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:


Add to index:

- Animal models 19
- Animal testing 19
- Cell cultures 19
- Drug testing 19

---

**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:


Add to index:

- Glyphosate herbicide 23
- Roundup-Ready crops 23
- Cotton 23
- Soybeans 23
- Chelation 23
- Enzymes, plant 23
- Respiration, plant 23
- Plant respiration 23
- Resistance, herbicide 23
- Redundancy, in biology 23

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:


Add to index:

Adenovirus 81
Agrobacteria 81
DNA vaccines 81
Vaccines, DNA 81
Electroporation 81
Immune response 81
Page 90:

Add to Section 3.1, after the sentence beginning “They do not take part …”, this sentence:

Looking at the periodic table, flammability decreases from left to right, and toxicity increases from top to bottom.

Add to index:

Toxicity of elements 90

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:


Add to Index:

Bacteria, and arsenic 91
Arsenic, in bacteria 91

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:

- Detergents 93
- Phosphates 93

**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:


Add to index:

- Protein 115
- Nitrogen, in protein 115

**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 mesophillic (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).**

<table>
<thead>
<tr>
<th>Compost Material</th>
<th>C:N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sawdust</td>
<td>442:1</td>
</tr>
<tr>
<td>Straw-wheat</td>
<td>127:1</td>
</tr>
<tr>
<td>Rice hulls</td>
<td>121:1</td>
</tr>
<tr>
<td>Straw-general</td>
<td>80:1</td>
</tr>
<tr>
<td>Corn stalks</td>
<td>60-73:1</td>
</tr>
<tr>
<td>Finished compost</td>
<td>30-50:1</td>
</tr>
<tr>
<td>Hay-general</td>
<td>15-32:1</td>
</tr>
<tr>
<td>Horse manure-general</td>
<td>30:1</td>
</tr>
<tr>
<td>Cattle manure</td>
<td>19:1</td>
</tr>
<tr>
<td>Grass clippings</td>
<td>17:1</td>
</tr>
<tr>
<td>Sheep manure</td>
<td>16:1</td>
</tr>
<tr>
<td>Turkey litter</td>
<td>16:1</td>
</tr>
<tr>
<td>Broiler litter</td>
<td>14:1</td>
</tr>
<tr>
<td>Swine manure</td>
<td>14:1</td>
</tr>
<tr>
<td>Cottonseed meal</td>
<td>1-7:1</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>4-6:1</td>
</tr>
<tr>
<td>Animal carcass</td>
<td>5:1</td>
</tr>
</tbody>
</table>

Add to Refs:


Add to index:

- Composting 120
- Carbon to nitrogen ratio 120
- Bacteria, thermophillic 120
- Aerobic metabolism 120
- Digestion, aerobic 120
- Digestion, anaerobic 120
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).

Add to refs:

Ebbinghaus, S., A. Dhar, J.D. McDonald, and M. Gruebele, 2010, Protein Folding

Add to index:

Protein folding 130
Cell conditions 130
Cytoplasm 130

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, amyotrophic lateral sclerosis (Lou Gehrig’s disease), cystic fibrosis, some
tumors, osteogenesis imperfecta (King et al., 2002), and transmissible spongiform
encephalopathy (TSE).

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:


Add to index:

Prions 133
Evolution 133
Yeast 133
Transmissible spongiform encephalopathies 133
Protein misfolding 133
Memory, and prions 133
Synapse, nerve 133
Environmental response 133
Replication of prions 133
Beta sheets, protein 133
Alpha helix, protein 133

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:


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 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:


Add to index:

<table>
<thead>
<tr>
<th>Mimicry</th>
<th>225</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selective advantage</td>
<td>225</td>
</tr>
<tr>
<td>Survival</td>
<td>225</td>
</tr>
</tbody>
</table>

Page 237:

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

<table>
<thead>
<tr>
<th>Genetic</th>
<th>Environmental</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Human Personality
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:


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:

Add to index:

| DNA replication                          | 245 |
| Genetic error correction                 | 245 |
| SSB protein                              | see Single-stranded binding protein |
| Single-stranded binding protein          | 245 |
| Rec A protein                            | see DNA replication                 |

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).

Add to Refs:


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

Add to index:

<table>
<thead>
<tr>
<th>Term</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize color</td>
<td>256</td>
</tr>
<tr>
<td>Corn color</td>
<td>256</td>
</tr>
<tr>
<td>Transposons</td>
<td>256</td>
</tr>
<tr>
<td>Powdery mildew</td>
<td>256</td>
</tr>
<tr>
<td>Genetic parasites</td>
<td>256</td>
</tr>
</tbody>
</table>

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:


Add to index:

Synthetic genes 268
Genes, synthetic 268

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%)”:

\[10^{13}\text{, or}\]

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:


Add to the index:

<table>
<thead>
<tr>
<th>Topic</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Yellowstone Park</td>
<td>278</td>
</tr>
<tr>
<td>Wolves</td>
<td>278</td>
</tr>
<tr>
<td>Ecological balance</td>
<td>278</td>
</tr>
</tbody>
</table>

**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:


Add to Index:

<table>
<thead>
<tr>
<th>Term</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin D</td>
<td>295</td>
</tr>
<tr>
<td>Cancer</td>
<td>295</td>
</tr>
<tr>
<td>Heart disease</td>
<td>295</td>
</tr>
<tr>
<td>Blood vessels</td>
<td>295</td>
</tr>
<tr>
<td>Serotonin</td>
<td>295</td>
</tr>
<tr>
<td>Autoimmune diseases</td>
<td>295</td>
</tr>
<tr>
<td>Depression</td>
<td>295</td>
</tr>
<tr>
<td>Ricketts</td>
<td>295</td>
</tr>
</tbody>
</table>

**Page 296:**

Add a box at the end of 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.
Argentosaurus 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:


Add to index:

Dinosaurs 296
Appetite, dinosaurs 296
Body temperature, dinosaur 296
Temperature regulation, dinosaur 296
Fermentation 296
Food, dinosaur 296
Body temperature 296

Be sure to include the title of this box in 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:


Add to Index:

<table>
<thead>
<tr>
<th>Term</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruit flies</td>
<td>313</td>
</tr>
<tr>
<td>Trichomes</td>
<td>313</td>
</tr>
<tr>
<td>Genetic expression</td>
<td>313</td>
</tr>
<tr>
<td>Shavenbaby gene</td>
<td>313</td>
</tr>
</tbody>
</table>

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


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).

Add to Refs:


Page 324:

Add to Section 6.10:

**Example 6.10.2 Microbes Respond to External 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:

Natural selection 324
Environmental pressure 324
Biofuels 324
Bioremediation 324

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 (Amáible-Cuevas, 2010).

Add to the Refs:


Add to index:

<table>
<thead>
<tr>
<th>Term</th>
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<tr>
<td>Penicillin</td>
<td>338</td>
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</tbody>
</table>

**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.

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<tbody>
<tr>
<td>Cellular environment</td>
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<td>Three-dimensional cell culture</td>
<td>346</td>
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<td>Cell culture</td>
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</tbody>
</table>

**Page 351:**

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.
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:

Quote, Robert H. Carlson 351
Carlson, Robert H. quote 351
Genetic variability 351
Optimum, broad or narrow 351

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:

ABA 360
Abscissic acid 360
Drought tolerance, plant 360

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:


Add to index:

Microbiome 370
Human gut 370
Microbes, gut 370
Allergies 370
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 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:


Add to Index:

- Oocysts 379
- Schizophrenia 379
- Cat parasite 379

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. Bioluminescence 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).

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<td>Anglerfish</td>
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<td>Reproduction, in deep fish</td>
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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.

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<td>Plant pollination</td>
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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 located, the vervets pounce on the snake 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:


Add to index:

- Vervet monkeys 396
- Predator calls 396
- Predator defenses 396
- Monkeys 396

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:


Add to index:

- Groups 401
- Indole 401
- Antibiotic 401
- Resistance, antibiotic 401

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:


Add to index:

- Machupo virus 402
- Membrane receptors 402
- Ligands 402
- Iron 402
- Warmth 402
- Mental concepts 402
- Rough objects 402
- Smooth objects 402
- Hardness 402
- Packaging 402
- Heaviness 402
- Touch 402
- Acetaminophen 402
- Pain 402
- Depression 402

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.
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:


Add to index:

- Fluorescence resonance energy transfer 404
- FRET see Fluorescence resonance energy transfer

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:


Add to index:

- Communication, with animals 405
- Nonverbal expression 405
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:


Add to the Index:

- Pheromones 409
- Cats 409

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 *magnetosomes*.

Add to index:

- Magnetic sensing 410
- Magnetoception 410
- Magnetosome 410
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 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:


Add to index:

- Fear 451
- Memes 451
- Fight or flight reaction 451
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:


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.
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:


Add to Index:

Testosterone 471
Cortisol 471
Dominance 471
Power, body position 471
Body position 471
Driving 471
Vibrator seats 471

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:


Add to the index:

Animals, for food 477
Food, from animals 477
Animal slaughter 477

Page 529:
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:


Add to Index:

- Cats lapping 529
- Water, drinking 529

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:
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:


Page 755:

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

248

Add to the entry for “Electroporation”:

81