
b. The stomach
c. The small intestine
d. The large intestine
e. The colon

58. The major inhibitory neurotransmitter in the central nervous system is:
a. Acetylcholine
b. Epinephrine
c. GABA
d. Dopamine
e. Serotonin

59. In animals, consuming glucose causes insulin release from the pancreas, which causes the liver and muscles to take in glucose from the blood stream. This is an example of:
a. Thermoregulation
b. Circulatory feedback
c. Positive feedback
d. Negative feedback
e. Receptor feedback

60. Which of the following would NOT be an effective strategy for thermoregulation in a hot environment?
a. Evaporation of water from the skin surface
b. Restricting activity to nights
c. Countercurrent exchange
d. Increasing blood flow to extremities
e. Muscle contraction

61. An embryo directly maintains pregnancy by secreting which hormone?
    a. Human chorionic gonadotropin (HCG)
    b. Gonadotropin releasing hormone (GnRH)
    c. Luteinizing hormone (LH)
    d. Follicle stimulating hormone (FSH)
    e. None of these

62. Which hormone stimulates the development of the endometrium?
    a. Human chorionic gonadotropin (HCG)
    b. Gonadotropin releasing hormone (GnRH)
    c. Luteinizing hormone (LH)
    d. Follicle stimulating hormone (FSH)
    e. None of these

63. Which of the following is *not* true of gametogenesis?
    a. Meiosis I and meiosis II take place years apart from each other in oogenesis
    b. No polar bodies are produced in spermatogenesis
    c. Sperm and eggs have unequal amounts of cytoplasm
    d. Sperm and egg production are both cyclical
    e. Spermatogenesis begins at puberty

64. Which of the following hormones promotes thickening of the endometrium?
    a. Gonadotropin releasing hormone (GnRH)
    b. Progesterone
    c. Luteinizing hormone (LH)
    d. Serotonin
    e. Androgen

65. Which of the following structures contains the genetic material in sperm?
    a. The acrosome
    b. The midpiece
    c. The tail
    d. The flagellum
    e. The head

66. Which stage of embryonic development is characterized by a hollow ball of cells?
    a. Zygote
    b. Gastrula
    c. Morula
    d. Blastula
    e. Coelomate

67. Which of the following extraembryonic membranes encloses the fluid surrounding an animal embryo?
    a. Amnion
    b. Allantois
    c. Yolk sac
    d. Chorion
    e. Placenta

68. The neural tube of chordates is derived from this germ layer
    a. Gray crescent
    b. Primitive streak
    c. Ectoderm
    d. Mesoderm
    e. Endoderm

69. Which of the following is NOT true of the mammalian placenta?
    a. It is formed from maternal and embryonic tissues
    b. It allows for gas and nutrient exchange
    c. It allows for waste exchange
    d. It is formed from the chorion
    e. It is formed from the amnion

70. Which of the following is not an extraembryonic membrane in mammals?
    a. Yolk sac
    b. Amnion
    c. Allantois
    d. Dorsal lip
    e. Chorion

71. A pea plant with purple flowers is crossed with a pea plant with white flowers. Half the progeny have purple flowers and half have white flowers. The allele for purple flowers is _____ to the allele for white flowers.
    a. Dominant
    b. Co-dominant
    c. Recessive
    d. Incompletely dominant
    e. Impossible to determine from the information provided

72. What will be the genotype of the gametes produced by a *Tt* individual?
    a. All T
    b. All t
    c. ½ T and ½ t
    d. All Tt
    e. ½ Tt and ½ *tT*

73. Two alleles of a gene will have the same
    a. Dominance
    b. Phenotypes
    c. Frequency in a population
    d. Locus
    e. Penetrance

74. In a dihybrid cross between bean plants with red (*R*) wrinkled (*w*) seeds and white (*r*) smooth (*W*) seeds, the F1 progeny is all red and smooth. F1 plants are selfed, and the progeny are ½ red and smooth, ¼ red and wrinkled, and ¼ white and smooth. Red is dominant to white and smooth is dominant to wrinkled. Which is true of the R and W genes?

a. They are linked
b. They are unlinked
c. They are sex-linked
d. They are on different chromosomes
e. They cause abnormal chromosome segregation

75. Hemophilia is a sex-linked trait. From which parent(s) did an affected boy inherit the trait?

a. Only the father
b. Only the mother
c. Both the father and the mother
d. The mother or the father but not both
e. Impossible to tell

76. In fruit flies, the traits for abdomen bristles and wing shape have several alleles but are always inherited together. This is an example of:

a. Epistasis
b. Pleiotropy
c. Linkage
d. Polygenic inheritance
e. Incomplete dominance

77. If non-disjunction occurs in a late stage of embryonic development, the result will be

a. Polyploidy
b. Down syndrome
c. Mosaicism
d. Turner syndrome
e. Deletion

78. A child is born with the O blood type. His mother is type O and his father is type A. What are the genotypes of his mother and father?

a. IAIA and ii
b. ii and IAi
c. IA i and IA i
d. IAi and IBi
e. ii and ii

Population Biology Practice Questions

79. The diagram above represents a pyramid of energy (p 244). Level 2 corresponds to which trophic level?
    a. Primary producers
    b. Decomposers
    c. Primary consumers
    d. Secondary consumers
    e. Tertiary consumers

80. Domestic animals used for food or work are nearly always herbivores because
    a. They are easier to tame
    b. They are safer to handle
    c. They have longer life spans
    d. They reach maturity faster
    e. They require less energy input than carnivores

81. What is the largest reservoir of phosphorous on the planet?
    a. The ocean
    b. Plants
    c. Soil
    d. The atmosphere
    e. Rocks and ocean sediments

82. Which of the following is the major way in which nitrogen is assimilated into living things?
    a. Erosion from sediments
    b. Fixation by bacteria
    c. Respiration from the atmosphere
    d. Transpiration
    e. Absorption from soils

83. Which of the following is the best example of a K-selected species?
    a. Grasses
    b. Mosquitoes
    c. Gorillas
    d. Mice
    e. Beetles

84. About a thousand years ago, the human population began growing exponentially. Which of the following was NOT a factor that led to this?
    a. Elimination of large carnivores
    b. Increased food supply
    c. Reduction in disease
    d. Improved sanitation
    e. Expansion of habitat

85. As ecological succession progresses,
    a. Biomass increases and species diversity decreases
    b. Biomass decreases and species diversity increases
    c. Biomass and species diversity decrease
    d. Biomass and species diversity increase
    e. Biomass and species diversity do not change

86. Which of the following habitats would provide an opportunity for primary succession?
    a. Burned cropland
    b. A pond in which most living things had been poisoned
    c. A lake that had been filled in by sediment
    d. A 500 year old forest
    e. A glacial moraine

87. Which of the following biomes is most likely to contain animals that hibernate seasonally?
    a. Tropical rain forest
    b. Savannas
    c. Marine biomes
    d. Taigas
    e. Temperate grasslands

88. Species that inhabit an island because they were transported there by humans are called
    a. Invasive species
    b. Introduced species
    c. Dispersed species
    d. Native species
    e. Mutualistic species

89. If a population's growth rate is zero, it has likely reached its
    a. Minimal viable population size
    b. Full range
    c. Carrying capacity
    d. Mature age structure
    e. Intrinsic growth rate

90. Which of the following is an example of a density-independent limiting factor?
    a. Sunlight for photosynthesis
    b. Food availability
    c. Predation
    d. Transmission of infectious diseases
    e. Pollution

91. A species of finch is able to live all along cliffs on a coast, but is usually found only at the top of the cliffs because lower nesting spaces are taken by gulls. This is an example of:
    a. Mutualism
    b. Character displacement
    c. Resource partitioning
    d.Competitive exclusion
    e. Realized niches

92. Egrets gather around cattle and eat the insects that are disturbed by cattle grazing. This is an example of:

a. Mutualism
b. Commensalism
c. Parasitism
d. Coevolution
e. Resource partitioning

93. The combination of natural selection and Mendelian genetics is known as:

a. Inheritance of acquired characters
b. Microevolution
c. Macroevolution
d. The modern synthesis
e. Natural transformation of species

94. As a result of herbicide treatment, nearly an entire population of a grass possesses an herbicide-resistant gene. This is an example of:

a. Stabilizing selection
b. Directional selection
c. Disruptive selection
d. Sexual selection
e. Artificial selection

95. Which of the following is *least* likely to cause a change in allele frequencies in a population?

a. Mutation
b. Random mating
c. Immigration
d. A rapid decrease in population size due to a natural disaster
e. Inbreeding

96. Which of the following could be a source of genetic variation in a haploid species?

a. Crossing over
b. Outbreeding
c. Mutation
d. Hybridization
e. Heterozygote advantage

97. Which of the following conditions could lead to sympatric speciation?

a. Polyploidy
b. Rapid reduction in population size due to a natural disaster
c. Habitat fragmentation
d. Introduction of a species onto a previously uncolonized island
e. A high frequency of mutation

98. New mutations
    a. Are rare
    b. Are usually beneficial
    c. Result from sexual reproduction
    d. Result from reproductive isolation
    e. Are the raw material for natural selection

99. A population of pea plants has 25% dwarf plants and 75% tall plants. The tall allele, *T*, is dominant to dwarf (*t*). What percentage of tall plants is heterozygous?
    a. 0.75
    b. 0.67
    c. 0.5
    d. 0.25
    e. 0.16

100. Which of the following conditions would most likely lead to adaptive radiation?
    a. A mountain rising up and creating two separate populations of a species
    b. A plant becoming polyploid
    c. Hybridization between two species of flowers
    d. Inbreeding among a population
    e. Introduction of an animal onto a previously uncolonized island

101. Both sharks and penguins have torpedo-shaped bodies and peripheral fins, although they are not closely related. This is an example of:
    a. Divergent evolution
    b. Convergent evolution
    c. Parallel evolution
    d. Coevolution
    e. Macroevolution

102. Which of the following is a pair of analogous structures?
    a. Fish eggs and snake eggs
    b. A pinecone and a flower
    c. Bat wings and human arms
    d. Dog fur and bird feathers
    e. A squid eye and a cat eye

103. In the absence of selective pressure, but in a small population, allele frequencies will likely change because of:
    a. Genetic drift
    b. Gene flow
    c. The founder effect
    d. Nonrandom mating
    e. Sexual selection

104. The absence of which of the following molecules in the earth's early atmosphere allowed chemical evolution to occur?

a. CO2
b. O2
c. H2
d. HCl
e. S

105. Evidence that eukaryotic organelles evolved from prokaryotes includes all of the following EXCEPT:

a. Mitochondria and chloroplasts have their own DNA
b. Fossils of early endosymbionts
c. Mitochondria and chloroplasts have two membranes
d. Mitochondria and chloroplasts reproduce independently of the cell cycle
e. Internal organelles are similar in size to prokaryotes

Questions 106 – 108, match each sentence with the choice below that most closely matches it. Each lettered choice may be used more than once or not at all.

106. Female mosquitoes move toward mammals by moving toward CO_2 and lactic acid.

a. Associative learning
b. Fixed action patterns
c. Taxis
d. Observational learning
e. Chemical communication

107. A dog runs to the door when it sees its leash.

a. Associative learning
b. Fixed action patterns
c. Taxis
d. Observational learning
e. Chemical communication

108. A bird had never opened the door to its cage although it was not locked. After another bird who knew how to open the door was introduced to the cage and the first bird saw the second one open the door, the first bird could open the door.

a. Associative learning
b. Fixed action patterns
c. Taxis
d. Observational learning
e. Chemical communication

109. Which of the following classes of organisms is not in the phylum chordata?

a. Chondrichthyes
b. Arthropoda
c. Mammalia
d. Amphibia
e. Osteichthyes

110. Which of the following demographic changes would lead to a population with a younger age composition?

a. Increased birth rate
b. Medical advancements that prolong life
c. Shifting from agrarian to urban dwellings
d. Introduction of birth control
e. Uneven food supply

111. The final stage in the human population's demographic transition will be:

a. High death rates due to lack of food and disease
b. Increased birth rate due to better food production and disease prevention
c. Lowered birth rates through contraception
d. Continued exponential growth
e. Continued decrease in doubling time

112. Which of the following organisms would be most likely to have DDT in its body?

a. Mosquitoes
b. Algae
c. Grasses
d. Predator fish
e. Filter-feeding fish

113. Releasing chlorofluorocarbons (CFCs) into the atmosphere leads to which environmental problem?

a. Global climate change
b. Acid rain
c. Ozone depletion
d. Desertification
e. Eutrophication

114. Overuse of fertilizers leads to which environmental problem?

a. Biological magnification
b. Deforestation
c. Acid rain
d. Eutrophication
e. Desertification

115. Genetic engineering

a. Is equivalent to cloning
b. Involves introducing new proteins to a cell
c. Involves crossing species to create hybrids
d. Uses bacteria to proliferate cloned DNA sequences
e. Can have no environmental effects

Answers and Explanations

1. B: The bonds between hydrogen and oxygen in water involve shared electrons and are therefore covalent. But the electrons are shared unequally because oxygen is more electronegative than hydrogen, so the shared electrons are more attracted to oxygen. Hydrogen – oxygen bonding *between* water molecules is an example of hydrogen bonding.

2. E: Water adheres to hydrophilic substances through hydrogen bonding. Such substances include the vascular tissue of plants, so that when a water molecule is lost through evaporation, another water molecule fills its place and so on down to the roots, where water molecules are taken up from the soil.

3. A: Water has a high heat capacity, which means that it takes a lot of energy to heat or cool water. The temperatures of large bodies of water are very stable compared to the temperature of the surrounding air.

4. C: Plants have cellulose as the major structural component of their cell walls. However, plants store energy as starch, not cellulose. Starch is a polymer of α-glucose molecules, whereas cellulose is a polymer of β-glucose molecules. The different chemical bonds between glucose molecules in starch and cellulose make the difference in whether or not the polymer is digestible in plants and animals.

5. A: Proteins have a greater diversity of functions than any other biological molecules. It is nucleic acids that encode genetic information: proteins merely carry out the instructions encoded in genes.

6. B: Although DNA and RNA have the same basic structure, there are some important chemical differences between them. DNA uses deoxyribose as its sugar, while RNA uses ribose. In RNA, the base uracil replaces thymine. RNA can base-pair with itself to form a double stranded molecule; however, it generally is single-stranded.

7. A: Amino acids contain carbon, oxygen, nitrogen, hydrogen, and sometimes sulfur. Polypeptides do not contain phosphate as an integral component. However, they may be phosphorylated by an enzyme following translation.

8. E: Triglycerides are hydrophobic. They consist of three fatty acids joined to a glycerol molecule, and because of their long hydrocarbon chains, they are not soluble in water.

9. B: The active site of an enzyme is a uniquely shaped three-dimensional space that is the site of biochemical reactions. Substrates fit within the active site in such a configuration that the enzyme and substrate can bind together. This union is called the enzyme-substrate complex. This pairing is very short lived because as soon as the chemical reaction that the enzyme catalyzes takes place, the enzyme and product dissociate.

10. C: Coenzymes are organic cofactors that are necessary for certain enzymatic reactions. Cofactors bind to the active site and allow the substrate to fit properly. Many coenzymes are vitamins, some of which are not made by cells but must be obtained through the diet.
11. B: This is an example of negative feedback, a process whereby an increase in an outcome causes a decrease or slowing in the pathways that led to the outcome.

12. C: In competitive inhibition, the competitor binds to the same active site as the substrate, preventing the substrate from binding. In feedback inhibition, an end product acts as an inhibitor: the question does not tell you that this has occurred. An allosteric enzyme has two binding sites, one for substrate (the active site) and one for effector (the allosteric site), and an allosteric inhibitor binds to the latter, not the former.

13. B: The activation energy, or peak, is lower in curve 2, which means that a catalyst was present. Enzymes work by lowering the activation energy of reactions.

14. A: A cofactor binds to the active site along with the substrate in order to catalyze an enzymatic reaction. Like the enzyme, it is not consumed by the reaction. Allosteric effectors bind to a second binding site on the enzyme, not the active site.

15. B: The three-dimensional structure of an enzyme is critical for its ability to bind substrates and catalyze reactions effectively. The three-dimensional structure is held in place by hydrogen bonds between amino acids, and these hydrogen bonds are easily disrupted, denaturing the protein (enzyme), by changes in temperature and pH.

16. A: Glycolysis is the first step in cellular respiration. As a result of glycolysis, a glucose molecule is split into two pyruvate molecules. This process does not require oxygen and can occur in either an aerobic or an anaerobic environment. Pyruvate can either be metabolized in the aerobic pathway, ending in oxidative phosphorylation, or the anaerobic pathway, ending in lactic acid or ethanol fermentation.

17. D: Oxygen is the final electron acceptor, which is why oxygen is required for cellular respiration. Oxygen combines with two electrons and two protons to form water, one of the waste products of cellular respiration. The other waste product is carbon dioxide.

18. B: Water and carbon dioxide are the two essential consumable molecules in photosynthesis. First, water is split into oxygen, protons, and electrons, and then carbon dioxide is used in the Calvin cycle to create glucose. The electrons from splitting water are used in photosystem II, the protons are used to create NADPH, and oxygen is a waste product of the splitting of water.

19. A: During chemosmosis, energy from light is used to extract electrons from water and pump protons across the thylakoid membrane, creating a creating a proton gradient that powers the generation of ATP and NADPH. Once these molecules are created, they power the processes described in alternatives B-E.

20. C: Kinetochore microtubules attach to the centromere during prophase of mitosis. During anaphase, some shorten, pulling sister chromatids apart into their respective hemispheres of the cell, while others lengthen, pushing against each other and forcing the poles of the cell farther apart.

21. B: Prior to anaphase, each chromosome is still duplicated contains two DNA strands (sister chromatids). Interphase chromosomes have one DNA strand.
22. B: Tetrads are held together at the crossover points, referred to as synaptonemal complexes. Each homologous pair is linked by centromeres, but during prophase I crossing over between homologs creates a physical connection called a synaptonemal complex. When homologs separate in anaphase I, the synaptonemal complexes are broken.

23. E: Microtubules from the spindle apparatus pull the kinetochores of each chromosome to their respective poles at the beginning of anaphase of mitosis.

24. A: At the metaphase stage of mitosis, the cell has duplicated every chromosome. The diploid chromosome number for humans is 46, so the number of chromosomes after DNA duplication but before cell division is 92.

25. C: Topoisomerase removes twists and knots that form in the double helix as a result of rapid unwinding by helicase.

26. A: Telomerase is an enzyme made from an RNA template that adds a base sequence (TTAGGG) to the end of the lagging strand of DNA synthesis. It prevents the loss of terminal DNA sequences (telomeres), and does not require a chromosomal DNA template for synthesis.

27. B: The semiconservative model for DNA replication, known to be correct, states that each of the two new DNA molecules consists of one original strand and one newly synthesized strand. The conservative model, which was originally proposed, held that one of the newly synthesized DNA molecules would consist of two new strands while the other would consist of the two original strands.

28. E: Because DNA synthesis is continuous on the leading strand, DNA ligase is not needed. DNA ligase is needed on the lagging strand in order to join Okazaki fragments.

29. B: Changes to the DNA sequence of chromosomes are considered genetic mutations because they are passed to all daughter cells and present in all RNA transcripts. Errors in transcription may result in an improper amino acid sequence in proteins, but not a genetic mutation.

30. D: Following transcription, a 5′ cap is added to the mRNA. The 5′ cap is a guanine nucleotide with two additional phosphate groups. It provides stability to the mRNA molecule as well as a point of attachment for the small ribosome subunit.

31. A: RNA polymerase attaches to a promoter region on DNA. Often, the promoter contains the sequence TATA, called the "TATA box."

32. C: In eukaryotes, mRNA transcripts contain exons, which code for polypeptides, and introns, which do not. Introns must be removed before translation, and this is done by small nuclear ribonucleoproteins, or snRNPs.

33. C: Histones are proteins, and proteins are the products of translation.

34. B: Regulatory genes help control gene expression. They code for proteins that affect the transcription of other genes. They may be either repressor or activator proteins.
35. E: An operator is a binding site on DNA to which a repressor protein can bind, preventing gene transcription. More than one operator can be present. The operator or operators that control the expression of related genes, plus the gene's promoter, constitute an operon.

36. C: A virus that invades a bacterium is called a bacteriophage ("phage"="eating"). Bacteriophages can bring part of a previous host cell's DNA, usually as part of the viral coat, into a new bacterial cell, thereby injecting the foreign DNA into the bacterium. This is transduction. Transformation occurs when a bacterial cell takes up new DNA from its immediate environment.

37. E: Retroviruses have single stranded RNA as their genetic material. Upon infecting a cell, they use reverse transcriptase to make a DNA complement that is then transcribed to make mRNA.

38. A: In all viruses, nucleic acid is enclosed by a protein coat, called a capsid. Some viruses have an additional coat called an envelope. The envelope is made from cell membrane fragments of the host.

39. B: Restriction endonucleases, also called restriction enzymes, cut DNA at very specific sequences. They are used in recombinant DNA technology to cut, and then bring together, DNA sequences from various sources.

40. D: Phloem is made of stacked cells with sieve plates between them that allow nutrients to pass from cell to cell. It transports sugars from photosynthetic tissues to non-photosynthetic tissue

41. A: The cuticle covers all of the green surfaces of a plant. It is made of waxes and helps protect leaves and other tissues from water loss. It also protects the plant from injury and helps defend the plant.

42. C: Xylem is composed of long tubular cells whose cell walls interconnect. Xylem transports water and dissolved ions from the roots to the branches and leaves of plants. At leaf surfaces, water evaporates through transpiration, drawing up water through the xylem.

43. D: The radicle develops at the bottom of the embryo and is the embryonic root. Above the radicle is the hypocotyl, which is the embryonic shoot, and the cotyledons, which are the embryonic leaves.

44. A: The apical meristems have actively dividing, or meristematic, cells. The actively dividing cells in the tips of these regions form the roots and shoots of the plant. Many plants, including most monocots, have meristematic cells only in the shoot and root apical meristems, whereas woody plants have lateral meristems that produce secondary growth (increase in diameter).

45. B: The sapwood contains living xylem tissue that transports water from roots to shoots. Sapwood is young xylem tissue. As it ages, it dies and becomes heartwood, which has no fluid transport.

46. E: Tree trunks contain two kinds of meristematic tissue: the vascular cambium, which gives rise to xylem and phloem tissue, and the cork cambium, which gives rise to the epidermis.

47. D: The concentration of solutes in roots is such that water flows into them through osmosis.

48. C: In plants, all eggs and sperm are produced by gametophytes. In mosses, the gametophyte is the most prominent stage. In angiosperms, gametophytes are tiny and found inside anthers and pistils.

49. D: In simple plants like ferns and mosses, the gametophyte and sporophyte generations are temporally and physically separate. But in gymnosperms and flowering plants, gametophytes grow and develop within sporophyte tissues. In gymnosperms, cones house the gametophytes; in angiosperms, flowers house the gametophytes.

50. A: In flowering plants, the anthers house the male gametophytes and the pistils house the female gametophytes.

51. A: Fertilization of eggs takes place in the pistil. Pollen grains are deposited on the stigma—the receptive surface of the pistil—and grow tubes that deliver sperm to the ovules.

52. E: Auxin controls cell wall plasticity and is produced at root and shoot tips. It controls the responses of these structures to light and gravity.

53. B: Auxin is found in higher concentrations on the shaded side than the sunny side of a stem. More elongation on the shaded side causes the stem to bend toward the light.

54. E: Short-day plants flower when day length is decreasing or night length is increasing. When plants are exposed to light during the night period, it resets their circadian-rhythm clocks and interferes with their calculation of night length.

55. A: When the CO_2 concentration is high, more carbonic acid is formed, and the body needs to increase respiration to remove it from the blood. Thus, a drop in pH causes an increase in the respiratory rate.

56. D: Insects and most mollusks have open circulatory systems. Vertebrates, the phylum Annelida (earthworms), and some mollusks (squid and octopuses) have closed circulatory systems.

57. A: The mouth produces salivary amylase, the enzyme that begins the breakdown of starch into maltose.

58. C: GABA is an inhibitory neurotransmitter in the brain, although it may occasionally function as an excitatory neurotransmitter.

59. D: In negative feedback, when a pathway's output (increased blood glucose) exceeds normal limits, a mechanism is activated that reduces inputs to the pathway (reduction of blood glucose). Conditions are monitored by a control center, and when homeostasis returns, the corrective action is discontinued.

60. E: Muscle contraction (shivering) creates heat, so this would not be an effective way of maintaining body temperature in a hot environment.

61. A: If implantation occurs, the embryo secretes HCG. This stimulates the corpus luteum to produce estrogen and progesterone to maintain the pregnancy.

62. E: Estrogen and progesterone, which are produced by the corpus luteum, cause the endometrium to thicken and prepare for implantation by an embryo.

63. D: Spermatogenesis is a continuous process whereas an egg is made available (ovulation) approximately once a month.

64. B: The corpus luteum (present after ovulation) produces progesterone and estrogen. Both of these hormones stimulate the development of the endometrium.

65. E: The head contains a haploid nucleus with 23 chromosomes. The head also contains the acrosome, a lysosome containing enzymes that are used to penetrate the egg.

66. D: The blastula is a very early-stage embryo. Cell divisions produce a solid ball of cells called a morula, which becomes filled with liquid to form the blastula. Following this stage, differentiation begins with the formation of the gastrula.

67. A: The amnion encloses the amniotic cavity, which is filled with fluid and cushions the developing embryo.

68. C: The neural tube, which develops into the central nervous system of chordates, is derived from ectoderm directly above the notochord.

69. E: The placenta is formed from the extraembryonic layer known as the chorion, as well as from maternal tissues. It allows the exchange of gases, nutrients, and waste between mother and fetus. The amnion encloses the fluid-filled cavity that cushions the developing embryo.

70. D: The dorsal lip is part of the embryo itself. It is the top edge of the blastopore, present in the gastrula.

71. E: Because we are not told whether the parent plants are homozygous or heterozygous, it is not possible to determine the dominance of one allele over another.

72. C: Gametes are haploid and have only one allele. Half the gametes from this individual will have the *T* allele and half will have the *t* allele.

73. D: A locus is defined as the location of a gene on a chromosome. Alleles of a gene are different forms of the same gene, and they have the same locus. Some alleles may be recessive and some may be dominant.

74. A: If the genes were unlinked, a 9:3:3:1 distribution of phenotypes would appear in the F2 generation because of independent segregation of the traits.

75. B: Sex-linked, or X-linked, traits can only be transmitted to males through the mother.

76. C: If two different traits are always inherited together, they do not segregate in meiosis and are linked.

77. C: If non-disjunction occurs late in embryonic development, only some of the individual's cells will have extra or missing chromosomes, resulting in mosaicism.

78. B: The mother can only be *ii* and the father must be heterozygous because the son is type O.

79. C: Primary producers are the largest trophic level, followed by primary consumers. Primary consumers consume primary producers. Much energy is lost at each trophic level.

80. E: The meat a carnivore consumes would far exceed the meat a carnivore would yield, so the energy used to raise the carnivore would exceed its value in food or work.

81. E: Phosphorus, like other minerals such as calcium and magnesium, is found in its largest quantities in rocks and other sediments. It is released into the environment through erosion. Synthetic fertilizer is the main source of phosphorous for crop plants.

82. B: Plants and animals cannot use inorganic nitrogen. It must be fixed, or reduced to ammonium, in order to enter a living ecosystem.

83. C: A K-selected species has a population size that is constantly at or near carrying capacity. Its members produce few offspring, and the offspring are large and require extensive parental care until they mature.

84. A: Predation by carnivores was not a major factor holding back population growth for humans. Humans are and have long been at the top of their food web, so other factors like food supply and habitat expansion played a greater role in growing the human population.

85. D: Succession is the change in composition of species over time. Some species gradually replace others, while overall, both species diversity and biomass increase.

86. E: Primary succession occurs on substrates that never previously supported living things.

87. D: Taigas are coniferous forests. They have very cold winters with precipitation in the form of snow, and they support animals that hibernate throughout the winter.

88. B: Species that inhabit a particular ecosystem that were transported by humans to that location are called introduced species. They may or may not be invasive, depending on whether or not they displace native species.

89. C: The carrying capacity is the maximum number of individuals a habitat can sustain, so when the population size reaches this number, growth will stop.

90. E: Pollution affects the health of ecosystems and can limit population growth, but as it is a byproduct of human activity, it is not dependent on the density of the population.

91. E: Species may theoretically be able to inhabit a particular area, called its fundamental niche. But the presence of competing species may mean that it only occupies part of its niche, called a realized niche.

92. B: In this example, the egrets benefit while the cattle are neither helped nor harmed, so it is an example of commensalism.

93. D: Darwin and Mendel were contemporaries but were apparently not aware of each other's work. Around the beginning of the 20th century, Mendel's discoveries about genetics were incorporated into Darwinism, resulting in what is called the modern synthesis.

94. B: Selection that favors one extreme trait over all others is called directional selection. If directional selection continues for many generations, the population will end up with only one allele for that trait.

95. B: Random mating would lead to an equilibrium of allele frequencies, while nonrandom mating (for example, inbreeding or sexual selection) would cause changes in allele frequencies.

96. C: Mutation produces new genetic variation and occurs in diploid and haploid species. However, certain sources of variation, like crossing over, independent assortment of alleles, and hybridization, are limited to diploid species.

97. A: Sympatric speciation occurs when an ancestral species diverges into two different species in the absence of a geographic barrier. The most common way this happens is through genetic barriers, for example, after polyploidy occurs.

98. E: The variation caused by mutation is the raw material for natural selection.

99. C: According to Hardy-Weinberg equilibrium, $p + q = 1$ and $p^2 + 2pq + q^2 = 1$. In this scenario, $q^2 = 0.25$, so $q = 0.5$. p must also be 0.5. $2pq$ is equal to 2(.5)(.5) or 0.5.

100. E: Adaptive radiation is the evolution of several species from a single ancestor. It occurs when a species colonizes a new area and diverges as its members specialize for a particular set of conditions.

101. B: Convergent evolution describes unrelated species with similar traits that arose not because they share a common ancestor, but because they have adapted to similar ecological conditions.
102. E: Squid are not vertebrates, so although their eyes are similar in form and function to vertebrate eyes, they are analogous, not homologous, structures.

103. A: Genetic drift is the random change in allele frequencies. In a small population, some alleles may increase or decrease for no other reason than by chance.

104. B: Simple molecules were able to form in the earth's early atmosphere because oxygen was absent. Oxygen is very reactive and it would have supplanted other molecules in chemical reactions if it were present.

105. B: The endosymbiont theory, that early prokaryotes invaded other cells and took up residence there, is based on structure and function of current organelles. The fossil record does not provide direct evidence of this because early microscopic organisms would be unlikely candidates for fossilization.

106. C: Taxis are a directed movement in response to certain stimuli. The stimulus may be chemical, or not. But if the response is directional, then the movement is considered taxis

107. A: Associative learning occurs when an animal recognizes that events and/or things are connected.

108. D: Observational learning occurs when an animal copies the behavior of another animal without having experienced any positive or negative reinforcement.

109. B: The phylum Arthropoda consists of organisms with an exoskeleton such as crabs, spiders, and insects. They do not have notochords like fish, amphibians, reptiles, birds, and mammals do.

110. A: As its birth rates increase, a population will include proportionally more younger members. Advancements that prolong life have the opposite effect.

111. C: According to the theory of demographic transition, there are progressive demographic time periods in human population growth. The final stage, following decreased death and infant mortality rates, is decreased birth rates through contraception.

112. D: DDT is a long-lasting insecticide that was used in the middle of the 20th century. It is fat-soluble and can be stored in body tissues. Animals that eat other animals are most likely to accumulate DDT in their bodies.

113. C: CFCs react with ozone in the atmosphere, causing the ozone layer to thin ("holes"). This allows UV radiation to penetrate the atmosphere to a greater degree than is desirable. Efforts to reduce the use of CFCs in products have been successful in reducing holes in the ozone layer.

114. D: Overuse of fertilizers means that runoff from farms has high levels of phosphates and other nutrients. This causes algal blooms, in which algae deplete the oxygen in lakes and cause fish to die. This process of nutrient enrichment and increased biomass is called eutrophication.

115. D: Genetic engineering is a general term to describe altering DNA sequences through adding or removing stretches of DNA from a native sequence. Generally, bacteria are used to carry and proliferate the engineered DNA.

Special Report: Retaking the Test: What Are Your Chances at Improving Your Score?

After going through the experience of taking a major test, many test takers feel that once is enough. The test usually comes during a period of transition in the test taker's life, and taking the test is only one of a series of important events. With so many distractions and conflicting recommendations, it may be difficult for a test taker to rationally determine whether or not he should retake the test after viewing his scores.

The importance of the test usually only adds to the burden of the retake decision. However, don't be swayed by emotion. There a few simple questions that you can ask yourself to guide you as you try to determine whether a retake would improve your score:

1. What went wrong? Why wasn't your score what you expected?

Can you point to a single factor or problem that you feel caused the low score? Were you sick on test day? Was there an emotional upheaval in your life that caused a distraction? Were you late for the test or not able to use the full time allotment? If you can point to any of these specific, individual problems, then a retake should definitely be considered.

2. Is there enough time to improve?

Many problems that may show up in your score report may take a lot of time for improvement. A deficiency in a particular math skill may require weeks or months of tutoring and studying to improve. If you have enough time to improve an identified weakness, then a retake should definitely be considered.

3. How will additional scores be used? Will a score average, highest score, or most recent score be used?

Different test scores may be handled completely differently. If you've taken the test multiple times, sometimes your highest score is used, sometimes your average score is computed and used, and sometimes your most recent score is used. Make sure you understand what method will be used to evaluate your scores, and use that to help you determine whether a retake should be considered.

4. Are my practice test scores significantly higher than my actual test score?

If you have taken a lot of practice tests and are consistently scoring at a much higher level than your actual test score, then you should consider a retake. However, if you've taken five practice tests and only one of your scores was higher than your actual test score, or if your practice test scores were only slightly higher than your actual test score, then it is unlikely that you will significantly increase your score.

5. Do I need perfect scores or will I be able to live with this score? Will this score still allow me to follow my dreams?

What kind of score is acceptable to you? Is your current score "good enough?" Do you have to have a certain score in order to pursue the future of your dreams? If you won't be happy with your current score, and there's no way that you could live with it, then you should consider a retake. However, don't get your hopes up. If you are looking for significant improvement, that may or may not be possible. But if you won't be happy otherwise, it is at least worth the effort.
Remember that there are other considerations. To achieve your dream, it is likely that your grades may also be taken into account. A great test score is usually not the only thing necessary to succeed. Make sure that you aren't overemphasizing the importance of a high test score.

Furthermore, a retake does not always result in a higher score. Some test takers will score lower on a retake, rather than higher. One study shows that one-fourth of test takers will achieve a significant improvement in test score, while one-sixth of test takers will actually show a decrease. While this shows that most test takers will improve, the majority will only improve their scores a little and a retake may not be worth the test taker's effort.

Finally, if a test is taken only once and is considered in the added context of good grades on the part of a test taker, the person reviewing the grades and scores may be tempted to assume that the test taker just had a bad day while taking the test, and may discount the low test score in favor of the high grades. But if the test is retaken and the scores are approximately the same, then the validity of the low scores are only confirmed. Therefore, a retake could actually hurt a test taker by definitely bracketing a test taker's score ability to a limited range.

Special Report: Additional Bonus Material

Due to our efforts to try to keep this book to a manageable length, we've created a link that will give you access to all of your additional bonus material.

Please visit http://www.mo-media.com/west/bonuses to access the information.