Page 19:

Add to Section 1.4.4:

Example 1.4.4 Animal Models for Drug Testing

Animal models are often used to test predictions of effects of drugs intended for human use. However, animals meant for this purpose have many disadvantages (Dove, 2010):

1. there are ethical and moralistic concerns about animal use and care.
2. animals often give poor predictions of human responses.
3. animals are expensive and inconvenient.
4. animal populations used for drug testing usually have uniform genotypic and phenotypic characteristics, and so do not display idiosyncratic reactions.

For these reasons, alternatives have been sought. Human cell cultures hold promise; they can be fast and inexpensive, but cultured human cells rarely act the same as identical cells in the body. Mathematical models of drug reactions are another possibility, but, until model results are validated by animal experiments, there is little confidence in model predictions. Indeed, validation of mathematical models could actually increase animal usage rather than decrease it.

Ref:

Dove, A., 2010, The Search for Animal Alternatives, *Drug Discovery and Development,* May: 10-13.

Add to index:

Page 23:

Example 1.6.4 Unintended Consequence of Roundup-Ready Crops

Glyphosate (commercially sold with the name “Roundup”) is a very popular herbicide because it kills both grasses and broadleaf weeds at any stage in their development. It works as a chelating agent that ties up minerals like iron, manganese, zinc, calcium, nickel, and copper. Some of these are essential for critical enzyme formation. Glyphosate kills plants by blocking the essential shikimic acid enzyme pathway required for plant respiration. It also interferes with enzymes necessary for disease resistance (Lehnert, 2010).

A plant gene conferring resistance to glyphosate had been inserted into popular genetically-engineered crops in the mid-1990s. This allowed these crops, called "Roundup Ready", to be grown with minimal herbicide use. One spray of glyphosate replaced four or five sprays of other, more environmentally-damaging herbicides. Glyphosate-resistant cotton and soybean crops became dominant due to their economic and management advantages. More than 143 million acres were planted to Roundup Ready crops worldwide, and 92 percent of the U.S. soybean crop was planted to glyphosate-resistant varieties in 2010 (Lancaster Farming, 2010).

Such reproductive pressure has rapidly led to the emergence of glyphosate-resistant weeds. There were no resistant weed species in 1995; there were 19 resistant species in 2010 (Lancaster Farming, 2010). Resistant weeds were a problem on 2.4 million acres of crops in 2007, 5.4 million acres in 2009, and 11.4 million acres in 2010.

The biological realm depends on redundancy for effectiveness. Scientists who developed Roundup Ready crops inserted just one gene into their plant genomes. The probability that effectiveness of one gene can be overcome is small, but finite. If there were two or three genes to overcome, the probability of developing resistance would be nearly zero. Biotechnologists, engineers, and scientists who wish to avoid the unintended consequence of making their creations widely ineffective need to depend on more than one mechanism to safeguard their works.

Add to Refs:

Lancaster Farming, 2010, Weed Expert: Roundup-Resistant Problem Must Be Dealt With, *Lancaster Farming*, 56(1): A50 (16 Oct).

Lehnert, R., 2010, Use Glyphosate with Caution, *Good Fruit Grower*, 61(14): 18-20 (Sept).

Add to index:

Page 58:

In Section 2.8.1, in the paragraph beginning “Within the cell, vesicles …”, Replace the last sentence of the paragraph with:

In the opposite process of *endocytosis*, the cell can incorporate material by surrounding it and forming a vesicle to either store or transport it to the interior of the cell. Endocytosis is important for lymphocytes to ingest invading microbes, and for other cells to transport materials too big to pass through membrane pores from the environment into the cell. Endocytosis is more likely to be developed in adherent cells than in suspended cells.

Add to Index:

Page 61:

Add to Section 2.8, this Example 2.8.5:

Example 2.8.5 Water Bears Need No Circulatory or Respiratory Systems

Water bears (also called *Tardigrades*) are extremely small aquatic animals found almost everywhere on Earth (Miller, 2011). Terrestrial water bears live in damp places in moss, lichens, leaf litter, and soil. They have amazing survival strategies, including *cryptobiosis*, or the ability to cease all metabolic activity in the absence of water. They are so small (Figure 2.8.5) that they contain only a little over 1000 cells, with enough access for water, oxygen, and nutrients that they lack circulatory or respiratory systems.

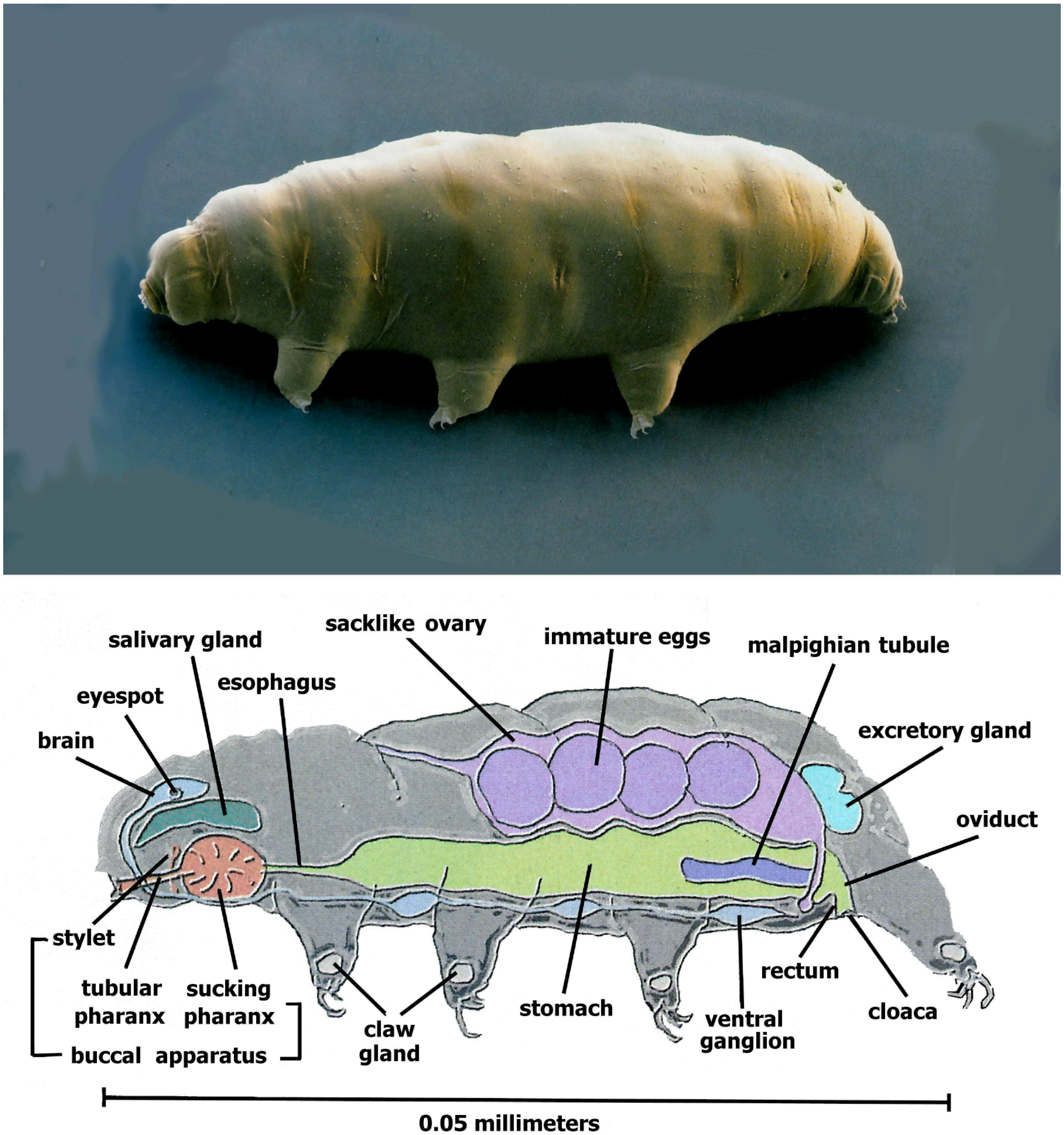


Figure 2.8.5 Water bears are microscopic animals with extreme survivability. They are small enough that they need no respiratory or circulatory systems.

Add to Refs:

Miller, W.R., 2011, Tardigrades, *Amer. Sci.* 99: 384-391.

Add to Index:

Figure source: Composite of parts of figure 5, pg 388 and figure 2, pg 386 of Miller (2011)

Page 69:

Add to Section 2.9.5, after the last paragraph:

Counteracting high internal pressures requires strong surrounding structures. Bacteria, fungi, plants, and some archea have tough, sometimes flexible outer cell walls that offer structural support, protection, and limited filtering. The cell wall prevents the cell from bursting when too much water enters the cell in a hypotonic (low solute concentration) environment. Different bacteria have generally two different kinds of cell walls that either stain or not with a standard blue dye. These are called gram-positive or gram-negative.

Add to the Index:

Page 81:

Add these sentences in Example 2.11.1, just after the sentence in the second paragraph beginning “Another means is electroporation, …”:

Once the pulse stops, the pores close.

Add after the sentence beginning “Large molecules such as DNA …”:

When the pores close, they are locked inside the cell.

Add as the last sentence, after the sentence beginning “Electroporation can also be used …”:

This approach is highly efficient, but can sometimes be deadly to the cell.

Page 81:

Add this example at the end of Section 2.11:

Example 2.11.2 Use of Electroporation to Increase DNA Vaccine Effectiveness (Morrow and Weiner, 2010).

Vaccines typically use an inactivated pathogen injected into a host to elicit an immune response. When subsequent exposure to a live pathogen happens, the immune system is primed to respond and fight the infection (see Section 6.20.3). New approaches to vaccine development use snippets of DNA called plasmids (see Section 5.3.11) instead of the entire pathogen. These plasmids enter the cells of the host, produce proteins identified as belonging to the pathogen, and elicit an immune response without any danger that could come from the entire pathogen. The host's own cells do the work of eliciting the immune response.

It is the protein produced from the plasmid that provokes the immune system, not the DNA plasmid itself. Thus, a critical step in the process is moving plasmids into enough of the host's cells so that the cells can begin producing the protein in large enough quantities.

DNA material does not easily translocate across the cell membrane. For this, a vector is needed. Vectors can include adenoviruses (common cold viruses) for humans or agrobacteria for plants. However, adenoviruses by themselves provoke an immune response that may not allow the plasmids to be incorporated into host cells.

Electroporation momentarily opens pores in the cell membranes to allow injected plasmids to translocate into host cells. This is thus a preferred method to move DNA past the cell membrane barrier.

DNA vaccines have been developed to treat or protect against human immunodeficiency viruses (for humans), West Nile virus (horses), infectious hematopoietic virus (salmon), melanoma (humans and dogs), fetal loss (pigs), hepatitis C (humans), human papillomavirus (humans), and liver cancer (humans).

Add to Refs:

Morrow, M. P., and D. B. Weiner, 2010, DNA Drugs Come of Age, *Sci. Amer.* 303(1): 49-53 (July).

Add to index:

Page 90:

Add to Section 3.1, after the sentence beginning "They do not take part …", this phrase and this sentence:

(although xenon has been found to form bonds with halogens, oxygen, carbon, and gold, under certain conditions). Looking at the periodic table, flammability decreases from left to right, and toxicity increases from top to bottom.

Add to index:

Page 91:

Add to Section 3.1, after the sentence beginning "Arsenic (33) is dangerous …":

Although toxic to almost all life, arsenic can apparently substitute for phosphorous without ill effect in a bacterium called GFAJ-1 (Wolfe-Simon et al, 2010). The arsenic was incorporated in the nucleic acids (as the DNA backbone), proteins, and cell membranes of healthy bacteria.

Add to Refs:

Wolfe-Simon, F., J.S. Blum, T.R. Kulp, G.W. Gordon, S.E. Hoeft, J. Pett-Ridge, J.F. Stolz, S.M. Webb, P.K. Weber, P.C.W. Davies, A.D. Anbar, and, R.S. Oremland, 2010, A Bacterium That Can Grow by Using Arsenic Instead of Phosphorous, http://www.sciencemag.org/content/early/2010/12/01/science.1197258, doi: 10.1126/science.1197258 (2 Dec).

Add to Index:

Page 93:

Add to the end of Section 3.1, this example:

Example 3.1.1 Phosphates in Detergents Cause Algal Bloom

Phosphorous as phosphate (phosphorous with the addition of four oxygen atoms) is an important constituent of many detergents. Cleaning agents remove dirt from dishes or clothes, and phosphorous binds to the dirt and keeps it suspended in water. The problem that results, however, is that phosphorous added to waste water acts as a fertilizer that stimulates algal growth. When the algae die, they decompose and absorb oxygen from the water, suffocating other forms of aquatic life.

Add to the Index:

Page 115:

Add this sentence to Section 3.6.3, third paragraph, after the sentence that begins “The amino functional group…”:

Protein contains approximately one part by weight of nitrogen for each 6.25 parts of protein (Lane, 2010).

Ref:

Lane, W., 2010, Efficient Nitrogen, *The Shepherd*, 55(5): 10-11 (May).

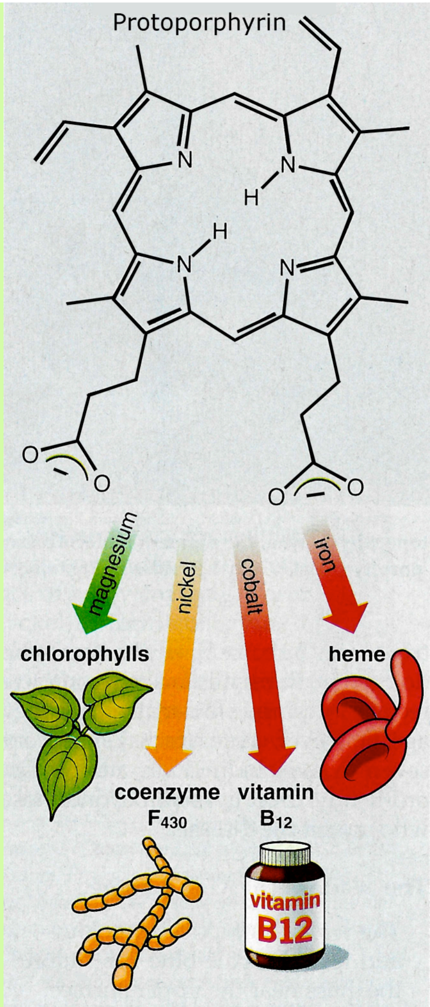
Add to index:

Page 115:

Add this box at the end of Section 3.6.2:

THE IMPORTANT PORPHYRIN RING
(REPRINTED FROM DAYAN AND DAYAN, 2011)

The porphyin pathway is ubiquitous in the biochemical realm, serving throughout the plant and animal kingdom as the assembly line for the most abundant pigments in nature. The ring-shaped porphyrin molecules bind an array of metal ions, with each combination associated with different biological functions. Porphyrin rings include chlorophylls that bind magnesium to play a pivotal role in photosynthesis. Heme binds iron to coordinate molecular oxygen and carbon-dioxide transport chains necessary for cellular respiration and contributes to the catalytic activities of many enzymes. Porphyrins bind nickel to form coenzyme F_{430}, which plays critically important roles in bacteria that metabolize methane. Vitamin B_{12} is formed from the binding of cobalt to a derivative of porphyrin; lack of the vitamin can result in pernicious anemia and impair the function of the brain and nervous system. Taken together, these porphyrin-derived pigments can be called the “colors of life”, in the sense that these rings are necessary to sustain key activities in nearly all organisms (Figure)



The porphyrin ring-shaped molecule can accept different metals to produce pigments essential to metabolism in various organisms. Heme and vitamin B_{12} are vital to animals, chlorophyll to plants, and coenzyme F_{430} to methane-processing bacteria.

Add to Refs:

Dayan, F. E., and E. A. Dayan, 2011, Porphyrins: One Ring in the Colors of Life, *Amer.Sci.* 99: 236-243.

Add to Index:

Figure source:
Figure 2, page 238, Dayan and Dayan, 2011.

Page 120:

Add Example 3.6.2 to the end of Section 3.6:

Example 3.6.2   C:N Ratio for Composting.

Composting is used to turn discarded or infected organic waste into a pathogen-free soil amendment. Composting is used to remediate pathogenic threats from animal carcasses as well as from infected plant matter. Composting uses mezophillic (medium warm temperature loving) and thermophillic (hot temperature loving) bacteria to metabolize organic matter, producing heat in the process. If the temperature rises high enough, pathogenic bacteria are killed and weed seeds are inactivated. The end product is a nitrogen and micronutrient rich fibrous material.

Nitrogen is required for the composting bacteria to form microbial tissue. Nitrogen and other essential nutrients are supplied by the organic matter to be composted. Carbon, however, must be added to supply energy for aerobic metabolism. Carbon may come from any number of sources: sawdust, straw, chopped newsprint, or other cellulosic material. Oxygen must also be available to achieve aerobic digestion. Anaerobic digestion, due to insufficient oxygen, results in an odorous product without killing pathogens.

The ideal ratio of carbon to nitrogen is in the range of 20 or 30 to 1. Table 3.6.3 gives a list of carbon to nitrogen ratios of common compost materials. It is apparent from this table that the required C:N ratio must be achieved with a mix of carbon-rich and nitrogen-rich sources.

Table 3.6.3.   Common Compost Materials (Payne and Pugh, 2010).

Compost Material	C:N
Sawdust	442:1
Straw-wheat	127:1
Rice hulls	121:1
Straw-general	80:1
Corn stalks	60-73:1
Finished compost	30-50:1
Hay-general	15-32:1
Horse manure-general	30:1
Cattle manure	19:1
Grass clippings	17:1
Sheep manure	16:1
Turkey litter	16:1
Broiler litter	14:1
Swine manure	14:1

Cottonseed meal	1-7:1
Soybean meal	4-6:1
Animal carcass	5:1

Add to Refs:

Payne, J. and B. Pugh, 2010, On-Farm Mortality Composting of Livestock Carcasses, *The Shepherd*, pp 26-29 (July).

Add to index:

Page 126:

Add to Section 3.7.2, to the figure caption of Figure 3.7.8, after the sentence beginning "This cross section through the cytoplasm …":

Macromolecules typically occupy 20 to 40 percent of cytoplasm volume (Clabby, 2011).

Add to Refs:

Clabby, C., 2011, Cracking Cellular Motion, *Amer. Sci.* 99: 28-29.

Page 130:

Add to Section 3.8, at the end of the paragraph beginning "This problem is the result …":

As might be expected, protein folding and other natural processes proceed more slowly in the crowded environment within the cell than they do in a test tube (Ebbinghaus et al., 2010). Also, proteins within the cell are constantly folding and unfolding, and may have many different, yet unstable, configurations (Perkel, 2011).

Add to refs:

Ebbinghaus, S., A. Dhar, J.D. McDonald, and M. Gruebele, 2010, Protein Folding Stability and Dynamics Imaged in Living Cell, *Nature Methods*, 7:319-323.

Perkel, J.M., 2011, The Ever Folding Protein Landscape, *Biotechniques* 51(4): 229-233 (Oct).

Add to index:

Page 133:

Delete the top paragraph on page 131 of Section 3.8, beginning "If the protein fails to fold properly …" and delete the last paragraph on page 133, beginning "There are many diseases …" . Insert these paragraphs at the end of Section 3.8:

If the protein fails to fold properly, its shape is incorrect and it cannot perform its intended function. Aberrations in protein folding appear to contribute to human and animal diseases. Among these are Alzheimer's disease, prion diseases, emphysema and cirrhosis, amyelotrophic lateral sclerosis (Lou Gehrig's disease), cystic fibrosis, some tumors, osteogenesis imperfecta (King et al., 2002), and transmissible spongiform encephalopathy (TSE). Unclustered prion molecules are harmless and found in all mammals. When bunched together, however, these same prions become infectious (Wilham et al, 2010).

Prions are misfolded proteins. When a protein converts to a prion, it polymerizes from coiled alpha helices that dominate normal protein structure into an aggregate of tightly packed beta sheets (Saltus, 2010A). The prion that is implicated in the cause of bovine TSE (mad cow disease), for instance, appears as a pleated sheet rather than a smooth helix. Prions have the unusual property that they can replicate without DNA or RNA (Saltus, 2010A). This gives the possibility that prions can act as an evolutionary route parallel to the genetic code for the organism. Whereas some prions have been identified as causing debilitating diseases, others in yeast, have been shown to change the pattern of gene expression in cells, at times enabling the cell to cope with radically different environmental pressures. The ability to self-replicate may also be important in the retention of memories through prion alteration of frequently-used neural synapses.

Treating these diseases at the protein level may be easier and more ethical than using gene therapy. The strategy would be to restore missing or nonfunctional proteins with pharmacological chaperone molecules inserted into the cells.

Add to Refs:

Saltus, R., 2010A, A Silver Lining, *HHMI Bulletin*, 23(2): 22-27.

Wilham, J. M., C. D. Orrú, R. A. Bessen, R. Atarashi, K. Sano, B. Race, K. D. Meade-White, L. M. Taubner, A. Timmes, and B. Caughey, 2010, Rapid End-Point Quantitation of Prion Seeding Activity with Sensitivity Comparable to Bioassays, *PLoS Pathog* 6(12): e1001217. doi:10.1371/journal.ppat.1001217

Add to index:

Page 138:

Add to Section 3.9, this box:

UNFOLDED, UNSTRUCTURED, AND MEANT TO BE THAT WAY

Most cellular proteins have a particular structure that they assume in order to serve their specific purpose. Enzymatic proteins are this way, and are ineffective if misfolded. Elaborate mechanisms inside cells detect misfolded proteins and either destroy or repair them.

However, about 35% of human proteins have long unstructured regions with no particular shape (Dunker and Kriwacki, 2011). Nearly all eukaryotic cells, but few, if any prokaryotes, depend upon these unstructured proteins for signaling and regulation functions. Enzymes must still form highly-regulated structures in order to be effective, but unstructured proteins are functionally flexible because they can wrap around many different types of molecules. When they wrap around enzymes, for instance, the enzymes are rendered ineffective. Hence, their functions are regulated by proteins that can assume any necessary shape. The ability to fold or unfold as the need arises presents many different possibilities.

Long, thin proteins can thread through small openings in the cell and carry other molecules with them. They can thus help regulate the availability of necessary chemicals, or help signal the cell of the chemical nature of the surrounding environment.

Not all proteins must have rigid structures to be effective; some work best if they can assume a multitude of shapes.

Add to refs:

Dunker, A.K., and R.H. Kriwacki, 2011, The Orderly Chaos of Proteins, *Sci. Amer.* 304(4): 68-73 (Apr).

Add to Index:

Page 193:

Add to Section 4.4.1, this sentence after the first sentence of the paragraph beginning "Surfaces of cell membranes …":

Each receptor is configured with a pocket into which a specific external molecule can fit.

Add to Section 4.4.1, this sentence at the end of the paragraph beginning "Surfaces of cells …":

Modern drug therapies are now targeting these receptors or the chemicals (often hormones) that bind to them in order to produce desired results (Amábile-Cuevas, 2010).

Add to Refs:

Amábile-Cuevas, C.F., 2010, Zeroing in On Cancer, *Amer. Sci.* 98:366-368.

Page 204:

Add to Section 4.4.3, to the box on Action Potentials, a phrase to make the last sentence on the page:

When the depolarization of the action potential reaches the synapse, a neurotransmitter is released by exocytosis into the small gap between the neurons.

Add to Index:

Page 213:

Add to Section 4.6, this box at the end:

Bodily Microbes As An Information Legacy

The mix of microbes on organismal body surfaces is different for each individual plant or animal. These microbes have personalized effects, ranging from disease cause or prevention, odor production, digestion of nonfood compounds, essential biochemical production, and proper development of the immune system. Some types of microbes are essential to all members of an organismal species. Examples are endophytes in certain grasses, nitrogen-fixing bacteria in legumes, cellulose-digesting microbes in termites and cud-chewing animals, and probiotics in humans and animals. These microbes are so important that behavioral mechanisms have evolved to assure the passage of specific microbes from one generation to the next. In certain animals, essential microbes are passed through fecal exposure; in mammals, probiotics are introduced through mammary gland secretions.

The effects of these transfers are so profound that offspring may not survive without them. Somatic microbes thus are often as important as the genome and cultural information (memes) as a means to pass information from one generation to the next. Realizing this, the biological engineer should be sure not to impede this process.

Page 223:

Add to the list of biological principles:

12. *There is usually an exception to any general biological rule as long as the general rule predominates.* Whether the rule concerns camouflage, defensive mechanisms, belonging to groups, sensations, biochemical mechanisms, or any other general tendency for biological units to follow, there is opportunity for nonconformists as long as they are few in number. Biological engineers can use these exceptions to form the basis for their designs to control living things, but the engineers must be certain not to upset the overall natural scheme, or their designs will fail. In eexamples involving interference of viral attachment to cell membrane ligands or using certain species to remediate environmental pollutants, selection pressure will tend to overcome design goals unless steps are taken to maintain biological balance. See Section 5.4.

Add to Index:

Page 225:

Add this example to the end of Section 5.1, before the Applications and Predictions:

Example 5.1.1 Species that Mimic Each Other

Mimicry, the situation where an unrelated species develops an appearance similar to another species, is sometimes an important strategy in biology. There are survival benefits to the mimicking species if the species being mimicked has some kind of defense against predators. This type of mimicry confers a selective advantage as long as the mimicking species remains scarcer than its model. Even defenseless species may mimic each other if it reduces the chance that any individual may be lost to predators (Vogel, 2010).

Add to Refs:

Vogel, S., 2010, The Deceptional Life, *Amer. Sci.* 98: 436-437.

Add to index:

Page 232:

Add this paragraph to the end of Section 5.3.1. Figure 5.3.3 must be added, and numbering for present Figure 5.3.3 through Figure 5.3.14 must be changed.

DNA is a very stiff molecule, with its double-helix structure and surface charges that repel other DNA surface charges (Babbit, 2011). Because of this, DNA does not curl up unaided into a tight ball inside the cell. Instead, DNA is wrapped spool-like around histone protein cores, called *nucleosomes*, that keep the DNA strands from straightening out into their full 2 m length (in human cells) and disrupting chromosome structure inside the five micron diameter cell nucleus (Figure 5.3.3). Nucleosome positions with respect to one another help to determine gene expression within the cell, or expose certain genes to epigenetic methylation. These positions appear to have evolved over time by natural selection pressures exerted by the environment.

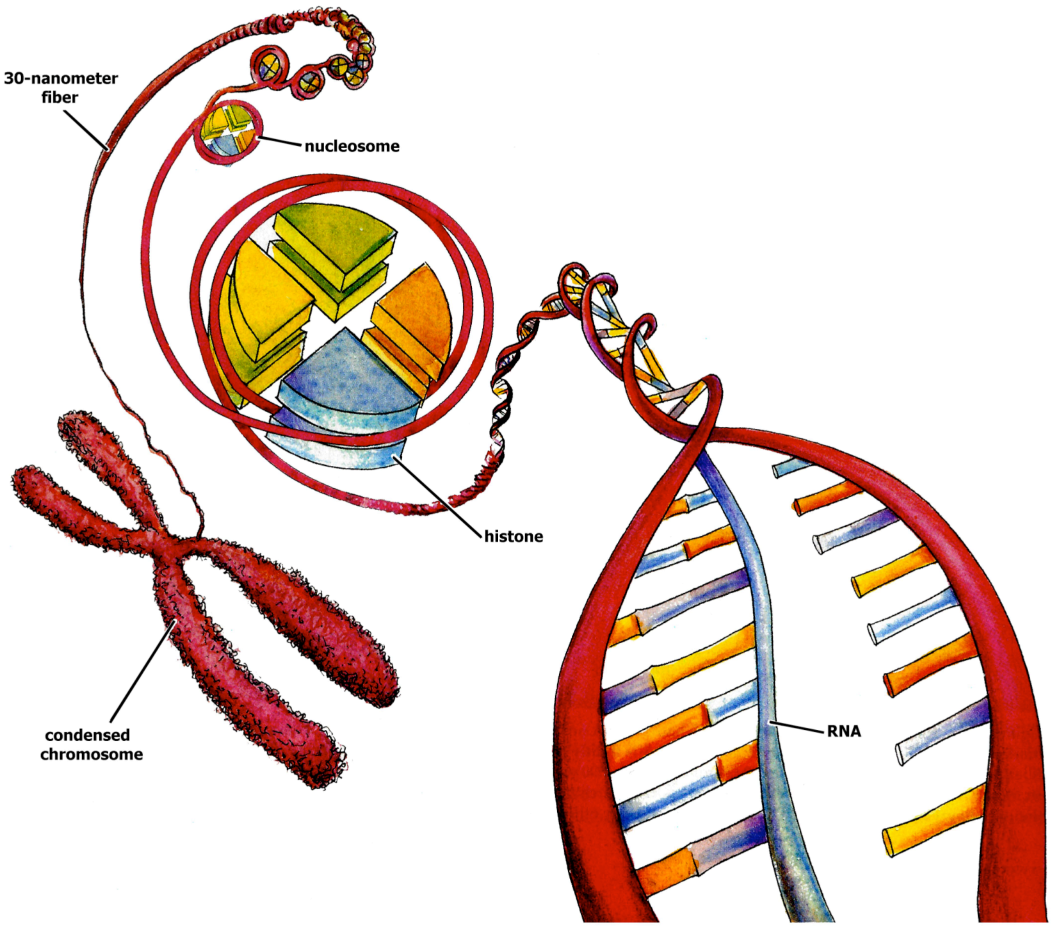


Figure 5.3.3 DNA is such a stiff molecule that it would not coil up enough by itself to fit inside the cell nucleus. Instead, it is wrapped around histone proteins to form nucleosomes that are serially located along the chromosome fibers 30 nanometers in diameter. The positions of different genetic materials (genes) in the nucleosomes probably influences genetic expression. Here, a single-stranded RNA molecule is also seen to be transcripted from one side of the DNA double helix (Babbit, 2011).

Add to Refs:

Babbit, G.A., 2011, Chromatin Evolving, *Amer. Sci.* 99: 48-55.

Use Figure 3, p 50 as Figure 5.3.3.

Add to Index:

Page 233:

Add to the end of Section 5.3.2, this last pargraph:

There are some transcribed strings of RNA that do not produce proteins; these are called noncoding RNA, or ncRNA (or, lincRNA for linear ncRNA). These appear to function by regulating gene expression. Some ncRNAs are important for the expression of Hox genes in human epithelial cells I(Gupta et al., 2010; Williams, 2011).

Add to Refs:

Williams, S.C.P., 2011, Skin Sense, *HHMI Bulletin* 24(1): 10-11 (Feb).

Gupta, R.A., N. Shah, K.C. Wang, J. Kim, H. M. Horlings, D. J. Wong, M.-C. Tsai, T. Hung, P. Argani, J.L. Rinn, Y. Wang, P. Brzoska, B. Kong, R. Li, R.B. West, M.J. van de Vijver, S. Sukumar, and H.Y. Chang, 2010, Long non-coding RNA HOTAIR reprograms chromatin state to promote cancer metastasis, *Nature* 464(7291): 957-1094 (15 Apr).

Add to Index:

Page 237:

Add to Table 5.3.1, Section 5.3.4, after the entry "Height":

	Genetic	**Environmental**
Human Personality		
Optimism	50%	50%
Resilience	50%	50%

Page 238:

Add the following paragraph to Section 5.3.4, immediately prior to the paragraph beginning "The Hoxc8 gene …":

The Hox genes are a set of genes present in nearly all animals from insects to humans, including worms, frogs, chickens, and mice. These genes regulate the animal's basic body configuration, organizing the arrangement from head to tail (Figure 5.3.8). The order of the Hox genes along the chromosome corresponds to the order of body segment development, starting from the head and ending at the tail (Willmore, 2010).

Use Figure 4, p 223 of Willmore, 2010.

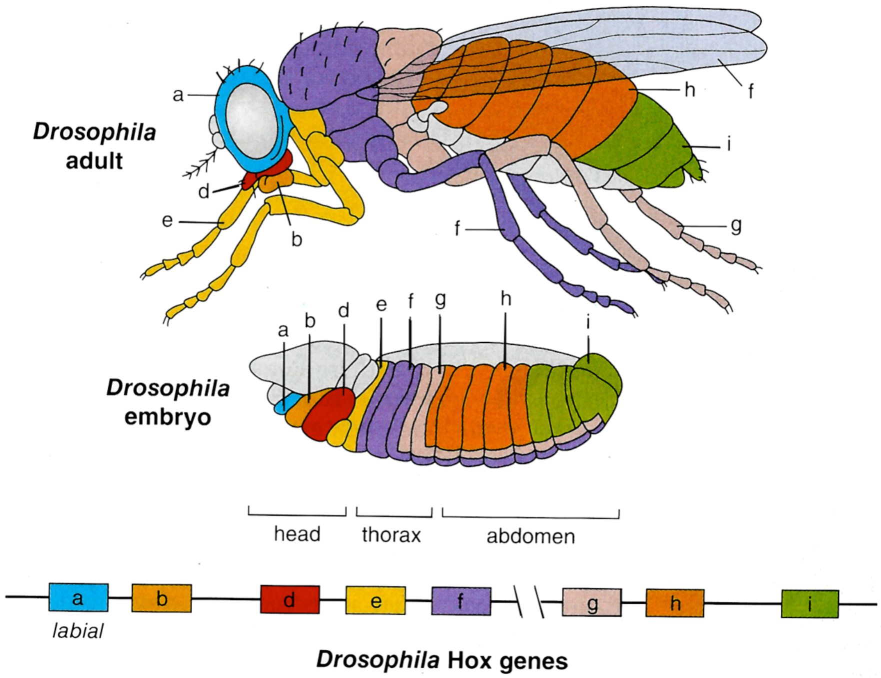


Figure 5.3.8. Hox genes in the fruit fly and the portions of the body that they help form. The first gene, known as *labial*, is necessary for the genes to be expressed. The order of the genes on the chromosome corresponds to the order of body part development (Willmore, 2010).

Add to refs:

Willmore, K.E., 2010, Development Influences Evolution, *Amer. Sci.*, 98: 220-227.

Add to index:

Hox genes	238
Fruit fly	238
Body structure	238
Body development	238

Also, change the numbers of subsequent figures 5.3.8 through 5.3.14 to be 5.3.9 through 5.3.15. Change figure references in the text.

Page 241:

Add these paragraphs to the end of Section 5.3.4:

The chemical switches and markers in the *epigenome* that affect how genes are expressed are important to direct each body cell into the type of cell it needs to become. These switches assure that the proper set of genes is expressed and that other, interfering genes present in precursor cells are not. The epigenome is vulnerable to disruption by environmental toxins, pollutants, and poor nutrition, thus leading to organic diseases such as various types of cancer.

It has also been found that methylation of the nucleic acid cytosine (the "C" in DNA base units) occurs chronologically in the human genome. Thus, epigenetic changes occur that are correlated with age of the individual (Bocklandt et al, 2011).

Add to refs:

Bocklandt, S., W. Lin, M. E. Sehl, F. J. Sánchez, J. S. Sinsheimer, S. Horvath, and E. Vilain, 2011, Epigenetic Predictor of Age, *PLoS ONE* 6(6): e14821, http://www.plosone.org/article/info:doi%2F10.1371%2Fjournal.pone.0014821

Add to Index:

Page 242:

Add to Section 5.3.5, as the last paragraph:

Bacteria subject to virus (bacteriophage) infections can acquire new DNA sequences identical to sequences in the infecting phages. They then become immune to further infection by the same phages through a mechanism similar to the iRNA mechanism in eukaryotic cells (Baker, 2011; Haurwitz et al, 2010).

Add to Refs:

Baker, M., 2011, When Worlds Collide, *HHMI Bulletin* 24(1): 8-9 (Feb).

Haurwitz, R.E., M. Jinek, B. Wiedenheft, K. Zhou, and J. A. Doudna, 2010, Sequence- and Structure-Specific RNA Processing by a CRISPR Endonuclease, *Science* 329 (5997): 1355-1358 (10 Sep).

Add to Index:

Page 245:

Insert in Section 5.3.8, in the second paragraph, third sentence, immediately following the words "There are enzymes …":

Insert these words: “(Figure 5.3.9)”

Insert a new Figure 5.3.9, and renumber Figures 5.3.9 through 5.3.14.

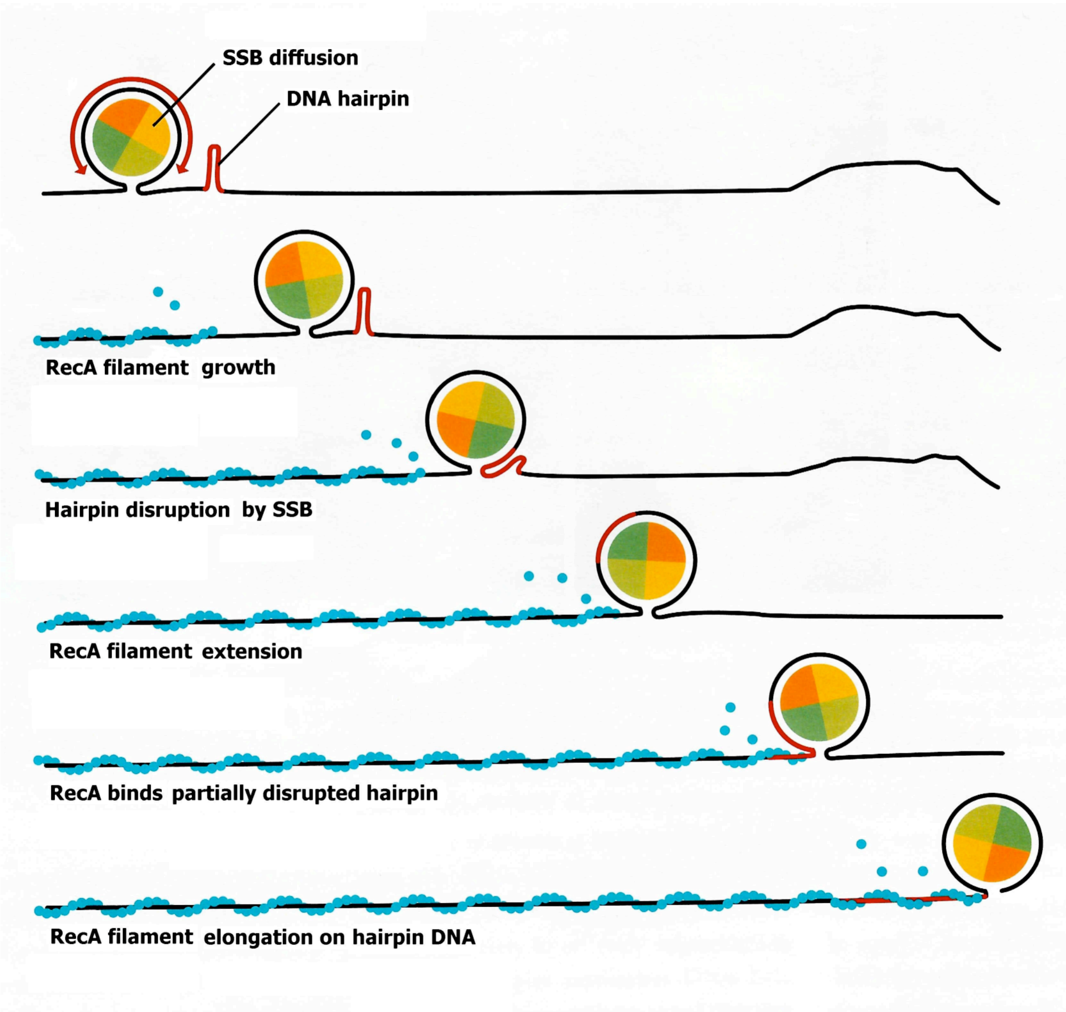


Figure 5.3.9. Part of the repair and maintenance operation for single-stranded DNA involves two proteins: single-stranded binding protein (SSB), and Rec A. Double helix DNA unwinds and separates into two single strands during replication. Immediately after separating, each single strand wraps itself around SSB proteins. SSB shuttles back and forth along the strand, fixing small defects known as hairpins. Rec A builds behind SSB and binds to the DNA strand. This action keeps SSB moving along the strand in the right direction and makes the SSB leave the DNA strand at the right time (Schnabel, 2010).

Add to Refs:

Schnabel, J., 2010, Nano-Motion Pictures, *HHMI Bulletin* 23(1): 45 (Feb).

Add to index:

Figure source:

Howard Hughes Medical Institute, HHMI Bulletin, v23(1) pg 45 (Feb 2010).

Page 256:

Add to the box "Selfish Genes" in Section 5.4 after the paragraph that begins "Perhaps the paradigm …":

Transposable segments of DNA are present in all organisms, and were found in maize (corn) many years ago. Transposable elements comprise about 85% of maize DNA and affect the color of corn kernels (Figure). The maize genome with ten chromosomes and 2.5 billion base pairs is almost as big as the human genome (ASABE, 2010).

Because of their activities, transposons have been called "genetic parasites". They do serve a useful purpose sometimes. In the fungal disease called powdery mildew, transposons disguise the pathogen by changing the genomic structure determining target molecules that identify it to the host plant (Spanu et al, 2010).

Figure caption: Transposons are responsible for the different colors of kernels in these corn ears.

Add to Refs:

ASABE, 2010, New High-Quality Maize Genome Sequence Will Advance Basic and Applied Research, *Resource*, 17(3): 24-25 (May/June).

Spanu, P.D., J. C. Abbott, J. Amselem, T. A. Burgis, D. M. Soanes, K. Stüber, E. V. L. van Themaat, J. K. M. Brown, S. A. Butcher, S. J. Gurr, M.-H. Lebrun, C. J. Ridout, P. Schulze-Lefert, N. J. Talbot, N. Ahmadinejad, C. Ametz, G. R. Barton, M. Benjdia, P. Bidzinski, L. V. Bindschedler, M. Both, M. T. Brewer, L. Cadle-Davidson, M. M. Cadle-Davidson, J. Collemare, R. Cramer, O. Frenkel, D. Godfrey, J. Harriman, C. Hoede, B. C. King, S. Klages, J. Kleemann, D. Knoll, P. S. Koti, J. Kreplak, F. J. López-Ruiz, X. Lu, T. Maekawa, S. Mahanil, C. Micali, M. G. Milgroom, G. Montana, S. Noir, R. J. O'Connell, S. Oberhaensli, F. Parlange, C. Pedersen, H. Quesneville, R. Reinhardt, M. Rott, S. Sacristán, S. M. Schmidt, M. Schön, P. Skamnioti, H. Sommer, A. Stephens, H. Takahara, H. Thordal-Christensen, M. Vigouroux, R. Weßling, T. Wicker, and R. Panstruga, 2010, Genome Expansion and Gene Loss in Powdery Mildew Fungi Reveal Tradeoffs in Extreme Parasitism, *Science*, 330 (6010): 1543-1546.

Add to index:

Page 256:

Add to Section 5.4, this box:

Hamilton's Rule

William D. Hamilton was a theoretical evolutionary biologist who, among other contributions, expounded on altruistic actions performed by individuals for others (Hamilton, 1964 A&B). Each of these actions is considered to have a cost in resources that could be used to support reproductive success. On the other hand, each action by a benefactor could enhance the resources available to the recipient to boost the recipient's chance of reproductive success. So, each action has a cost to some genes, and a benefit to other genes. Hamilton's Rule states that the altruistic action will be performed if the cost to the benefactor (C) is less than the fitness benefit to the recipient (B) times the probable degree of genetic relatedness (R) between the two:

$$B \bullet R > C$$

The probable degree of genetic relatedness is a number, less than or equal to 1.0, that expresses the probability that two individuals share the exact same genes. The closer the relationship between two individuals, the larger the degree of relatedness.

Table of Probable Degree of Genetic Relatedness

Relationship	R
Parent-offspring	½ (0.5)
Grandparent-grandchild	¼ (0.25)
Great grandparent-great grandchild	1/8 (0.125)
Identical twins	1.0
Full siblings	½ (0.5)
Half siblings – one parent the same out of two	¼ (0.25)
First cousins	1/8 (0.125)
Second cousins	1/32 (0.03125)
Full hymenopteran sisters – ants, termites, bees, wasps, etc.	¾ (0.75)
Full siblings, sex linked genes	¼ (0.25)

Hamilton's Rule has been identified as leading to the field of *sociobiology*, that posits a genetic basis for all actions among individuals (Dawkins, 1989). According to sociobiology, all genes are in competition with one another to reproduce to the maximum extent possible.

Add to Refs:

Hamilton, W.D., 1964A, The Genetical Evolution of Social Behaviour I, *J. Theor. Biol.* 7: 1-16.

Hamilton, W.D., 1964B, The Genetical Evolution of Social Behaviour II, *J. Theor. Biol.* 7: 17-52.

Dawkins, R., 1989, *The Selfish Gene*, 2nd ed., Oxford University Press, Cambridge.

Add to Index:

Page 259:

Example 5.4.2 Sanctuary Crops

Agricultural crops have been genetically modified (GM) to defeat common pests. One such crop is Bt corn, incorporating genes from a common soil microbe, *Bacillus thuriengensis*, that cause certain insect larvae to sicken and die after eating the plant. The target pests in this case are corn borer and corn root worm. Both of these can severely damage corn plants and greatly reduce yields.

Bt corn is very effective, virtually eliminating the insect threat. The danger, however, is that under the extreme selection pressure of the Bt gene, the pests will develop resistance to the gene. As long as all corn in any area carries the Bt gene, the only larvae to survive are those with Bt resistance. Biologically speaking, resistance development would be inevitable.

To prevent or at least delay resistance development, there must be a significant proportion of nonresistant insect available to breed with those that develop resistance. Any resistant insect genes will then be diluted in the hybrid offspring. This is the same way that defensive mechanisms (including the original Bt gene) remain effective in nature.

For this reason, farmers that plant Bt corn must also plant 5-10% of non-Bt corn. The non-Bt corn acts as a refuge for insects not subject to the same genetic pressure as are insects feeding on Bt corn. Even if the refuge crop is completely damaged by insect pests, 90-95% of the total crop will not be damaged, and there is some assurance that future crops will remain protected for many years to come.

This sanctuary strategy is important for biological engineers to know. It is an intelligent way to deal with inevitable resistance development, and should be applied in a wide variety of applications.

Add to Index:

Page 268:

Add to Section 5.5.3, after the paragraph beginning “A top-down approach …”:

Enough is now known about genetic expression that synthetic genes can be fabricated to produce a protein in a specific organism like *E. coli.* Algorithms have been developed to design synthetic genes to express target proteins optimally (May, 2010). These proteins can be used in pharmaceutical research.

Add to Refs:

May, M., 2010, The Synthetic Side of Protein Expression, *Drug Discovery and Development,* May: 14-15.

Add to index:

Page 269:

Insert in the box entitled “Human Ecology System”, in Section 5.5.4, in the first line after “100 trillion”, and before “cells”:

(10^{14})

Insert in the first line after “10 trillion (“ , and before “10%)”:

10^{13}, or

Page 278:

Add to the list of principles:

32. There is usually an exception to any general biological rule as long as the general rule predominates.

Page 278:

Add to the end of Section 5.6, this box and this example:

Box:

Naming of Genes

Discovering and describing a new gene confers with it the privilege of naming that gene. Some genes carry prosaic names related to their location in the genome, such as SDCCAG8 in humans (related to a kidney failure disease). Others, however, are named creatively and imaginatively by investigators. Thus, we have, in fruit flies, *couch potato* and *benchwarmer* (related to laziness), *tweek* (quivering), *Piwi* (small testes), *ken* and *barbie* (external genetalia), *kojak* (baldness), *cheapdate* (sensitive to alcohol), *VanGogh* (hair patterns), and *18wheeler* (stripes on larvae). There are others, such as *superman* (flowers with extra stamens), *tiggywinklehedgehog* (neural patterning in Zebra fish), *werewolf* (plants with hairy roots), and *tigger* (human transposon).

Add to Index:

Add to the end of Section 5.6:

Example 5.6.1 How Wolves Saved Yellowstone (Ward, 2010).

Wolves historically inhabited Yellowstone Park in the western US, but were exterminated in the early 1900's to protect livestock herds bordering the area. This set off an ecological chain of events that ended up drying streams, creeks, marshes, and springs.

Without wolves, native elk overpopulated Yellowstone. They chewed and overgrazed willow and aspen seedlings while they were still small. Without replacements, the population of these trees declined dramatically. Beavers, which normally ate these trees and used them for building dams and lodges, fell into decline. Without the beavers to build dams and ponds, wetlands disappeared, and so did the natural habitats for insects, amphibians, fish, birds, and plants. Water runoff that was no longer slowed and distributed by ponds, rushed down streams and was soon lost to the uplands.

Yellowstone's overgrazed river banks eroded and silted spawning beds for fish. Amphibians lost precious shade, and nearly disappeared. Birds that once thrived in the lushness of Yellowstone soon flew on by. The area dried up, and turned arid. Springs that had been recharged by pond water seeping into the ground no longer flowed, and drought became common.

Wolves were reintroduced into Yellowstone in 1995-1996, and immediately began to have a beneficial ecological effect. They killed fat elk, thinning the herd and improving the genetic quality of the survivors. Without so many elk, the trees regrew. With the trees came beavers and water to recharge springs and create habitats. Wolves had regulated the Yellowstone ecosystem from the top down, and restored ecological balance.

Add to Refs:

Ward, C., 2010, Saving Wolves Saved Yellowstone, *Baltimore Sun*, 1 Oct, p17.

Add to the index:

Yellowstone Park	278
Wolves	278
Ecological balance	278

Page 284:

Add to Section 6.0, this paragraph before the paragraph beginning "Generally, the same responses …"

There is a surprising similarity across all levels of biology. In many ways, an environmental wetland can act the same as the human kidney. Conditions for soil bacteria are very similar to conditions for bacteria in the human gut.

Page 295:

Add at the end of Section 6.3.2, this new paragraph:

Vitamin D can be produced in the skin when exposed to the ultraviolet rays of the sun. It was once thought that the only effect of a vitamin D deficiency was a childhood disease called rickets, where the bones grew weak and malformed. Lately, however, vitamin D has been found to be very important in the adult years (Park, 2010). It has been found that vitamin D dramatically reduces the risk of cancers by suppressing cell growth and blood vessel formation. Vitamin D controls the release of stress hormones that lead to high blood pressure and inflammation. Because of this, it can reduce incidence of heart disease. The vitamin has also been found to protect against autoimmune diseases, such as multiple sclerosis, lupus, and rheumatoid arthritis. It may also help to reduce depression by promoting the release of the mood enhancing hormone serotonin. Perhaps related, vitamin D helps to alleviate back pain.

Add to Refs:

Park, A., 2010, The Vitamin-D Debate, *Time*, 30 Aug, p66.

Add to Index:

Page 296:

Insert a new Section 6.3.3:

6.3.3 Microbes Assist Digestion

Simplicity is the ultimate sophistication.

- Leonardo DaVinci

Microbes (bacteria, protozoa, algae, and fungi) are extremely important to the nutrition of animals, insects, and plants. Microbes in the soil decompose complex organic matter into simpler forms that can be readily absorbed by plant roots. This is especially true for nitrogen and phosphorus compounds. Some microbes, called *mycorrhizal fungi*, are necessary to pine species and other conifers to form root structures that allow these species to absorb water and nutrients from the soil. Some soil microbes degrade harmful pesticide chemicals residing in the soil that might otherwise accumulate and kill or depress growth of plants growing in those soils.

Microbes living in the mammalian gut, called *microflora*, are important to supply certain nutrients that cannot be synthesized by the animal or human. They either extract these nutrients from undigested foods or aid in the digestion of otherwise indigestible compounds. Dietary fiber, lactose, and sugar alcohols are examples of non-starch polysaccharides that escape digestion in the upper part of the intestine. Microflora ferment these foods into short-chain fatty acids that are readily absorbed in the colon.

There are between 300 and 1000 different microfloral species in the human gut that collectively add over 1 kg to body mass. These microbes are first introduced to babies through breast milk and more can be added through ingestion of fermented milk (yogurt), and uncooked fruits and vegetables. One of the most beneficial microbe types belongs to the genus *Lactobacillus*, found in yogurt.

Taking antibiotics kills beneficial as well as disease organisms, and it is important to reestablish thriving microfloral colonies after discontinuing the drug. Other ingested substances that kill gut microbes are alcoholic beverages, chlorinated water, and food preservatives.

Herbivores with rumens are particularly dependent on microbes to digest cellulosic materials into sugars, fatty acids, and vitamins. Termites also rely on the same types of microbes for their nutritional requirements. Without these microbes, the animals or insects would die of starvation.

Bacteria and yeasts in honey bee saliva ferment the tough outer shell of pollen grains and partially digest them for bee food. Without these microbes, pollen would be indigestible; with them, pollen becomes the major protein source for honey bees.

Rename the present Section 6.3.3,

6.3.4 Synthetic Growth Media

Change the Table of Contents accordingly.

Add to the Index:

Page 296:

Add a box at the end of new Section 6.3.3:

The Really Big Dinosaurs Had Really Big Appetites

Dinosaurs lived on Earth between 65 and 230 million years ago (Lane, 2010). The sauropods were the largest class of these, and were much larger than any animal of our time. The most massive of these was the *Argentinosaurus,* longer than 100 feet and weighing 100 tons. The largest African elephant weighs only a tenth as much.

Argentosauruses were herbivores that ate leaves, ferns, and shrubs. They likely maintained in their digestive systems populations of fiber-fermenting microbes to help digest this plant material, similar to herbivorous animals of today. If they ate only 1-1.5%

of their body weights in a day, then they consumed 2000-3000 pounds of dry matter each day. Plant material was probably about 75% water, so these dinosaurs needed to consume more than 8000 pounds of leaves per day. They had to keep moving just to find enough forage to eat.

Fiber fermentation does not happen efficiently at low temperatures. In order for the fiber-digesting microbes to survive and perform as needed, they must be kept at 60˚ F or above. Thus, the dinosaur probably had some body temperature regulation mechanism uncharacteristic of cold-blooded animals of today.

Add to refs:

Lane, W., 2010, Dinosaur Dreams, *The Shepherd* 55(2): 18-19 (Feb).

Add to index:

Be sure to include the title of this box in the Table of Contents.

Page 305:

Insert these additional sections in Section 6.5, after section 6.5.4. Insert the examples after Example 6.5.1:

6.5.5 Too Hot

No amount of experimentation can ever prove me right; a single experiment can prove me wrong.

- Albert Einstein

Excessive temperatures can pose a threat to life. At high temperatures, critical enzymes become denatured and metabolism goes awry. Neural circuits misfire, causing seizures and loss of thermoregulation. Intercellular clefts open and allow microbes access to physical body interiors. Cognition, dexterity, and coordination suffer. Human decision-making becomes impaired; plants just bake.

Responses of living organisms to excessive temperatures include:

1) moving to cooler locations, if possible.

2) enhancing water evaporation.
3) increasing heat loss surface area.
4) making use of convective or conductive heat loss.
5) increasing surface temperature to increase heat loss.
6) shedding or adding surface insulation, depending on radiation exposure.
7) reducing metabolic heat production.

So, important physical parameters in the heat relate to air temperature, air humidity levels, and radiant energy. Each of these directly affects heat gain or loss.

There is a metabolic advantage to high body temperatures. Higher temperatures allow for faster chemical reactions, quicker responses, and higher signals-to-noise in sensors. Movement becomes sustainable. Honeybees, for instance, must tense their flight muscles on cold mornings to raise their temperatures and allow them to contract fast enough to sustain flight. If they did not perform this pre-flight ritual, they would fall from the air and die.

The disadvantage of high body temperature is the proximity to the lethal temperature limit. Thus, it is imperative that living organisms be able to confine body temperature increases to the safe range.

The issue of human activity in the heat is so critical that indices have been developed to estimate the ability for people to continue work during hot exposure (Moran and Pandolf, 19990. Some of these are calculated from physical measurements only (temperatures, humidity, wind speed, and radiation), and some use physiological data also (heart rate and rectal temperatures). When these heat stress indices reach threshold values, the exact value depending on the index used, employers are legally obligated to ameliorate the stress, either by stopping or modifying work schedules or by providing cooling strategies.

6.5.6 Too Cold

Simplicity is the ultimate sophistication.

-Leonardo DaVinci

Cold temperatures can pose a threat if they are very low and convective heat loss is very high. Under these conditions, flesh can freeze. If this is a continuing problem, then the organism has likely developed strategies to lessen the threat. Deciduous plants, for instance, lose their leaves and greatly decrease their water dependences. Some arctic poikilotherms circulate glycoproteins throughout their bodies to act as natural antifreeze. Other homeotherms develop thick insulating furs or feather coats. For humans able to move freely and dress warmly, cold temperatures are mostly of interest from a comfort standpoint.

Weather bureaus in various countries have empirically developed correlations of physical weather factors with comfort, and often report these as wind-chill temperatures. The wind-chill temperature is influenced largely by convective heat loss caused by air moving across bare skin. The wind-chill temperature is supposed to be the temperature equivalent to that with the sensation of bare skin under minimal wind speed (usually taken to be 1.8 m/sec) conditions.

Example 6.5.2 Heat Stress in Cattle

Cattle, too, are susceptible to heat stress (Figure 6.5.2). This stress can be accompanied by diminished appetite, reduced growth rate, compromised disease resistance, or death (McGinnis, 2010). People who raise cattle want none of these.

Cattle, like humans, use sweating to remove heat. Some animals are more able to control body temperature in this way, and some are not. In order to identify individual animals that may require targeted management of their thermal environment, agricultural engineers developed index values that evaluate animals susceptible to heat stress (Brown-Brandl, 2008).

The index they came up with relates to respiration rate of cattle in the heat (above 80˚F):

Breathing rate index = 2.83×air temperature (˚F) + 0.58×relative humidity (fractional) + 0.76×wind speed (mi/hr) + 0.039×solar radiation (Watts/m^2) - 196.4

If no solar radiation data are available, use 1000 W/m^2.

A score < 90	cattle are fine
90 – 110	cattle are on alert
110 – 130	cattle in danger
> 130	emergency

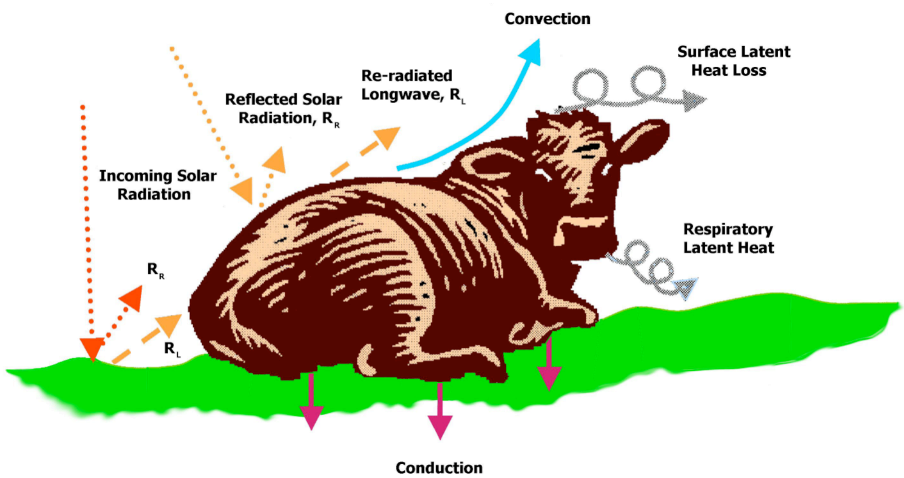


Figure 6.5.2. Heat transfer modes for a bovine outside without shade (Brown-Brandl, 2008).

Example 6.5.3 Wind Chill Temperature

The U.S. National Weather Service provides wind-chill equivalent temperatures as charts of equivalent temperature with ambient temperature and wind speed. Values in these charts are based on the formula:

$$T_{wind\ chill} = 35.74 - 0.6215\ T_{ambient} - 35.75\ \text{wind speed}^{0.16} + 0.4275\ (T_{ambient})(\text{wind speed})^{0.16}$$

Temperatures are in ˚F and wind speeds are in mi/hr. This equation is limited to temperatures at or below 50 ˚F and wind speeds above 3.0 mi/hr.

Add to refs:

Moran, D.S., and K.B. Pandolf, 1999, *Physiological Strain Index (PSI) to Evaluate Heat Stress*, Technical Report T99-XX, US Army Research Institute of Environemntal Medicine, Natick, MA 01760-5007.

McGinnis, L., 2010, Helping Cattle Keep Their Cool, *Agr. Res.* 58(3): 20-21 (Mar).

Brown-Brandl, T.M., 2008, Heat stress in Feedlot Cattle, *CAB Reviews: perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources* 3 (016); doi 10.1079/PAVSNNR20083016.

Add to Index:

Figure source:
Figure 1, p2, Brown-Brandl (2008).

Be sure add these sections to the Table of Contents.

Page 313:

Add to Section 6.6, this example:

Example 6.6.5 Genetic Expression of Fruit Fly Larvae Hairs

The tiny hairs that exist on the surface of newly-hatched fruit fly larvae are called *trichomes.* The pattern of trichomes is governed by a gene called *shavenbaby*, which is influenced by at least six other enhancer DNA sections, some of which are far removed from the shavenbaby gene. Mutations in these enhancers can produce different trichome patterns in different species (McGregor et al, 2010; Michalowski, 2010).

These different patterns do not show up when fruit flies are reared in the laboratory with comfortable temperatures. The only time larvae have been found to have different trichome patterns is when the flies are raised in more natural temperature conditions of hot days and cold nights. Environmental conditions can have a direct bearing on genetic expression.

Add to refs:

McGregor, A.P., V. Orgogozo, I. Delon, J. Zanet, D.G. Srinivasan, F. Payre, and D. L. Stern, 2010, Morphological Evolution Through Multiple cis-Regulatory Mutations at a Single Gene, *Nature* 448: 587-590.

Michalowski, J., 2010, Reality Check, *HHMI Bulletin* 23(4): 10-11 (Nov).

Add to Index:

Page 313:

Add to the end of Section 6.6, this example:

Example 6.6.6 All Clones Are Not Alike

Poplar trees readily reproduce asexually, and each new tree produced this way is a clone of its progenitor. However, it has been found that poplar trees raised for many years in different regions of Canada with diverse environments respond differently to environmental stresses. This is despite harboring the same genes as all the other trees.

The reason for this divergence is epigenetic changes in their genomes, and these changes accumulate with time. The longer the trees had lived apart, the more divergent were the methyl groups attached to their genes (Raj et al, 2011). Divergent epigenetic changes have also been observed in aging human identical twins living apart.

Add to refs:

Raj, S., K. Bräutigam, E. T. Hamanishi, O. Wilkins, B. R. Thomas, W. Schroeder, S. D. Mansfield, A. L. Plant, and M. M. Campbell , 2011, Clone History Shapes *Populus* Drought Responses, *Proc. Nat. Acad. Sci. USA,* 108(30): 12521-12526 (11 July).

Add to Index:

Page 320:

Add to Section 6.9:

Example 6.9.2 Slithering Snakes.

Snakes and some lizards move with body undulations that depend on friction between their bodies and surfaces underneath. As the snake wiggles, it produces reaction forces both normal and axial to its body segments (Figure 6.9.1). The sum of the forward normal forces must exceed the backward axial forces in order to propel the snake forward.

On their undersides, snakes have overlapping scales that snag on the ground more in the backwards direction than in the forward direction (*frictional anisotropy*). Measurements made of friction coefficients of a milk snake on a cloth surface were 0.10 in the forward direction, 0.14 in the backward direction, and 0.20 in the sideways direction (Goldman and Hu, 2010). This helps snakes turn body undulations into forward motion.

To reduce friction even further, snakes raise parts of their bodies off the ground when moving. This dynamic load balancing can increase speed by 35% and efficiency by 50%. Snakes slithering on land use a similar amount of energy as a legged organism of the same weight.

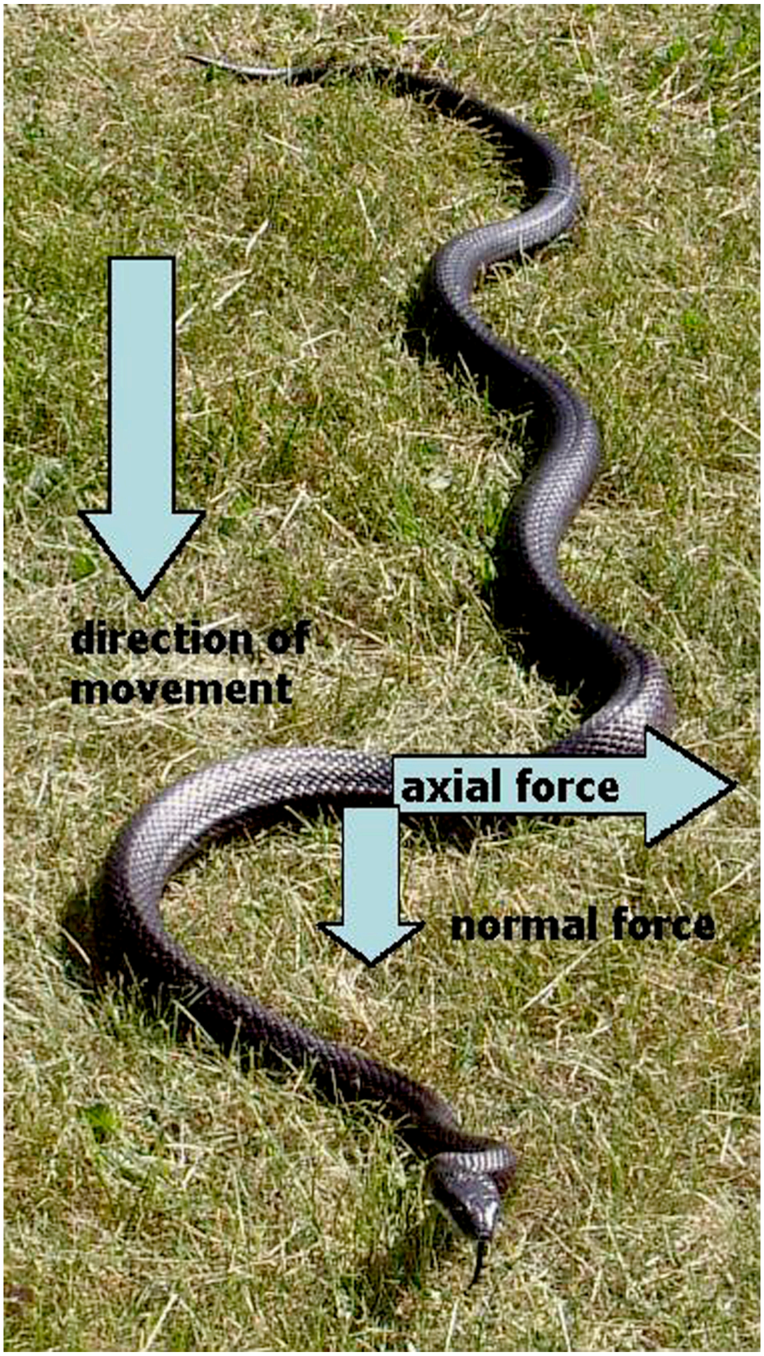


Figure 6.9.1. As the snake slithers, its forward reaction forces normal to its body propels it forward; axial reaction forces hold it back.

Ref

Goldman, D.I., and D.L. Hu, 2010, Wiggling Through the World, *Amer. Sci.* 98:314-323.

Add to index:

Page 321:

Add to Section 6.10, at the end of the paragraph that begins "Various environmental conditions …":

Barriers that isolate a population and lead to a new species formation (Shermer, 2010) are geographic (such as a mountain range, desert, ocean, or river), morphological (changes in coloration, body type, or reproductive organs), or behavioral (a change in breeding season, mating calls, or courtship actions).

It was shown previously that adaptations require extra energy and resources that could otherwise be used for growth and reproduction, thus reducing growth and reproduction. Adaptation, as a term used in this book, is meant to mean a nonpermanent, non-genetic, change in a BU. Before the discovery of epigenetic gene silencing, it was easy to distinguish between adaptation and evolution. The latter involved a change in the genetic code whereas the former did not. However, epigenetic changes can persist for many generations without a fundamental genetic change. Therefore, the feature most distinguishing between adaptation and evolution must then be that adaptation reduces growth and reproduction, whereas evolution leads to BU more successful at growth and reproduction.

Add to Refs:

Shermer, M., 2010, Our Neandertal Brethren, *Sci. Amer.* 303(2): 34 (Aug).

Page 324:

Add to Section 6.10:

Example 6.10.2 Microbes Respond to Environmental Pressures

An alternative to recombinant DNA methods with microorganisms (see Section 8.2) is growth under selective environmental pressure. Microbes have very short generation times and high populations in small spaces. If it is desired to produce a microbe with particular characteristics, that microbe may result from growth in an environment that selects for those particular capabilities. This is especially true if the genes giving those capabilities are already present, but some enhancement is needed. This technique has been used to produce algae capable of increased production of biofuels and to produce microbes to remediate certain environmental pollutants.

Add to index:

Page 338:

Add as a box to Section 6.12.7 just before the box entitled "Mysterious Foal Deaths in Kentucky":

The First Biological Therapy

The first biologically-based drug therapy was very expensive when first used around 1940. When used clinically, the drug was transported in armored trucks with police escort. The drug was even recovered from the urine of patients to whom it had been administered because that procedure was less expensive than manufacturing it anew. The name of that drug is penicillin, which is now cheaper than the glass vials in which it is sold (Amábile-Cuevas, 2010).

Add to the Refs:

Amábile-Cuevas, C.F., 2010, Zeroing in On Cancer, *Amer. Sci.* 98:366-368.

Add to index:

Page 346:

Add to Section 6.13.4, after the paragraph beginning "Also, the ability …":

Somatic and stem cells grown outside the body prefer three-dimensional matrix and basement membrane growing environments to two-dimensional flat plates or Petri dishes (Saltus, 2010B). Cells nurtured in 3-D environments experience more normal physiological, biochemical, metabolic, and physical conditions, and, in turn, function more like the types of cells they began as. The microenvironment of the cell plays a large role in directing its growth and shaping its behavior.

Add to Refs:

Saltus, R., 2010B, Into the Third Dimension, *HHMI Bulletin*, 23(3):24-27.

Add to index:

Page 346:

Insert a new section at the end of Section 6.13.4 and before Example 6.13.1:

6.13.5 Whole Plant Responses

If anything, living systems consistently violate all of the criteria for reducibility. The number of elements that compose any living system – an ecosystem, an organism, an organ, or a cell – is enormous. In living systems, the specific identities of these parts matter. Unlike chemistry, for instance, in which an electron in a lithium atom is identical to an electron in a gold atom, all proteins in a cell are not equivalent or interchangeable. Each protein is the result of its own evolutionary trajectory. We understand and exploit their similarities, but their differences matter just as much. Perhaps most importantly, the relations between the components of living systems are complex, context-dependent, and weak.

- Robert L. Dorit

Physical stresses impose limits or otherwise affect cellular responses, as was presented in the previous sections. When cells join to form multicellular organisms, the possible range of physical effects increases greatly. Not only can individual cells respond to mechanical stresses, but the integrity of the whole organism can be compromised when intercellular connections become stressed beyond limits.

Plants, for instance, can be challenged by high winds, hail, or herbivore grazing. Plants that are habitually eaten sometimes develop tougher tissues that are less palatable than rapidly-growing stems and leaves. This is in addition to the chemical responses discussed elsewhere in this text.

When mechanical stresses exceed strength limits, limbs may break or the plant may snap off at ground level. These stresses may take the form of bending, tension, compression, shear, or torsion. Mature wood has maximum stress levels in the range of 5000-1000 pounds per square inch (psi). Green (immature) wood may tolerate a greater degree of bending than can mature wood, but is more likely to tear off (weaker in tension and bending). Plants constantly challenged by mechanical stresses that do not exceed physical limits often develop extra tissue to help cope with chronic mechanical stress. Although this extra tissue does not significantly alter the ultimate strength stress that can be tolerated, it does add bulk that when multiplied by stress results in larger forces that can be resisted:

$$\text{Stress} \times \text{area} = \text{force} \qquad (6.13.1)$$

This is analogous to the myocardial hypertrophy that develops in a human heart resisting high blood pressure.

Wood is a composite material made from linear polymer cellulose fibers embedded in a *hemicellulose* matrix. *Lignin* acts as a glue to hold the fibers together. The *grain* of the wood is the direction parallel to the cellulose fibers. Wood is stronger in this direction than in any other.

Some trees grow more slowly than others, and these produce wood that is denser than faster-growing species. More dense wood translates into stronger wood. Dried wood is also stronger than green wood. The values in Table 6.13.1 are for dried wood. These values should be degraded by at least 50% for wood still part of a tree.

Table 6.13.1. Strengths of Some Wood Species

Wood Species	Specific Gravity	Compressive Strength (psi)	Bending Strength (psi)
Ash	0.60	7,410	15,000
Aspen	0.38	4,250	8,400
Basswood	0.37	4,730	8,700
Beech	0.64	7,300	14,900
Birch, Yellow	0.62	8,170	16,600
Butternut	0.38	5,110	8,100
Cedar, Aromatic Red	0.47	6,020	8,800
Cedar, Western Red	0.32	4,560	7,500
Cherry	0.50	7,110	12,300
Chestnut	0.43	5,320	8,600
Cypress	0.46	6,360	10,600
Elm	0.50	5,520	11,800
Fir, Douglas	0.49	7,230	12,400
Hemlock	0.45	7,200	11,300
Hickory	0.72	9,210	20,200
Lauan	0.40	7,360	12,700
Mahogany, African	0.42	6,460	10,700
Maple, Hard	0.63	7,830	15,800
Maple, Soft	0.54	6,540	13,400
Oak, Red	0.63	6,760	14,300
Oak, White	0.68	7,440	15,200
Pine, White	0.35	4,800	8,600
Pine, Yellow	0.59	8,470	14,500
Poplar	0.42	5,540	10,100
Redwood	0.35	5,220	7,900
Sassafras	0.46	4,760	9,000
Spruce, Sitka	0.40	5,610	10,200
Sycamore	0.49	5,380	10,000
Teak	0.55	8,410	14,600
Walnut	0.55	7,580	14,600

6.13.6 Bodies in Motion

There are no things man was not meant to know.
Michael Kurland

As long as human beings are using only their own bodily capabilities to move or perform work, then they most likely easily remain within tolerable limits of strength, comfort, and tissue failure. However, when they use modern tools, devices, or modern transportation modes, humans can experience discomfort, injury, or even death when physical limits are exceeded.

Dealing with a sentient being goes beyond the mechanical limits of physical failure discussed in the previous section on plants. There are also issues of comfort, psychological damage, and chronic health effects to consider.

Rapid accelerations and decelerations of the human body can cause many problems. The maximum deceleration ever recorded for a human was 46 times the acceleration due to gravity (9.8 m^2/sec), also called 46 g's (Ward, 2011). At this rate of deceleration, the human body was distorted, with some organs shifting position. The eyes, for instance, displace from their eye sockets. Some representative accelerations for different events appear in Table 6.13.2.

Table 6.13.2 Acceleration and the Human Body

Acceleration (g's)	Event
2.9	Sneezing
3	Space Shuttle flight
3.5	Coughing
3.6	Crowd jostle
3-4	Roller coaster, maximum
4.1	Slap on back
4-6	Induces blackout in fighter planes
8	Fighter pilot, brief maximum
8.1	Hopping off a step
10.1	Plopping down in a chair
30-35	Car crash, wearing a seat belt

60	Chest acceleration limit during car crash at 48 km/h with airbag
70 – 100	Crash that killed Diana, Princess of Wales, 1997
150 – 200	Head acceleration limit during bicycle crash with helmet

Rapid accelerations cause large forces, and these can be enough to cause breakage. Without tissue cushioning and elastic energy storage in the muscles and tendons, a jump of less than ½ meter would be enough to break a femur (Johnson, 2007). Over time, such forces would result in extra strength added to the bone.

The maximum tolerable acceleration depends both on the direction of the force and the type of restraint used. A seat belt or shoulder harness helps to protect against horizontal accelerations, for instance. Forward thrust horizontal accelerations are tolerated better than reverse-thrust acceleration. Both the brain and the eyes may be damaged with horizontal forces. Accelerations of 70-100 g's during car crashes can tear the pulmonary artery from the heart.

Vertically-upward acceleration drives the blood down to the feet. This deprives the eyes and the brain of needed oxygenation. Loss of consciousness or even death can result. The remedy for fighter pilots, who commonly up to experience 4-6 g's, is a "g-suit" that applies external pressure to the legs to push blood back up again. Vertically-downward acceleration does just the opposite, forcing blood to the eyes and the retina, causing a "red-out" of vision.

It is important to maintain comfort for humans. Commercial standards in the U.S. limit acceleration to 1.5 g and deceleration to 1 g (Ward, 2011). These are applied to various modes of transportation. Commercial airplanes can accelerate passengers by no more than 16 g's, and banking angles on turns can be no more than 30˚. Horizontal movement can be very uncomfortable also. These motions are tolerated better in the prone position than in the seated position.

The natural frequency of the human viscera is about 6-8 cycles per second. Vibration in that range can be extremely uncomfortable and must be avoided. Rocking back and forth, as riding on an animal, is more tolerable at higher frequencies (a horse) than at lower frequencies (a camel). This rocking can produce a condition called *motion sickness*.

Chain saw vibrations of 30 g's or more have been recorded on the hands and arms (Cundiff and Suggs, 1976), and these exceed international standards for tolerable vibration (Bingham et al, 1992). Other hand-held devices can also vibrate beyond tolerances. One common consequence of excessive hand vibration is constriction of the peripheral arteries shutting off the blood supply to the hands and fingers. This occupational condition, called *Raynaud's Syndrome*, can become permanent and result in loss of feeling, dexterity, and, in extreme cases, entire hand function.

Add this box at the end:

WOODPECKERS DO NOT SUFFER CONCUSSIONS

One interesting example of accommodation to mechanical shock is the woodpecker. This bird pounds into wood to find insects hidden underneath the surface. Although their heads decelerate at 1200 times the acceleration due to gravity, their shock-absorbing structures consisting of elastic beaks, musculotendinous attachments of the tongue and throat muscles (called *hyoids*), skulls with a minimum of cerebrospinal fluid, and partially spongy skulls that attenuate rapid accelerations protect their brains from injury (Yoon and Park, 2011). Brain injury is caused by a combination of acceleration and duration resulting in internal shear and excessive tensile forces. Studying the woodpecker can potentially benefit humans who suffer concussions, most notably from violent sports participation.

Add this example at the end of Section 6.13.1, after Example 6.13.1:

Example 6.13.2 Wind Load on a Small Poplar Tree.

Assume a small poplar tree as diagrammed in Figure 6.13.4. The wind blows against the tree at 30 miles per hour. Will the tree trunk break?

Solution: Determining the answer to this problem requires knowledge of statics and strength of materials. Wind load (F) in pounds can be calculated from:

$$F = A \times P \times C_d$$

Where A is the area presented to the wind in ft^2
P is the wind pressure in lb/ft^2
C_d is the drag coefficient, unitless

$$P = 0.00256\, v^2$$

Where v = wind speed in mi/hr

$$P = 00256\,(30)^2 = 2.304\ lb/ft^2$$

Assuming the tree top is spherical in shape, and relatively non-porous (opaque) to the wind,

$$A = \pi\, d^2/4 = 7.069\ ft^2$$

For a brisk wind, $C_d \approx 0.4$ for a spherical shape (Johnson, 1991). So,

$$F = 7.069\ ft^2 \times 2.304\ lb/ft^2 \times 0.4 = 6.51\ lb$$

The wind force can be considered to act at the center of the tree top. Thus, the moment (M) it causes at ground level is:

$$M = F \times L = 6.51 \text{ lb} \times (4 \text{ ft} + 1.5 \text{ ft}) = 35.8 \text{ ft}\bullet\text{lb}$$

From strengths of materials, the maximum bending stress on the trunk at ground level is:

$$\sigma_{max} = M \times c / I$$

Where σ_{max} is the maximum bending stress in lb/ft^2
M is the moment produced by a force acting over a distance in ft•lb
c is the maximum distance from the axis of rotation in ft
I is the moment of inertia of the circular cross-section in ft^4

For the circular cross-section of the trunk (Eshbach and Souders, 1975),

$$I = \pi\, d^4/64 = \pi \times (3 \text{ in}/ [12 \text{ in/ft}])^4 / 64 = 1.917 \times 10^{-4} \text{ ft}^4$$

Thus,

$$\sigma_{max} = 35.8 \text{ ft}\bullet\text{lb} \times (1.5 \text{ in}/[12 \text{ in/ft}]) / 1.917 \times 10^{-4} \text{ ft}^4 = 23{,}360 \text{ lb/ft}^2$$

From Table 6.13.1, The maximum bending stress for poplar wood is 10,100 lb/in^2, or 1,454,400 lb/ft^2. This is over 60 times higher than the wind-induced maximum bending stress. Hence, even the green wood of the tree trunk should be able to withstand the 30 mi/hr wind without breaking.

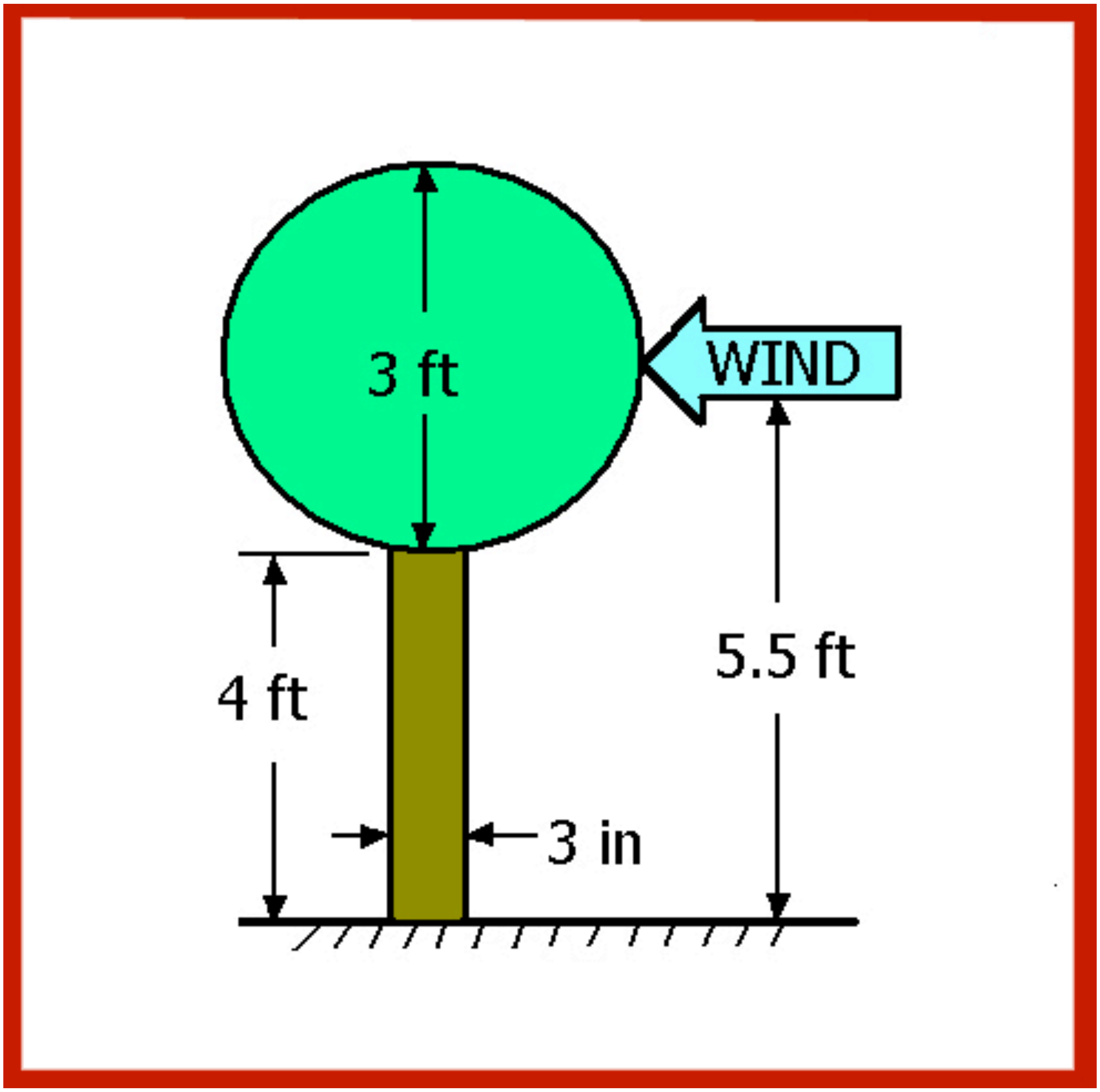


Figure 6.13.4 Simplified diagram of the poplar tree in Example 6.3.2.

Example 6.13.3 Entertainment Engineering for Fun and Excitement

Entertainment of visitors to highly technical shows and theme parks combines engineering with thrill solicitation. Shows such as the Cirque du Soleil bring extreme human gymnastic and artistic expression together with mechanical technology. The result is awe-inspiring.

Theme parks combine technology with interesting settings to elicit excitement from ride participants. These must convey a sense of danger without being dangerous.

There is a good deal of biomechanical engineering in entertainment engineering. Capabilities of humans to be accelerated, thrown about, and psychologically-challenged must be known and limits strictly observed. Yet, within these limits, a great deal of latitude results in unique experiences for participants. Entertainment engineering academic programs have been established to instruct students in the specialized knowledge applicable to the entertainment industry (Creighton, 2005).

Example 6.13.4 Enhancing Safety and Performance with Sports Engineering

Combining mechanical engineering, materials science, and applied physiology, sports engineering applies modern technology to sports equipment and sports measurements. Women tennis players, for instance, are four times more likely to injure their ankles than men (Grose, 2004). Realizing this, sports engineers can design better shoes for women tennis players; such shoes would differ from men's.

Sports engineers can also tackle designs of tennis racquets, golf clubs, rowing oars, and baseball bats. Of special importance is protective gear to minimize injury while skiing, playing baseball, football, or hockey, or even riding a bicycle. Sports engineers need to know the limits to human strengths and endurance. Along with knowledge of materials and mechanical design, they can make sports participation safer and more rewarding.

Add to the Index:

Add these two sections to the Table of Contents.

Add to Refs:

Cundiff, J.S., and C.W. Suggs, 1976, Analytical Model for Rigid Body Vibration of a Hand-Held Chain Saw Part I: The Gasoline Engine, *Trans. ASAE* (vol): 647-653.

Bingham, M.D., C.W. Suggs, and C.F. Abrams, 1992, Vibration Attenuation of Cushioned Gloves, *Appl. Engr. Agr.* 8(1): 4-8.

Johnson, A.T., 2007, *Biomechanics and Exercise Physiology: Quantitative Modeling*, Taylor and Francis, Boca Raton, FL.

Ward, J., 2011, Bodies in Motion, *Pop. Sci.* 278(5): 63-69, 93-94, 97 (May).

Yoon, S.-H., and S. Park, 2011, A Mechanical Analysis of Woodpecker Drumming and Its Application to Shock-Absorbing Systems, *Bioinspiration and Biomimetics* 6(1): 016003.

Eshbach, O.W., and M. Souders, 1975, *Handbook of Engineering Fundamentals*, John Wiley and Sons. New York.

Johnson, A.T., 1991, *Biological Process Engineering; An Analogical Approach to Fluid Flow, Heat Transfer, and Mass Transfer Applied to Biological Systems,* John Wiley and Sons, New York.

Creighton, L., 2005, The Science of Fun, *ASEE Prism*: 44-49 (Jan).

Grose, T.K., 2004, Really Cricket, *ASEE Prism*: 38-42 (Dec).

Page 351:

Insert new Sections 6.14.4 and 6.14.5, and renumber current Sections 6.14.4 and 6.14.5. Also renumber Figures 6.14.5, 6.14.6, and 6.14.7 and change their references in current Section 6.14.5. Add the new Sections 6.14.4, 6.14.5, and renumbered Sections 6.14.6 and 6.14.7 to the Table of Contents.

6.14.4 Genetic Variability

Biology has traditionally had more success when driven by good data rather than by theory.

- Robert H. Carlson

It was mentioned in Section 5.3.6 that there is genetic variation within a species that cannot be easily explained. The principle of survival of the fittest (natural selection) should result in the elimination of all but the most survival successful genes. This means that genes not optimum for survival in a competitive environment should not persist, no matter how small their disadvantage. However, a few of them remain, and they give the species the possibility that, should the environment change, there would be genes already present that could be better able to allow the species to adapt correctly.

If this is considered to be an optimization problem, then the unexplained genetic variation could be a consequence of the broad optima that characterize biological systems. Optima can be broad or narrow (Figure 6.14.5). Narrow optima are very selective, and don't tolerate much variation before the cost of locating at a nonoptimum point becomes too high to be sustained. Broad optima can still have the same optimum, but the costs of deviation from the exact optimum point do not rise significantly quickly. Biological systems seem to have broad optima.

Therefore, genetic variation could be explained by the fact that carrying nonoptimum genes does not turn out to be too expensive for the species as long as the result of those genes being present does not differ too much from the results of the fittest genes. As with all other biological optima, this means of genetic optimization turns out to be energetically less expensive (and maybe more likely for species survival) than an optimum that confers too much advantage to the best genes.

The broad genetic optimum can be a consequence of several properties characteristic of living things. The first is the ability of a living system to sense its environment and to communicate in various ways. The second is the ability to respond to the immediate environment that results in a mathematically chaotic system. That is, the end result is dependent on the pathway it takes to get there. The third property is the appearance of alternate forms that differ very little in energy levels. As a result of these properties, it is easy for biological systems to have varying forms with very little additional energy costs, but which have been determined by the history of the organism. In the case of the genome, each individual's genes are determined by history of the individual and its predecessors, but there persists genetic variability within a population because of somewhat different histories. The genes, once in place, cannot be routinely changed (despite some possibility of random mutations or of epigenetic expression modifications). In the case of optima for breathing rate, heart rate, and stride length, responses can vary with time.

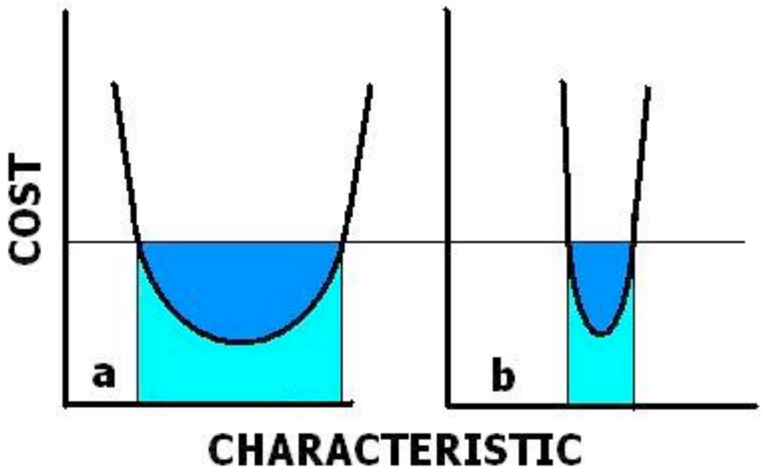


Figure 6.14.5. Illustration of broad (a) optimum and narrow (b) optimum. For the same level of cost, the broad optimum allows a greater range of the optimized characteristic. Biological systems seem to prefer broad optima.

Add to index:

6.14.5 Other Optima

It is not the critic who counts: not the man who points out how the strong man stumbles or where the doer of deeds could have done better. The credit belongs to the man who is actually in the arena, whose face is marred by dust and sweat and blood, who strives valiantly, who errs and comes up short again and again, because there is no effort without error or shortcoming, but who knows the great enthusiasms, the great devotions, who spends himself for a worthy cause; who, at the best, knows, in the end, the triumph of high achievement, and who, at the worst, if he fails, at least he fails while daring greatly, so that his place shall never be with those cold and timid souls who knew neither victory nor defeat.

-Theodore Roosevelt

Optimization even applies to the brain, which appears to operate for maximum information transfer among neurons per unit of neural action potential energy used. Thus, only one to 15 percent of the neurons in the human brain are active at any particular time.

Page 360:

Add to Section 6.15.4, this sentence after the first sentence:

Vegetative plants produce a natural stress hormone, abscissic acid (ABA) to help them survive drought by curtailing growth.

Add to index:

Page 361:

Add to Section 6.15, this Example:

Example 6.15.2 White Nose Syndrome in Bats

Since 2006, millions of bats in the eastern U.S. have died from a fungal disease called White Nose Syndrome. The disease attacks bats while they hibernate in caves in the winter. The disease irritates the bats and wakes them from their deep sleep. This increases their metabolism to nearly summertime levels. In winter, there is no food available, and the bats die of starvation. The disease is so pervasive that all the bats in the affected area die out. They have long generation times and low reproductive rates, so the threat is very serious. Bats are important ecologically because of the prodigious numbers of insects that they eat. One hundred fifty bats can eat millions of potentially-damaging insects in a year.

Add to Index:

Page 370:

Add to Section 6.16.4, after the paragraph beginning "Hepatocyte cells in the liver …":

The ecology of bacteria in the human gut has been called the *human microbiome* (Williams, 2010). These 10^{11} microbes in residence are different for each person. They stimulate immune responses, help detoxify food compounds, enhance new blood vessel growth, allow proper tissue development, produce vitamins, and transform undigestible compounds into useful forms. It's the balance of microbial populations that keeps individuals healthy or sick. Disrupting normal bacterial populations can lead to asthma, allergies, obesity, and weakened immune systems.

Add to Refs:

Williams, S.C.P., 2010, Gut Reaction, *HHMI Bulletin* 23(3): 12-17.

Add to index:

Page 370:

Add to Section 6.16.4, after the paragraph beginning "Cooperation can aid individuals …"

A dramatic example of common benefit over individual benefit involves the programmed cell death (*apoptosis*) of single-cell organisms (Durand et al, 2011; Youngsteadt, 2011). Should an individual single-cell organism be stressed to the point that it cannot survive, it commits suicide, actively expending energy to shrink, disassemble its own DNA, and release beneficial chemicals into the surrounding environment. These substances stimulate surrounding cells, probably having the same DNA or DNA similar to the suicidal cells, to grow robustly, even more effectively than would fresh nutrient broth or leftovers from unprogrammed cell death (*necrosis*). Necrotic substances contain toxics that can sometimes poison their neighbors. Therefore, it appears that some cells that would have trouble surviving turn their demise into a benefit for related neighboring cells.

Add to Refs:

Durand, P., A. Rashidi, and R. Michod, 2011, How an Organism Dies Affects the Fitness of Its Neighbors, *Amer. Naturalist* 177: 224-232.

Youngsteadt, E., 2011, Dying Generously, *Amer. Sci.* 99(3): 208-209.

Add to Index:

Page 374:

Add this example to the end of Section 6.16.

Example 6.16.4 Probiotic Treatment for Diabetes

Intestinal epithelial cells secrete insulin when stimulated by either of two proteins, GLP-1 or PDX-1 (Duan et al, 2008). The first of these causes secretion of insulin in response to blood glucose levels, and, with the second, insulin is secreted irrespective of blood glucose concentration. A common probiotic strain of *E. coli* was engineered to secrete either of these two proteins. It was found that ingestion of these bacteria could be a promising treatment for Type 1 (insulin-dependent) diabetes. A pancreas is not necessary for insulin secretion.

Add to Refs:

Duan, F., K. L. Curtis, and J. C. March, 2008, Secretion of Insulinotropic Proteins by Commensal Bacteria: Rewiring the Gut to Treat Diabetes, *Appl. Environ. Microbiol.* 74(23): 7437-7438.

Add to Index:

Page 374:

Add to the end of Section 6.16, this example”

Example 6.16.5 Bat Beacons

The flower of the plant *Marcgravia evenia* is pollinated by *Glossophaga sorincina* bats, and, in order to make it easier for the bats to find the flower, the plant has a special dish-shaped leaf positioned directly above the flower. This leaf reflects bat ultrasonic emissions from a wide range of angles; other leaves reflect only at certain angles. The leaf allows the bats to find the flowers twice as fast as they would without the leaf (Simon et al, 2011).

Add to refs:

Simon, R., M. W. Holderied, C. U. Koch, and O. von Helversen, 2011, Floral Acoustics: Conspicuous Echoes of a Dish-Shaped Leaf Attract Bat Pollinators, *Science* 333: 631-633 (29 July).

Add to Index:

Page 377:

Add to Section 6.17.3, after the paragraph beginning "Whereas the predator-prey competition …"

Mycoplasmas (not to be confused with mycobacteria, a normal sized bacterium) are exceptional parasites descended from bacteria that had lost their cell walls and shed much of their genomes and metabolic capacities. They became highly dependent upon host environments and host biomolecules (including cholesterol for their cell membranes), and, in the process, became the smallest (less than 1 μm in diameter) and simplest free-living organisms. They have extremely small genomes ranging from 450-1,000 million *Daltons* in size (a Dalton is a number equal to the molecular weight of the molecule), which makes them an obvious choice to be the starting point for synthetic biology (Morowitz, 2011).

Add to Refs:

Morowitz, H.J., 2011, When PPLO Became Mycoplasma, *Amer. Sci.* 99(2): 102-105.

Add to Index:

Page 378:

Add to Section 6.17.4, after the paragraph beginning: "Other means of expulsion …":

Diseases caused by bacteria are often more threatening when caused by gram-negative, rather than gram-positive, bacteria. The cell walls of gram-negative bacteria are often toxic, and their cell membranes are highly protective and antibiotic-resistant.

Add to Index;

Page 378:

Add this new Section 6.17.5:

6.17.5 Parasite Adaptations

Your time is limited, so don't waste it living someone else's life. Don't be trapped by dogma, which is living with the results of other people's thinking. Don't let the noise of others' opinions drown out your own inner voice. And most important, have the courage to follow your heart and intuition. They somehow already know what you truly want to become. Everything else is secondary.

- Steven Jobs

Parasites, and to some extent pathogens, are more successful at survival and reproduction if they do not harm or stress their hosts to an extreme. When either a parasite or pathogen jumps from a habitual host to a new species, it is often very virulent because the new host has not yet developed an immune strategy to deal with the new threat. Many host individuals die or are at least incapacitated. Over time, this does not suit the parasite or pathogen any more than it does the host, and, as a consequence, the parasite or pathogen adapts to have less effect on the host. It may evolve into a chronic rather than acute condition. Thus, humans have acquired Simian Immunodeficiency Virus (SIV) from monkeys, which became Human Immunodeficiency Virus (HIV), Severe Acute Respiratory Syndrome (SARS) from bats and cats, and strains of influenza virus (flu) from birds and swine. When first encountered, each of these has been devastating to the human population. The same pattern has been followed in other species (for example, Varroa destructor in honey bees).

Add to Index:

Page 379:

Add to Section 6.17, this example:

Example 6.17.5 Cat Parasite Has Unusual Neural Effects

Toxoplasma gondii is a parasitic microbe of cats with unusual characteristics (Shepherd, 2020). Cats come in contact with the microbe when they eat an infected mouse or bird. They don't usually get sick, but the parasite reproduces in the cat's gut, forming eggs (or *oocysts*) that develop and are shed in the cat's feces.

When another warm-blooded animal, such as a mouse, ingests the oocysts through contact with the cat's feces, the oocysts enter its gut. There they release cells that migrate mostly to the muscles and brain, forming cysts to protect themselves from the mouse's immune system.

But *T. gondii* must get back to into a cat to reproduce again. In order to do that, it needs the mouse to be eaten by the cat. So, it changes mouse behavior to induce it to take risks, including an attraction to the smell of cat urine. This makes mice vulnerable to attack by cats.

T. gondii has two unusual genes that contain instructions for an enzyme that makes the neurotransmitter dopamine. This is likely the mechanism that *T. gondii* uses to change normal mouse avoidance behavior. It may also explain a statistical link between *T. gondii* infection of humans and human schizophrenia. Some anti-schizophrenic drugs are dopamine antagonists.

Add to refs:

Shepherd, 2010, Scientists look for a Link Between Toxo Infections and Brain Disorders Such as Schizophrenia, *The Shepherd* 55(9): 12-13 (Sept).

Add to Index:

Page 384:

Add to the end of the first full paragraph of the page, Section 6.18.4, after the sentence that begins "Human telomeres consist of …" and before the sentence beginning "Telomeres in other species …":

The length of human telomeres is about 15,000 base pairs at conception, 10,000 base pairs at birth, and the rate of loss is about 50 base pairs a year after birth. At about 5000 base pairs, human cells have largely lost the ability to divide (Hooper, 2011).

Change the next sentence to read:

Telomere sequences in other species vary from one to another, but usually consist of repetitions of 6-10 base sequences.

Add to refs:

Hooper, J., 2011, The Man Who Would Stop Time, *Pop. Sci.* 279(2): 51-57, 79-81 (Aug).

Page 384:

Add to the second full paragraph on the page in Section 6.18.4, just before the sentence that begins "Prokaryotes avoid this problem … ":

Laboratory cultured cells, not immortal stem cells or cancer cells, can divide about 50-70 times before they die; this number of divisions is known as the *Hayflick Limit* (Hooper, 2011).

Add to the index:

Page 384:

Add to the end of Section 6.18.4, this box:

HeLa Cells

The HeLa cells are a line of immortal cervical cancer cells biopsied from Henrietta Lacks at Johns Hopkins University in 1951. They are amazingly resilient and robust. As such, they have been shared among many researchers world wide and used for research on cancer, Acquired ImmunoDeficiency Syndrome (AIDS), radiation, toxic substances, and gene mapping. This cell line is so hardy, prolific, and overpowering that it is a contaminant in perhaps 10-20% of all research cell lines.

HeLa cells differ from normal human somatic cells because of the presence of powerful telomerase that prohibits the shortening of the telomeres during cell division. These cells also have 82 chromosomes, unlike the normal human number of 46. The additional chromosomes apparently came from Human Papilloma Viruses (HPV) that fused with the original cancer cells. Although some variation in the HeLa cell genome has been reported when cultured under different environmental conditions, the HeLa genome has been remarkably stable over the course of hundreds of cell divisions.

The Hayflick Limit is the number of times that normal human somatic cells can divide before their telomeres are completely consumed. This number is a value somewhere between 40 and 60. When the Hayflick limit is reached, senescence sets in, eventually leading to cell death (apoptosis). The HeLa cell line has shown no evidence of a Hayflick Limit.

Add to Index:

Page 387:

Add at the end of Section 6.18.5, after the paragraph beginning "Then follows a set …":

Low light levels in deep ocean depths of 500 m or more can challenge animals that live there to find food and also to find mates. Bioluminescense is one way to signal the presence of an individual looking to reproduce (McClain, 2010). Also of importance in the quest to find a mate is the sense of smell. Small male anglerfish seek out females by smell. When a male contacts a much larger female, enzymes fuse his mouth to her body. Eventually all of his organs except his sperm-producing gonads atrophy, and he becomes a lasting source of sperm (McClain, 2010).

Add to Refs:

McClain, C., 2010, An Empire Lacking Food, *Amer. Sci.* 98: 470-477.

Add to index:

Page 389:

Add this paragraph at the end of Section 6.18.6:

This selection of partners with certain physical traits is called *assortative mating (or assortative pairing)*. It has a possible evolutionary basis by increasing the chances of maintenance and transmission of one's own genetic material by reproducing with a partner carrying similar genes.

Add to Index:

Page 391:

Add to Section 6.18.9, after the paragraph beginning: "Some flowers contain …"

Pollen grains are formed on male flower parts called *stamens*. The male gametes in pollen are encapsulated in several tough outer polymer layers to protect against drying and physical damage. There is a very small opening in the pollen grain, called a *micropore*, through which the gametes can leave when they land on the female flower structure, called a *pistil,* the top part of which is called a *stigma* (Figure 6.18.6). They then grow into the pistil to fertilize the ovule.

Figure source: Wikipedia Common.

Add to Index:

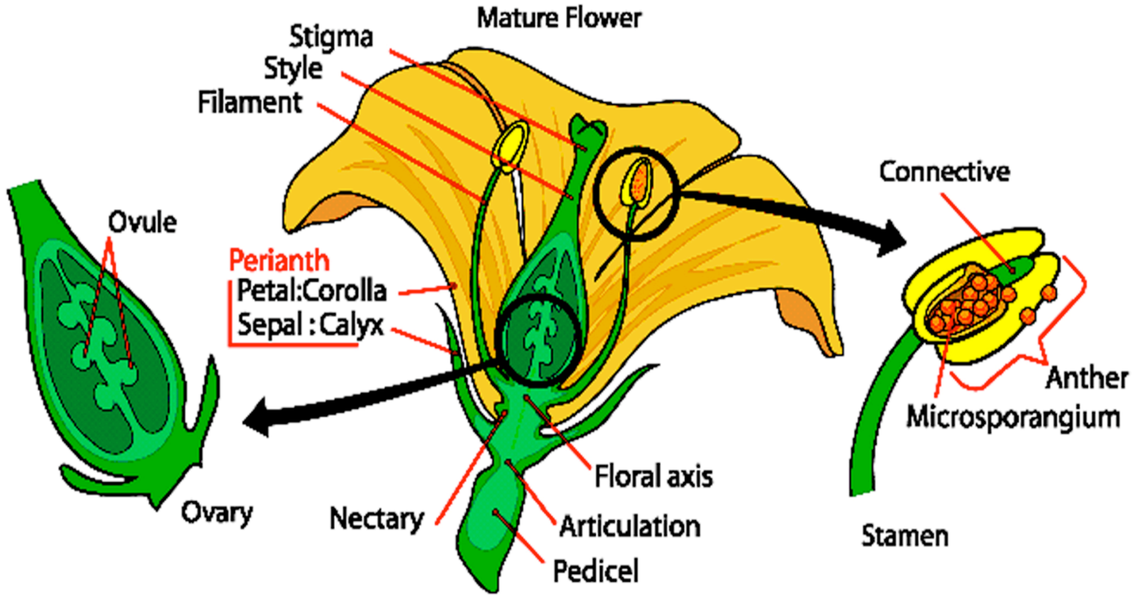


Figure 6.18.6. The reproductive parts of an angiosperm flower (source: Wikipedia, Marianna Ruiz, 2011).

Page 391:

Add to Section 6.18.9, after the paragraph beginning "The other strategy …":

Plants sometimes also have difficulty with fertilization by cross-pollination. There may be no other plants around to provide pollen, as at the edge of the geographical range of the species, or neighboring plants may still be many years away from sexual maturity. There are genes in some plants that control fertilization by interfering with self-pollination. The absence of one of these genes can allow the plant to become self-fertile under some environmental circumstances (Fessenden, 2010).

Some insects, especially bees, collect pollen as a protein source for raising their young. After they bring it back to their nests or hives, the pollen is partially digested to make the protein nutritionally available. Perhaps as a reproductive strategy, plants that depend upon insects for pollination have more protein in their pollen than plants that depend upon the wind for pollination.

Add to Refs:

Fessenden, M., 2010, The Fantastic World of Plants, *CALS News*, Spring: 15-18.

Add to index:

Page 396:

Add to the end of Section 6.19.1:

Vervet monkeys (small monkeys common throughout Africa) communicate among themselves about various predators. They have different alarm calls for leopards, eagles, and pythons, their chief predators. When the alarm call is made for leopards nearby, the monkeys run to the nearest trees and climb to the smaller branches where they are safe. The eagle alarm causes vervets to scan the sky and dive into the underbrush to avoid being seen from the air. The python, or snake, call causes monkeys to stop and alertly determine where the snake is located. Once the snake is located, the vervets pounce on it and drive it off. Lions, hyenas, and cheetahs as a group also have an alarm call (Shumaker, 2010).

Vervets fighting other vervets and getting the worst of the fight sometimes give the leopard call as a ruse to save themselves from further beatings. Once the call is given, all vervets stop fighting and display their defensive behavior.

Add to Refs:

Shumaker, R.W., 2010, The Missing Link? Maybe Fear, *Phi Kappa Phi Forum* 90(3): 14-15 (Fall).

Add to index:

Page 400:

Add this paragraph to Section 6.19.2, immediately after the paragraph on masting.

Women in close proximity tend to synchronize their menstrual cycles, and this is known as the *McClintock effect* (McClintock, 1971). The signals causing this are apparently chemical in nature, although exact mechanisms are unknown.

Add to refs:

McClintock, M., 1971, Menstrual Synchrony and Suppression, *Nature* 229: 244-245 (22 Jan).

Add to Index:

Page 401:

Add to Section 6.19.2, after the paragraph beginning "Quorum sensing also coordinates …":

Populations of bacteria can appear to be much more antibiotic resistant than expected. That is because some bacteria in the population will have resistance and some will not. Those resistant bacteria challenged with antibiotics emit a compound called *indole* that signals to surrounding non-resistant bacteria to expel antibiotic and to change chemical pathways to neutralize toxins produced inside the cell by the antibiotic (Williams, 2010; Lee et al, 2010).

Add to refs:

Williams, S.C.P., 2010, Bacteria Helping Bacteria, *HHMI Bulletin* 23(4):42 (Nov).

Lee, H.H., M.N. Molla, C.R. Cantor, and J.J.Collins, 2010, Bacterial Charity Work Leads to Population-wide Resistance, *Nature* 467: 82-85.

Add to index:

Page 402:

Add to Section 6.19.3, after the paragraph beginning "Touch is extremely important …":

Touch is one of the first sensations to be developed after birth, and seems to be important in classification of one's own physiological states and interpersonal relationships later in life. Human touch, especially as sensed through the hands, associates with relevant mental concepts. For instance, physically touching a warm object promotes interpersonal warmth (Williams and Bargh, 2008). Having heavy objects in one's hands associates with importance and seriousness in other people and other matters (Ackerman et al, 2010). Handling rough objects forms an impression associated with difficulty and harshness (Ackerman et al, 2010). Hard objects made others appear more strict, more stable, less emotional, and less flexible (Ackerman et al, 2010). Thus, we have the expressions that associate touch with personal attributes, such as:

1. warm-hearted
2. weighty thoughts
3. rough day
4. coarse language

5. hard-hearted
6. rock-solid
7. cold personality
8. keep in touch
9. smooth operator

Physical pain also has a psychological analog in depression or rejection (as exemplified by “I’m crushed” or “I’m hurt by that remark”). Acetaminophen (Tylenol) has been found both to relieve physical pain and, at the same time, social or moral conflicts that tend to cause depression (Stix, 2010).

These observations have biological engineering implications. The type of packaging may critically determine the attitude of customers toward the product inside. The design of human-occupied spaces may depend upon the use of the space and the impressions that are to be fostered. Manipulations of the human environment can be made easier if the correct tactile choices are made.

It is likely, too, that these results extend to the animal kingdom, too. Classical studies by Harlow(1958) on maternal-infant bonding in macaque monkeys demonstrated that infants preferred to stay close to a cloth surrogate mother warmed with a 100 W light bulb rather than a bare wire surrogate mother with a baby milk bottle as a source of food. Harlow’s conclusion was that contact comfort was very important to the monkey infants compared to meeting nourishment needs. Monkeys raised with the warm cloth mother developed relatively normal social skills, in contrast to infants with only wire mothers.

The cell membrane has many receptors, each with a specific function. Many of these provide the means for substances to be transferred into or out of the cell; the cell membrane is otherwise nearly impervious to transmembrane movement of larger ions or compounds. These receptors can also act as portals through which viruses access the cell interior. The Transferrin Receptor 1, for instance, which usually brings the element iron into the cell, can also act as access for the deadly Machupo virus to enter the cell (Vastag, 2010).

Add to Refs:

Ackerman, J.M., C.C. Nocera, and J.A. Bargh, 2010, Incidental Haptic Sensations Influence Social Judgments and Decisions, *Science* 328:1712-1714 (25 June).

Harlow, H., 1958, The Nature of Love, *Amer. Psychol.* 13:673-685.

Stix, G., 2010, Social Analgesics, *Sci. Amer.* 303:22-23 (Sept).

Williams, L.E., and J.A. Bargh, 2008, Experiencing Physical Warmth Promotes Interpersonal Warmth, *Science* 322: 606-607 (24 Oct).

Vastag, B., 2010, When Passion and Skill Converge, *HHMI Bulletin* 23(3):8-9.

Add to index:

Add to Applications and Predictions:

1. Conversations are friendlier with a warm beverage rather than cold.

Page 404:

Add to box "Seeing Inside Us", Section 6.19.4, at the end of the paragraph beginning "MRI detects individual …":

In order to detect rapid changes in blood oxygenation, images from fMRI must be faster than regular anatomical MRI; fMRI images consequently have lower resolution.

Add to the box, "Seeing Inside Us". Section 6.19.4, after the paragraph beginning "*Fluorescence spectroscopy …*":

Fluorescence resonance energy transfer (FRET) can be used to determine the locations of individual molecules. When two light-absorbing molecules lie close to one another, they can pass absorbed energy between them. The efficiency of this energy transfer depends precisely on the distance between donor and acceptor molecules. Measuring luminosities of each molecule can determine the distance between them. FRET has been used to track molecular movements along a DNA strand (Schnabel, 2010).

Add to Refs:

Schnabel, J., 2010, Nano-Motion Pictures, *HHMI Bull.* 23(1):44-45 (Feb).

Add to index:

Page 405:

Add to Section 6.19.5, before the first paragraph:

Nonverbal communication with animals is also a possibility. Mice, like humans, express pain through facial expressions (Dove, 2010). Knowing this, laboratory scientists can assure that animals under their care do not suffer unnecessarily. The same characteristic can also lead to improved pain-relief drugs for humans.

Pet owners usually agree that their animals can tell from non-verbal cues when there will be a change in normal routines; they can tell when their owners will go on vacation, take them to see the veterinarian, or give them baths. Communications with animals can happen at several levels, and there is opportunity for biological engineers to extend communication devices for human hearing or seeing impaired to connect to animals as well.

Add to refs:

Dove, A., 2010, The Search for Animal Alternatives, *Drug Discovery and Development*, May: 10-13.

Add to index:

Page 409:

Add to Section 6.19, this example:

Example 6.19.4 Pheromones for Your Cat

Sara was the name of a cat owned by Andrea Sachs (Sachs, 2010). Sara had come nine years ago from an animal shelter. She was a gentle cat, but skittish, afraid of new situations and strange people, a proverbial scaredy-cat.

Sammy was an aggressive and competitive cat which Andrea brought home two months ago from the shelter. Once Sammy moved in, he and Sara fought over and over until she would run to the nearest safe hideout. This continual fighting disrupted the peace and quiet of the household.

Desperate to get some sleep, Andrea consulted her veterinarian, who gave her pheromone collars and electric plug-in pheromone diffusers. The diffusers emitted a chemical that mimics a pheromone that cats leave behind when they rub their cheeks on furniture or people; the collar had a pheromone that mother cats emit while nursing. Both calm agitated cats.

Pheromones are known to have behavioral effects on many kinds of animals, from alarm alerts to soothing siblings. Besides cats, pheromone products are also available for dogs and humans.

Add to refs:

Sachs, A., 2010, Kitty Prozac, *Time* 176(20): 57-58 (15 Nov).

Add to the Index:

Page 410:

Add to Section 6.20.1, at the end of the paragraph beginning "Taste and smell are both …":

Sensing magnetic fields is called *magnetoception*, and involves the presence of small bits of the mineral magnetite located in subcellular organelles called a *magnetosomes*.

Add to index:

Page 416:

Add to the box on immune system, Section 6.20.3, after the sentence beginning "There are probably more than a million …":

Insects are among the number of animals that do not produce antibodies as part of their immune responses.

Page 420:

Add to Section 6.20.3, to the box on the immune system, before the paragraph beginning "If bacteria such as *Listeria* …", this paragraph:

Newborn ruminant mammals have very low protease activity in their digestive tract, which means that ingested proteins, including antibodies, are not degraded. Specialized receptors on small intestinal epithelial cells bind to antibodies and incorporate them into the body by endocytosis. This allows antibodies appearing in mother's first milk, called *colostrum*, to be passed to their offspring. Six to 12 hours after birth, the newborns lose the ability to absorb antibodies directly from the mother (Stewart, 2011).

Add to Refs:
Stewart, W., 2011, Colostrum: Immunity, Warmth, and Nutrition, *The Shepherd* 56(5): 6-7 (May).

Add to Index:

Page 427:

Add to the end of the box entitled "Phages to the Rescue" in Section 6.20.7:

There are also parasitic viruses (called *virophage*) that infect other viruses. The viruses they infect belong to a recently-discovered class of giant viruses as large as some prokaryotic cells (Van Etten, 2011).

Add to the refs:

Van Etten, J. L., 2011, Giant Viruses, *Amer. Sci.* 99: 304-311.

Add to the index:

Page 430:

Add the following example at the end of Section 6.20:

Example 6.20.5 Paleobiologists Using Immunities

There is epidemiological as well as forensic interest in identifying ancient parasites, bacteria, and viruses. Learning about these can shed light on the causes of famed pandemics, reasons that historical figures suffered or died, and the coevolution of microbes and hosts. The detection, identification, and characterization of ancient microbes in the environment or human remains have largely been based on analysis of tiny recovered samples of ancient DNA (aDNA). However, potential contamination by modern DNA and altered aDNA can make these methods unreliable. An alternative is to use nonnucleotidic biomolecules, including mycolic acids and proteins remaining from ancient microbes or other tissues. Assaying techniques include immunohistochemistry, immunochromatography, enzyme-linked immunosorbent assays (ELISA), and mass spectrometry.

Add to refs:

Tran, T.-N.-N., G. Aboudharam, D. Raolt, and M. Drancourt, 2011, Beyond Ancient Microbial DNA: Nonnuceotidic Biomolecules for Paleomicrobiology, *BioTechniques* 50(6): 370-380.

Add to Index:

Page 435:

Add the following paragraph and new Figure 6.21.6 to the end of Section 6.21.3. Renumber present Figures 6.21.6 through 6.21.11 to become Figures 6.21.7 through 6.21.12.

A comprehensive concept for aging has been offered by DePinho and colleagues (Sahin et al, 2011; Hooper, 2011). This scheme combines effects of telomeres, p53 gene, cellular mitochondria, nuclear DNA, and free radicals to explain how aging and cellular death can occur (Figure 6.21.6).

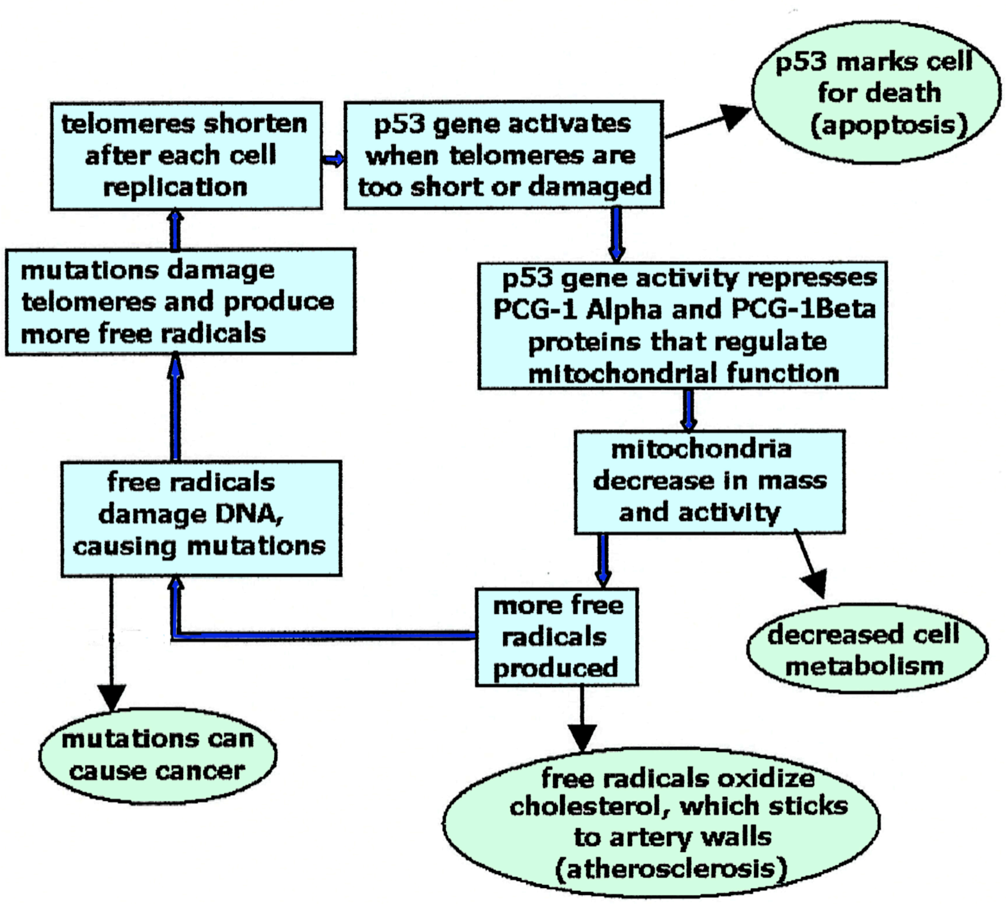


Figure 6.21.6. This comprehensive scheme explaining aging and cellular death in humans includes both genetic and environmental factors.

Add to refs:

Sahin, E., S. Colla, M. Liesa, J. Moslehi, F. L. Müller, M. Guo, M. Cooper, D. Kotton, A. J. Fabian, C. Walkey, R. S. Maser, G. Tonon, F. Foerster, R. Xiong, Y. A. Wang, S. A. Shukla, M. Jaskelioff, E. S. Martin, T. P. Heffernan, A. Protopopov, E. Ivanova, J. E. Mahoney, M. Kost-Alimova, S. R. Perry, R. Bronson, R. Liao, R. Mulligan, O. S. Shirihal, L. Chin, and R. A. DePinho, 2011, Telomere dysfunction induces metabolic and mitochondrial compromise, *Nature* 470,:359–365 (17 February).

Hooper, J., 2011, The Man Who Would Stop Time, *Pop. Sci.* 279(2):50-57, 79-81 (Aug).

Add to Index:

Page 441:

Add to Section 6.21.7, before the paragraph beginning "Human blood levels …":

There are blue light sensors in the mammalian eye separate from the rods (light level) and cones (color) that help to synchronize physiological circadian rhythms to day-night cycles. These sensors are active even in blind people who lack functional vision. This nonvisual photoreceptor system is also present in more primitive insects, amphibians, and arthropods. It depends on the production of a melatonin-related chemical called *melanopsin* (Provencio, 2011).

Add to refs:

Provencio, I., 2011, The Hidden Organ in Our Eyes, *Sci. Amer.* 304(5): 55-59 (May).

Add to Index:

Page 442:

Add at the end of the sentence that begins:"… It is no surprise…":

(see Table A.39).

Page 451:

Add to the end of Section 6.22.1, this box:

The Consequences of Fear

Fear is a very powerful emotion useful for survival. Fear alerts humans and animals to potential dangers, and readies them for combat or escape (the so-called *fight or flight reaction*). Fright speeds the heart and constricts some blood vessels to shunt blood to the arms and legs. Some prey animals freeze when frightened, so predators won't see them move. Fear maximizes sensory input by widening the eyes, dilating the pupils, and flaring the nostrils (Lilienfeld, 2010). People recognize facial expressions of fear quicker than those of other emotions, perhaps because fear almost always associates with some kind of danger. Fears distort reality for sufferers. Some of this is due to physiological effects and some is due to psychological changes. People with fear and phobias tend to overestimate real threats (Lilienfeld, 2010).

Women react to fear differently than do men. Whereas men prepare for fight or flight in a fearful situation, women tend to cling to those around them and bond to other females in a collective defensive posture (*tend and bond reaction*).

Some fears appear to be innate, but others are learned. Monkeys with no prior fear of snakes have learned that fear from other monkeys who have experienced the consequences of snake predation (Shumaker, 2010). This is an example of memes in action.

Add to Refs:

Lilienfeld, S.O., 2010, Fear: Can't Live With It, Can't Live Without It, *Phi Kappa Phi Forum* 90(3): 16-18 (Fall).

Shumaker, R.W., 2010, The Missing Link? Maybe Fear, *Phi Kappa Phi Forum* 90(3): 14-15 (Fall).

Add to index:

Page 455:

Add this paragraph at the beginning of Section 6.22.5:

Learning about the environment and how to respond best to environmental challenges take time. Those animals that learn more and learn better take more time to mature and require longer parental care than do those animals with hard-wired (innate) responses. Humans, in particular, seem to be created to learn; their brains take twenty years or more to mature because immature brains are flexible and can form new neural connections easily. Children explore creatively and easily; adults plan and act effectively. Each of these requires a different brain function and structure (Gopnik, 2010).

Add to Refs:

Gopnik, A., 2010, How Babies Think, *Sci. Amer.* 303(1): 76-81 (July).

Page 456:

Add this box to the middle of Section 6.22.5:

Animal Ingenuity

Maya is the name given by researchers to a matron of an isolated chimpanzee community in Africa. She has been observed to engage in the most sophisticated form of serial tool use by any nonhuman animal (Foer, 2010):

"Maya arrives at the termite mound, a rock-hard, bulbous structure three times her height, carrying in her mouth several plant stems that she will use to fish out its high-calorie occupants. First she rams a thick twig into a termite hole and widens it by jiggling the stick vigorously. Then she grabs a thin, flexible stem that she plucked off a nearby *Sarcophrynium* plant. Chimps in other parts of Africa are known to fish for termites with implements like this, but Maya goes one step further and modifies the tool. She drags the last six inches of the stem through her teeth to create a wet, frayed end, like a paint brush, and pulls it through her closed fist to straighten out the bristles. With the dexterity of a professional lock picker, she then threads the brush-tipped stem into the same hole, pulls it out, and nibbles off a couple bugs that cling to the wand's frayed edges.

"What's so remarkable about that fishing probe is that it represents a refinement. It's not just that some clever chimp figured out that it could break off a plant stem and use it to fish for termites – an impressive enough discovery in its own right – it's that some other chimp figures out a way to do it even better."

Another incident illustrating animal intelligence involves coyotes and sheep dogs. Shepherds located in regions with many sheep predators often keep sheep guard dogs with their flocks for protection. The dogs are trained to stay with the flock and ward off interlopers. Janet McNally (2010) is one of these shepherds, and described one of the incidents this way:
"I watched and listened as a coyote, just a stone's throw from a young … livestock guard dog, yapped at the dog, enticing her to chase. The [dog] would dash at the coyote, then retreat back toward the sheep. The coyote would come back and yap again, trying to lure the dog out into the woods. The coyote persisted for over three hours, but the [dog] was only 8 months old. Typical of her breed, she stayed close to the flock and would not be enticed out toward the freeway. The week before, this coyote succeeded in drawing three older, bolder livestock guard dogs out onto the highway where they were promptly struck

and killed by cars in three separate incidents over the course of two days. These were older dogs that were familiar with navigating traffic. Is a coyote smart enough to know the cars would kill the dogs?"

Add to Refs:

Foer, J., 2010, The Truth About Chimps, *Nat. Geog.* 217(2): 130-145 (Feb).

McNally, J., 2010, The Changing Predator Landscape, *The Shepherd* 55(12): 6-7 (Dec).

Add to Index:

Page 471:

Add to Section 6.22:

Example 6.22.6 Dominance is Reinforced by Body Position

There is a psychological, physiological, and behavioral positive feedback system working in the minds and bodies of human beings that reinforces correlations among these three variables such that they cannot be easily separated. Just the act of smiling has been found to influence disposition toward a more positive outlook; nodding the head "yes" inclines a person to be more open to suggestion.

It has been found that the simple act of posing in a powerful position (exhibiting dominance or expanding occupied space) results in higher levels of the aggression hormone testosterone, lower levels of the stress hormone cortisol, and greater assumption of risk than posing in less powerful positions (closed, receptive, and subordinate). As shown in Figure 6.22.15, these two types of positions by themselves had profound physiological and physical consequences (Dana et al, 2010).

It had been known that higher levels of testosterone correlate with human dominance, and that lower levels of cortisol are related to lower stress levels. This research showed that these hormonal adjustments can be induced solely by the act of demonstrating power.

The relationship between social dominance and poses extends to other animals: peacocks spread their tail feathers and strut to attract mates; cats advance sideways to give the appearance of size to ward off intruders; chimpanzees inflate and thrust their chests forward to intimidate others. It is likely that these poses were enhanced by testosterone, and it is likely that testosterone was enhanced by the assumption of these poses.

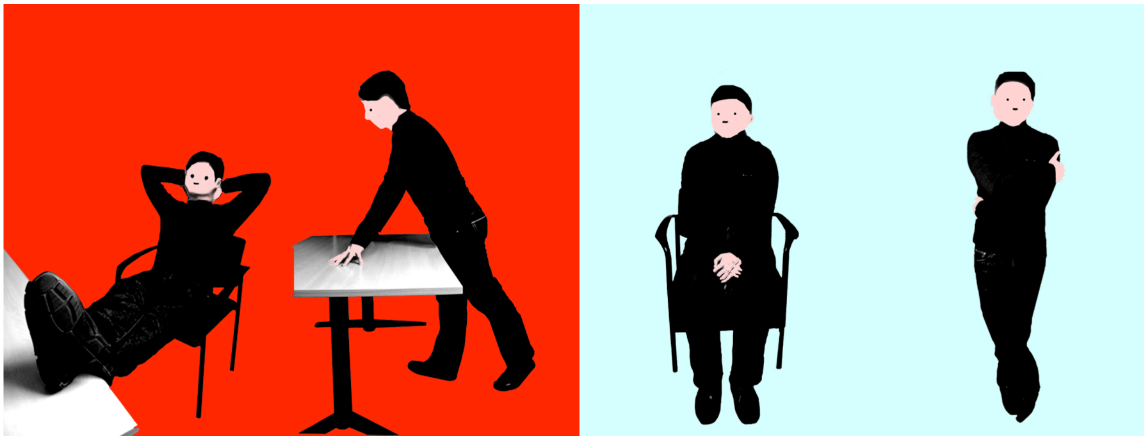


Figure 6.22.15. On the left are two poses found to demonstrate power and enhance testosterone and reduce cortisol. On the right are two poses that demonstrate conciliation, withdrawal, or subservience. Testosterone for the right hand poses was lower and cortisol higher (Redrawn from Carney et al, 2010).

Example 6.22.7 Sensory Overload in the Driver's Seat

Modern automobiles are designed and built for comfort by insulating the driver from noise, road bumps, and ambient conditions. The driver is isolated from the surrounding environment so well that a myriad of warning systems have had to be installed to indicate when there is trouble. There are dashboard lights for doors ajar, gas filler access flaps open, parking brake engaged, low fuel, engine trouble, air-bag malfunction, anti-lock brake condition, and many others.

When engineers decided to improve safety by warning drivers of nearby vehicles traveling in the blind spot for the driver, that place just to the left and slightly behind the driver (at least for autos driven on the right hand side of the road), they faced a decision about the best means to warn the driver (Corley, 2010). The visual sense was already overloaded while driving.

Engineers, instead, installed vibrators in the driver's seat. Surrounding vehicles activated vibrators in seat locations corresponding to positions of nearby cars; vehicles to the left activated left vibrators and vehicles to the right activated right-side vibrators. The closer the approaching vehicle, the more intense was the vibration. Engineers hope that using tactile feedback for drivers will help them take more appropriate actions in a timely manner.

Add to refs:

Carney, D.R., A.J.C. Cuddy, and A.J. Yap, 2010, Power posing: Brief Nonverbal Displays Affect Neuroendocrine Levels and Risk Tolerance, *Psychol. Sci.* 21:1363-1368.

Corley, A.-M., 2010, The Danger-Sensing Driver's Seat, *IEEE Spectrum* 47(7): 12-13 (July).

Add to Index:

Page 477:

Add to the end of Section 6.23.2:

Example 6.23.2 The Use of Animals for Food

Temple Grandin has made several observations related to animal use and animal welfare (Klein, 2010):

1. the natural cycle of birth and death means that for one living thing to survive, another living thing must die.
2. animals in the wild usually die a violent death from starvation, predators, or exposure.
3. wild animals seldom die from natural causes or old age.
4. killing animals for food at a slaughter house can be much gentler and more humane than death in nature.
5. prey animals hide their pain to keep predators from singling them out; however, they don't hide fear.
6. livestock have been bred to supply food for humans. They exist in their present forms because of human breeding. They deserve a decent life and a quick, painless death.

Add to refs:

Klein, L., 2010, Michigan Sheep Breeders Association/ Michigan Shepherds Weekend, *The Shepherd,* 55(2): 27 (Feb).

Add to the index:

Page 496:

Add to Section 7.4, at the end of the first paragraph, immediately following the sentence ending with the word "mountains":

Other fractally-organized (scale independent) biological features are chromosome organization (Babbit, 2011) and correlation lengths among birds flying in flocks (swarm intelligence; Hayes, 2011).

Add to Refs:

Hayes, B., 2011, Flights of Fancy, *Amer. Sci.* 99:10-14.

Babbit, G.A., 2011, Chromatin Evolving, *Amer. Sci.* 99:48-55.

Page 531:

Add to Section 7.4:

Example 7.4.4 Cats Lapping Water

When cats lap water, they do not cup their tongues, as dogs do. They use their tongues to slap the water, rather than scooping the water into their mouths. When a cat lifts its tongue, a column of water adheres to the tongue, and is drawn into its mouth by inertia (Reis et al, 2010).

Lapping frequency was found to be dependent upon cat body mass:

$$f = 4.6\ m^{-0.181}$$

where f is lapping frequency, in laps/sec
m is body mass, in kg.

Larger cats lap water slower than smaller cats. This makes sense, because larger cats have larger tongues that require more power to move as fast as smaller tongues.

Add to Refs:

Reis, P.M., S. Jung, J.M. Aristoff, and R. Stocker, 2010, How Cats Lap: Water Uptake by *Felis catus*, www.sciencexpress.org, doi 10.1126/science.1195421 (11 Nov).

Add to Index:

Page 531:

Add to the end of Section 7.4:

Example 7.4.5 King Kong's Structural Constraints (Willmore, 2010).

King Kong was a fictional movie character who appeared as a gorilla much larger than normal. All of his proportions were the same as a normal gorilla.

In real life, structural proportions of bone limit animal sizes and proportions. If King Kong were five times as tall as a normal gorilla, then his mass would scale as his volume, or $5^3 = 125$ times the mass of a normal gorilla. However, the strengths of his bones (limited by critical stresses) would depend on their cross-sectional areas, or $5^2 = 25$ times as strong as normal bones. Thus the forces on his leg bones would be 125/25 = 5 times larger than normal; his bones would be crushed. Apes can be smaller or larger, but structural considerations impose constraints.

Add to refs:

Willmore, K.E., 2010, Development Influences Evolution, *Amer. Sci.*, 98: 220-227.

Add to index:

Page 531:

Add to the end of Section 7.4, this example:

Example 7.4.6 Animals Shaking Off Water

Dogs aren't the only animals that shake when wet. Other animals also use this means to dry their bodies. The smaller the animal, the faster it shakes. Shaking frequency data in Table 7.4.6 appeared in *National Geographic* magazine (Bloch, 2011). Investigate to see if an allometric relationship can be developed between shaking frequency and body mass.

Solution: Nominal body mass data were obtained from Table a.1 in the appendix, and are given in Table 7.4.6. Because it is reasonable to suspect a power-law relationship between shaking frequency and body mass, data for each of these variables were converted into logarithms and the values plotted (Figure 7.4.23). The apparent straight line relationship is consistent with a power-law equation.

Using the least-squares technique explained in Section 4.2.3, the best-fit equation was found to be:

$$\log f = 1.07 \log m - 0.21 \quad (7.4.74a)$$

Converting this into a power-law equation requires taking the antilog of 1.07 to yield:

$$f = 11.8\ m^{-0.21} \quad (7.4.74b)$$

This equation predicts a shaking frequency of 4.1 cycles per second for the tiger and a frequency of 4.8 cps for a 70 kg human.

Table 7.4.6 Shaking Frequencies of Animals

Animal	Body Mass (kg)	Log (mass)	Shaking Frequency (cps)	Log (frequency)
Mouse	0.023	-1.64	29	1.46
Rat	0.25	-0.602	18	1.26
Guinea Pig	0.345	-0.462	14	1.15
Cat	3.3	0.519	9	0.954
Poodle	12	1.08	6	0.778
Lab Retriever	14	1.15	5	0.699
Sumatran Tiger	160	2.20	4	0.602
Brown Bear	550	2.74	4	0.602

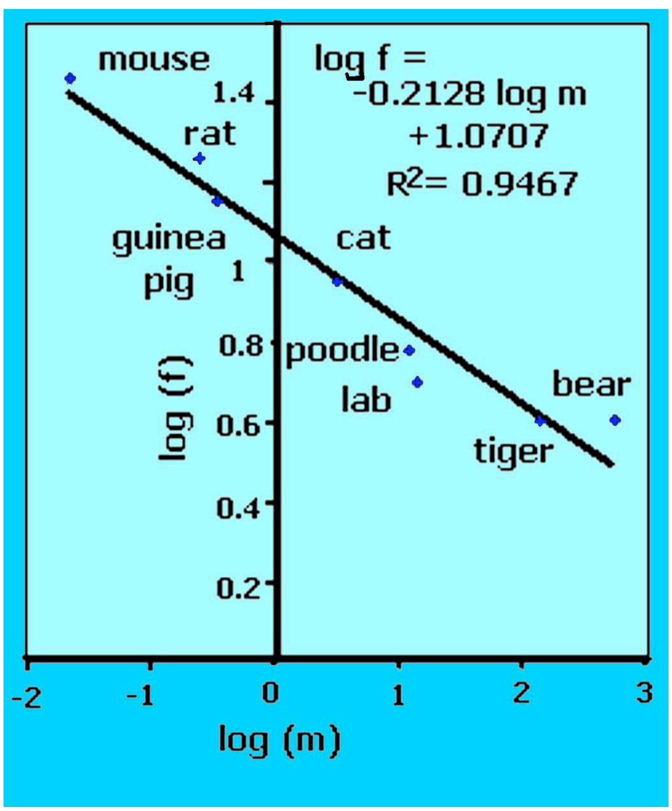


Figure 7.4.23 Graph of the logarithmic relationship between shaking frequency (cps) and body mass (kg) for several animals.

Add to refs:

Bloch, H., 2011, Shake It Off, *Nat. Geog.* 220(3): 32 (Sep).

Add to Index:

Page 539:

Add this example to the end of Section 7.6:

Example 7.6.2 Poaching of Rhinos

Powdered rhinoceros horn is prized in some parts of the world for its supposed ability to cure fever, arthritis, high blood pressure, and cancer. This demand has led to the unauthorized and illegal killing of rhinos in Africa and Asia. The horns are sawed off the carcass and smuggled to horn dealers.

The numbers of rhinos has plummeted due to this poaching. African black rhinos numbered about 100,000 in the early 1960s, but the population had waned to just 2400 in the early 1990s (Beech and Perry, 2011). At the beginning of the twentieth century, there were only about 50 African white rhinos alive. Now, thanks to conservation efforts, the number is about 20,000. The Sumatran and Javan rhinos, however, are on the verge of extinction.

Saving the African black rhino requires protection for a long enough time for the population to build up to sustainable levels. The mass of a black rhino is about 1200 kg (Clauss et al, 2005). The maximum population doubling time calculated from equations 7.6.8 a-d is 7.2 years. The actual number of black rhinos had doubled to about 4800 by 2011, giving a population doubling time of about 20 years. The difference can probably be attributed to the lasting effect of illegal killing.

Add to refs:

Beech, H., and A Perry, 2011, Killing Fields, *Time* 177(24): 40-47 (13 June).

Clauss M.,T. Froeschle, J. Castell, J.-M. Hatt, S. Ortmann, W.J. Streich, and J. Hummel, 2005, Fluid and Particle Retention Times in the Black Rhinoceros Diceros bicornis, a Large Hindgut-Fermenting Browser. *Acta Theriologica* 50: 367-376.

Add to the index:

Page 560:

Add to Section 8.2.3, after the paragraph beginning “Gene therapy is often conducted *ex vivo* …”:

There are generally four choices to deliver nucleic acid (DNA or RNA) into a target cell:

1. transfection reagents and endocytosis
2. electroporation
3. viruses
4. biolistics (shooting DNA- or RNA-coated pellets into the cell)

Of these, the first three are usually used with animal cells and the fourth can be use for agricultural work. *Lentiviruses* are sometimes used to transfect genetic material into non-dividing cells.

Add to Index:

Page 577:

Add at the end of Section 8.2, this example:

Example 8.2.6 Bioleaching of Metal Ores

Bacteria are increasingly being used to extract metals from low-grade ores or from ores difficult to mine. Strains of the bacterium *Thiobacillus ferrooxidans* thrive on mineral-rich rock. Many of these rocks contain heavy metal sulfides, and form acidic solutions when rainwater leaches through them. *T. ferrooxidans* facilitates this leaching when it uses the compounds for its metabolism. This process is called *bioleaching.*

Low-grade ores that contain concentrations of metals uneconomical to extract through conventional smelting can be ground and piled on a water-impermeable surface, and treated with *T. ferrooxidans.* The metals are recovered economically from the solutions of acidic water runoff coming from the pile (Rawlings and Silver, 1995).

More than 25% of the world’s copper is extracted using bioleaching. Bioleaching also shows promise for recovering gold, cobalt, and uranium. Because *T. ferrooxidans* survives in the harsh environments of acidic rock, this bacterium has been nominated as a means to extract valuable minerals from the surfaces of other planets (Olsson-Francis and Cockell, 2010).

Add to refs:

Olsson-Francis, K., and C.S. Cockell, 2010, The Use of Cyanobacteria for In-Situ Resource Use in Space Applications, *Planetary and Space Science* 58(10): 1279-1285.

Rawlings, D.E., and S. Silver, 1995, Mining with Microbes, *Nature Biotechnol.* 13: 773-778.

Add to Index;

Page 577:

Add to the end of Section 8.2, this example:

Example 8.2.7 Cyborg Beetles

Tiny robots that could fly inside caves, tunnels, and barricaded rooms could provide needed reconnaissance for the military, law enforcement personnel, or emergency first responders. Fully synthetic micromechanical robotic fliers require too much energy to be powered by present battery technology. Beetles have very efficient flying mechanisms, but they need to be able to carry miniature cameras and to be controlled to fly where they are needed. Beetles large enough to carry miniature radios, batteries, and controllers have been used for this purpose (Maharbiz and Sato, 2010). Several very thin wires implanted in the insect's brain and flight muscles permit humans to control beetles to start or stop flying, and to turn left or right in flight (Figure 8.2.22).

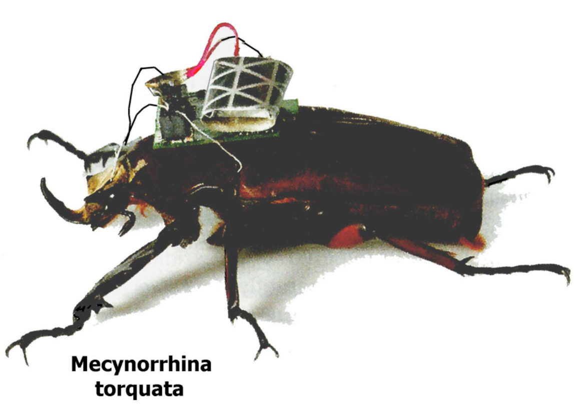


Figure 8.2.22 This beetle carries a miniature radio, controller, and battery and can be controlled in flight (Maharbiz and Sato, 2020)

Figure source: less than 10% of the area of unnumbered figure on page 97 of Maharbiz and Sato (2010).

Add to refs:

Maharbiz, M.M., and H. Sato, 2010, Cyborg Beetles, *Sci. Amer.* 303(6): 94-99 (Dec).

Add to Index:

Page 667:

Add Table A.39. Add an entry to the Table of contents.

Table A.39
Hours of Sleep for Mammals in Captivity

Animal	**Hours of Sleep**
Armadillo, Giant	18.1
Bat, Small Brown	19.9
Cat	12.5
Chimpanzee	9.7
Cow	4.0
Dog	10.1
Fox, Red	9.8
Horse	2.9
Human (not in captivity)	8.0
Lion	13.5
Mouse	12.5
Rabbit	8.4

Add to Index:

Page 755:

Add to the index entry “Viruses, entering cells”:

248

Add to the entry for “Electroporation”:

81