HOMEOSTASIS – The Immune System and Homeostasis

A. Defending The Body

- the human body is under constant attack from foreign invaders in the air, in food, and in water
- it must also fight against abnormal body cells that sometimes turn into malignant tumors
- there are three lines of defence that have evolved in humans to combat against these kinds of attacks
- the first two are nonspecific immune responses that do not distinguish one microbe from another
- the third line – the immune system – is a specific immune response that reacts in specialized ways to various kinds of invaders

THE FIRST LINE OF DEFENCE

- this is a physical line of defence
- it consists of the skin and mucous membranes that defend against viral and bacterial invaders
- skin cannot be penetrated by bacteria or viruses
- it also secretes acidic substances that keep the pH range within an intolerable level for microbes to grow (3 to 5)
- human tears, saliva, perspiration, and other mucous secretions destroy bacterial cell walls, killing them on contact
- for example, the mucous produced in the respiratory passage traps incoming microbes and foreign debris
- tiny hair-like cilia filter and trap invading substances as well (see Figure 2, p. 463)
- the cilia move in a one-way sweeping wave motion so as to push out the unwanted particles toward the point of entry, where coughing expels them
- any invading microbes that make their way into the stomach are killed by corrosive acids and protein digestive enzymes

THE SECOND LINE OF DEFENCE

- the line of defence that occurs if an invader makes its way into the body, surviving the first line of defence
- **leukocytes** – large opaque blood cells that originate from the bone marrow, destroy any potentially destructive agent

- they are unlike red blood cells because they possess a nucleus, and they are unlike platelets because they are larger
- each class of leukocyte is distinguished by the shape and size of their nucleus, and by the granules found in the cytoplasm
- for example, **granulocytes** are white blood cells that contain granules in their cytoplasm and are produced in the bone marrow, whereas **agranulocytes** are white blood cells that are also produced in the marrow, but have no granules in their cytoplasm – they are sent to the lymph nodes where they are modified
- the process of **phagocytosis** – the ingestion of invading microbes by certain types of white blood cells is what constitutes this nonspecific second line of defence
- for example, when a foreign object penetrates the skin the following two kinds of phagocytic events occur:

1. monocytic response

   - special leukocytes called **monocytes** migrate from the blood into the damaged tissue
   - the monocytes develop into **macrophages** – meaning “big eaters”
   - the macrophages extend long protrusions, called **pseudopods** that attach to the surface of the invading microbe
   - the microbe is then engulfed and destroyed by enzymes within the macrophage

2. neutrophilic response

   - w.b.c.s called **neutrophils** are attracted to chemical signals given off by cells that have been damaged by microbes
   - **chemotaxis** occurs -- the neutrophils squeeze out of capillaries and migrate toward the infected tissue
   - engulfing of the microbe takes place and lysosomal enzymes are released by the neutrophil
   - these lysosomes digest both the microbes as well as the leukocyte
   - the remaining fragments of protein, dead leukocytes, and digested invader are called **pus**
   - Figure 3, p. 463 illustrates this response very well

- when the body is using this second line of defence, such as during an infection or flu, as the neutrophils and macrophages are digesting the invaders, chemicals are released in the bloodstream
- the hypothalamus receives the chemicals and resets the body thermostat to a higher temperature
- the high temperatures create an unfavorable environment for bacteria to survive in
- if the infection persists, more neutrophils and macrophages are released, causing greater chemical stimulation of the hypothalamus, and a higher temperature setting results
- the greater the infection, the higher the fever
- if Tylenol is taken to reduce the fever, the infection may in fact be prolonged
- however, if the temperature keeps on rising without having an effect on the bacteria, it could result in more harm than good

- fevers of 41°C or higher can cause convulsions in young children and can denature many of the body's respiratory enzymes, which can deplete ATP production and weaken the body
- above 43°C, human body cells die!

- Figure 4, p. 464 summarizes the development of phagocytic white blood cells, red blood cells, and lymphocytes from the bone marrow
- bone marrow is the source of all types of blood cells
- it is found mainly in four areas – the spongy part of the upper leg bone, upper arm bone, breastbone, and shoulder blades

Homework: **1-5, p. 465**

B. The Immune Response

- there are two types of leukocytes – those that migrate throughout the blood and search for foreign invaders, and those that are at fixed locations at certain body tissues, that trap and filter out microorganisms and foreign invaders that enter the blood
- Figure 1, p. 466 shows the structures of the lymphatic system – a system that filters out pathogens, foreign cells, and debris

COMPLIMENT PROTEINS

- foreign organisms in the body activate antimicrobial plasma proteins called **compliment proteins** (see Figure 2, p. 467)
- 20 known proteins exist normally, in the inactive state in the blood
- the marker proteins found on invading microbes activate the compliment proteins, which in turn, serve as messengers
- the compliment protein seals the invader and triggers a second group of proteins to puncture the cell membrane of the invader (see Figure 2b)
- when this happens, water rushes into the cell, causing it to burst
- then a third group of proteins attaches to the invader (see Figure 2c), making them less soluble and more susceptible to phagocytosis by leukocytes

ANTIBODIES

- a specialized group of white blood cells called **lymphocytes** produce **antibodies** when intruding cells or foreign proteins are present in the blood
- antibodies are Y-shaped protein molecules that are engineered to target foreign invaders

- antibodies are specific – each antibody type kills a specific kind of antigen
- a bacterial cell membrane, like all cell membranes, contains cell markers
- every cell is "marked" by its own tag called an **antigen** (see Figure 3, p. 467)
- the cell markers (or antigens) are recognized by special cells called **T cells** (stored in the thymus gland of the endocrine system)
- once the antigen of the invader is recognized, another T cell passes this information on to the antibody-producing **B cell**
- the B cells multiply quickly, releasing their specific type of antibody, displaying it along the cell membrane
- some B cells that are released by the bone marrow and enter the circulatory system, differentiate into super-antibody-producing cells called **plasma cells**, producing as many as 2000 antibody molecules every second

I. ANTIGEN-ANTIBODY REACTIONS

- the tails of all Y-shaped antibodies are similar
- variations only exist at the outer edge of each arm – the position where the antibody attaches to the antigen (Figure 4, p. 468)
- for example, antigen markers found on the influenza virus are different from those found on HIV
- the antibody arm shape "fits" the antigen marker of the invader that it kills
- each antibody attaches only to its complementary marker
- every invading cell or virus contains more than one kind of antigen, which means that more than one kind of antibody can attach to it
- when antibodies attach to antigens, a complex is formed
- the more antibody attachments, the larger the complex
- when the invader's antigens meet up the immune system's antibodies, the invader becomes larger and more susceptible to wandering macrophages

II. ANTIBODY PROTECTION AGAINST TOXINS

- antibodies also prevent poisons from destroying cells
- most poisons or toxins have a specific shape that is similar to regular hormones or proteins that should normally bind to special receptor sites of body cells
- this means that they attach to the body cell, instead of the substances that should attach to them
- antibodies interfere with the attachment of the toxins to the cell membrane's receptor sites by actually binding with the toxins, thus altering their shape so they no longer "fit" the cell membrane's receptor sites (see Figure 5, p. 468)
- the same principle applies to viruses
- for example, the cold virus is shaped in such a way that it binds specifically to lung cell membranes

- HIV is shaped in such a way that it binds to T cells (see Figure 6, p. 468), thereby hiding inside the very cell assigned to recognize it – it is like disarming the enemy
- antibodies attach themselves to invading viruses, thus altering their shape and preventing access to receptor sites

III. HOW THE BODY RECOGNIZES HARMFUL ANTIGENS

- Figure 7, p. 469 illustrates how the body recognizes harmful antigens:

1. bacteria enters the body
2. T cells, that are in constant search of foreign invaders that pose a potential threat, "tag" the invaders
3. macrophages attack and engulf invaders, pushing the antigen markers to their own outer membrane
4. **helper T cells** recognize the invader antigens that exist on the macrophage membrane
5. helper T cells release **lymphokine**, which causes B cells to divide into identical clones
6. a second messenger is sent from the helper T cells to the B cells, which triggers the production of antibodies
7. B cells are released into the blood stream, each having their own antibodies attached to their membranes
8. the antibodies are released and begin attaching themselves to antigen-marked bacteria

The Effects of Killer T cells

- helper T cells activate an additional defender called **killer T cells**, that search and destroy intruders by puncturing their cell membrane
- as well, killer T cells locate body cells that are housing viruses by binding to the virus protein coat that is left on the outside of the infected cell
- once the host cell is located, it is killed, preventing the virus from reproducing
- killer T cells also destroy mutated cells (see Figure 8, p. 470)
- these mutated cells can become cancerous
- one belief is that all people develop cancers, but, in most cases, the killer T cells eliminate them before they develop into tumors
- killer T cells may also be the bases for the rejection of organ or tissue transplants
- the donor's antigen marker causes killer T cells of the recipient to initiate an attack
- cyclosporin can be given to a recipient to help slow down killer T cell action
- however, this could make the recipient extremely susceptible to bacterial infection during the acceptance period

When the battle is over…

- once the battle against foreign invaders is won, a **suppressor T cell** signals the immune system to shut down
- most of the B cells and T cells will die off within a few days
- however, a small amount of these cells remain long after just in case the same infection returns
- phagocytes “survey” the area, cleaning up the debris left from dead and injured cells
- tissues then begin the work of repair and replacement

IV. THE IMMUNE SYSTEM’S MEMORY

- helper T cells read a “blueprint” of the invader before B cells produce antibiotics
- the “blueprint” is stored even after the invader is destroyed just in case the same invader returns
- a **memory B cell** is generated during the infection and remain in the blood after the fight is over
- these memory B cells contain an antigen imprint that characterizes the invader
- as long as the memory B cell survives, the individual is “immune” to any similar subsequent invasion
- this is why a disease like chicken pox is only caught once

V. MATCHING TISSUES FOR ORGAN TRANSPLANT

- donor organs are often identified as a foreign invader by distinctive protein markers (antigens)
- the distinctive marker is known as **major histocompatability complex (MHC)**, is a protein fingerprint unique to each individual
- those individuals that have similar MHCs can receive each other’s organs for transplant with less potential for rejection

VI. STEM CELL RESEARCH

- stem cells are cells that can differentiate and develop into a variety of different tissues such as epithelial tissue, muscle tissue, or nerve tissue
- stem cells are **pluripotent cells** that can give rise to different types of body cells
- stem cells can transform into bone marrow, brain tissue, muscle, skin, pancreas, liver, or practically any human tissue
- they could replace destroyed islet cells that produce insulin, repair damaged cartilage, or repair cardiac tissue that has been destroyed by heart disease

Homework: **1-5, p. 472**

C. Malfunctions of the Immune System

- two problems may result if there is a malfunction:

1. **Immune Deficiency Disease** - caused by….

    - foreign agents, such as HIV (which attacks T cells), or
    - hereditary conditions, such as severe combined immunodeficiency (SCID), which is caused by a gene mutation that results in the inability to produce B cells and T cells
    - cancer therapy or prolonged use of anti-inflammatory drugs such as cortisol

2. **Inappropriate Attacks of the Immune System** – where the immune system attacks nonthreatening agents – it basically goes on a rampage

    - hypersensitivity of harmless agents called allergic reactions, or autoimmune responses can result in the destruction of tissues and organs….

A. ALLERGIES

- ✓ immune system mistakes harmless agents for harmful invaders
- ✓ even though the agent is safe, the immune system prepares an attack against it
- ✓ this could result in increased mucus secretion, tissue swelling, and in more severe cases, constricted air passages to the point that the reaction is life-threatening
- ✓ a common allergic response is what is known as an **anaphylactic reaction** – involves both the respiratory and circulatory systems and is accompanied by swelling of different body parts, hives, and itching
- ✓ anaphylactic reactions due to drugs, vaccines, or foods (peanuts, shellfish, eggs, berries, and milk) occur in this manner…

    - when you eat a food that your body perceives as a foreign invader, a chemical messenger is released called **bradykinin** – which stimulates the release of another chemical stimulator called **histamine**
    - histamine is produced by white blood cells called **basophills** and by mast cells found in connective tissues
    - histamine increases capillary cell permeability and results in enlarged capillaries that redden the immediate areas
    - proteins and white blood cells exit the capillaries to search for the agents that are perceived as harmful invaders

- as these agents leave the capillaries, the osmotic potential in the capillaries drops
- less water is absorbed by the capillaries, and the tissues swell
- symptoms are weakness, sweating, difficulty breathing, nausea, diarrhea, and drop in blood pressure

✓ as a precaution, a person may carry an allergy kit around with them that includes a syringe full of epinephrine that they would inject into a large muscle in their body, or antihistamines

B. AUTOIMMUNE DISEASE

✓ this is when the immune system launches an attack on its own body tissues

✓ **renegade T cells** trigger **renegade B** cells to make antibodies that attach to healthy tissue cells

✓ the result is an attack on these cells by macrophages

✓ one theory suggests that renegade T cells and B cells exist in everybody, but they are kept in check by **suppressor T cells**

✓ suppressor T cells can be weakened by drugs or serious infections, and decrease with age

✓ artificial immune suppressor drugs have been developed that reduce the intensity of autoimmune attacks

✓ some individuals are born with defective suppressor T cells, thus experience autoimmune responses their whole lives

✓ suppressor T cells secrete a substance that tells the macrophages to engulf the renegade cells and not the healthy tissues

✓ examples of autoimmune responses are:

- *rheumatoid* arthritis – where the suppressor T cells fail to control renegade T cells in rheumatoid arthritis – where an autoimmune response is launched against connective tissues surrounding the joints
- *rheumatic* fever – an exaggerated immune response which scars the heart muscles
- *type 1 diabetes* – a response **against** the islets of Langerhans – the insulin producing cells of the pancreas
- *lupus* – the accumulation of antigen-antibody complexes in the walls of blood vessels, joints, kidneys, and skin

Homework: **1-4, p. 475**

D. Pathogens and Disease

- a pathogen is any invader that causes a disease to the body

- Figure 1, p. 476 is s micrograph of a common pathogen, *Escherichia coli*
- not all invaders are pathogens…
    - microbes found in the large intestine that help process waste products and provide the body with needed vitamins
    - microbes on the skin feed off the body's oils and dead cells and at the same time protect the skin from harmful microbes that might colonize
- diseases caused by pathogens are transmitted from person to person – the microorganism moves from one host to another
- many human diseases most likely originated from domesticated animals, and after a random mutation, the microbes were able to survive in another species
- for example, rabies, a virus, is a microbe that move from the blood to the nervous system and causes rapid deterioration of the brain
- the only way you could get rabies is from blood to blood contact
- the AIDS virus, HIV, is received by blood transfusion or through direct sexual contact
- cholera is an example of a bacterial disease that is both virulent and highly contagious and deadly
- the influenza virus, or commonly known as the flu, is highly contagious as well
- the common cold virus is another highly contagious microbe

BUBONIC PLAGUE: THE BLACK DEATH

- catastrophic results in Europe in the 14^{th} and the 17^{th} century
- originated in China
- caused by the bacterium *Yersinia pestis*
- carried by rats and transmitted to humans by flea bites
- symptoms began with headaches, nausea, aching joints, vomiting
- later, a fever developed, along with painful swelling of the lymph nodes in the neck, armpits, and groin
- the swelling is referred to buboes, thus the name
- red spots developed on the skin, which later turned black
- the plague was transferred from China to Europe on merchant ships
- by 1348, more than half of the urban population of Europe died from it
- in 1665, 60% of the population died from the plague

A. How a Disease is Caught

- ✓ there are many ways of catch a pathogen
- ✓ Table 1, p. 477 shows common pathogens and their transmission
- ✓ Figure 3, p. shows one of the most common ways in which infections are transmitted – **a droplet infection**
- ✓ other ways include **waterborne infections**, **direct contact infections**, or **infections caused by vectors**
- ✓ waterborne infections have a greater potential to spread (i.e. Walkerton), whereas direct contact infections spread slower
- ✓ direct contact infections, like gonorrhea or AIDS, for example, enter through a mucous membrane contact – genitalia, mouth, etc.
- ✓ some direct contact infections need to be blood to blood contact, like rabies
- ✓ common vectors that transfer diseases are insects – houseflies, lice, ticks, fleas, and mosquitoes

B. Discovery of Pathogens

- ✓ the discovery of microbes was first made by Anton van Leeuwenhoek, the inventor of the microscope, in 1683
- ✓ although he was the first to describe bacteria, he still didn't exactly know what they were
- ✓ the connection between disease and microbes was first made by Louis Pasteur in 1854
- ✓ he was interested in what caused the spoiling of wine
- ✓ first he identified these tiny white spheres in the wine as living yeast cells and noticed that as the number of these yeast cells increased, the alcohol content of the wine increased as well, concluding that yeast cells produced the alcohol
- ✓ when he analyzed spoiled wine, he noticed that it contained another substance, called lactic acid
- ✓ under a microscope he then noticed that spoiled wine contained these rod-shaped bacteria, and concluded that it was the presence of these bacteria that caused the wine to go bad
- ✓ soon after this, Pasteur, as well as some other scientists began looking for microbes as the cause for human diseases
- ✓ this lead to the **germ theory** – a theory that took quite some time to be accepted by the biological scientific community

- Bacteria

  - ➢ single-celled organisms that damage tissue cells by producing poisons or toxins that are harmless to the bacteria, but deadly to the host
  - ➢ the poisons and toxins may be produced in one infected area and transmitted by the blood to other targeted tissue cells
  - ➢ examples are…

    - *typhoid* – attack the cells of the stomach
    - *tuberculosis* – attack tissues of the lungs

- *diphtheria* – bacteria lodges in the throat and then produces toxins that affect other body tissues
- *botulism* – often fatal disease where bacteria produce poisons in areas that are low in oxygen (i.e. in canned foods or home preserves
- *salmonella* – a less likely fatal common bacterial food poisoning

- Viruses

  - Figure 6, p. 480 compares the size of viruses with bacteria and a red blood cell
  - viruses were first noticed in 1927
  - they aren't considered cells and are not really considered living things by scientists
  - they reproduce only if they coexist with a host cell – isolated viruses cannot reproduce
  - some common examples are…

    - influenza virus
    - chicken pox
    - common cold virus
    - human immunodeficiency virus

  - once it enters a cell it becomes active, taking over the host cell's DNA, and using it to make more viruses
  - one of the deadliest known viruses today is the **human immunodeficiency virus (HIV)**
  - it causes **acquired immune deficiency syndrome (AIDS)**
  - there are two know strains – HIV-1, discovered in 1981, and HIV-2, discovered in 1985
  - both strains must be transmitted directly in order to pass from host to host – i.e. direct sexual contact, during pregnancy, at the time of birth, or through breast milk (rare)
  - there is no cure yet
  - HIV targets helper T cells, called T4 lymphocytes – the cells that act as guards against invading pathogens
  - the result is that the individual's immune system becomes incapable of defeating other invading organism

- Prions

  - discovered in the 1970s by Dr. Stanley Prusiner
  - when studying a particular infection that affected nerve tissue, he realized no bacterial evidence or foreign nucleic acid or virus particles present

- by 1982 he determined that the cause was in fact due to a protein molecule, which he termed **proteinaceous infections particle**, or **prion** for short
- he found that injections of prions of different abnormal configurations into animals caused the development of more similar-like proteins to occur (see Figure 7, p. 481)

Homework: **1-6, p. 481**

E. Induced Immunity: Active and Passive Immunity

- induced immunity can come from within the body itself, or from an outside source
- when the body takes an active role in producing antibodies for particular antigens it is called **active immunity**
- however, immunity to one strain of a virus does not guarantee immunity to another – the architecture of one antibody does not "fit" more than one strain of antigen
- when antibodies are taken and introduced to the body directly it is called **passive immunity**
- however, antibodies introduced directly into a person's system only last for a certain amount of time
- for example, the tetanus antibody, that comes from the plasma of a horse, has a limited amount of time that it will stay functional
- this is why doctor's quite often ask you when you've had your last tetanus shot when you get cut badly

A. Vaccinations

- these substances induce active immunity
- a weakened or dead microbe is introduced to the body
- sometimes even a small portion of protein from the microbe is used as the vaccine and is enough to cause active immunity
- today, synthetic proteins, that have a similar geometry to the harmful antigen and stimulate the immune response without presenting a risk, are used – hepatitis B vaccination is an example of such technology
- since all antibodies eventually disappear, boosters are required to expose the immune system to the antigen a second time
- Figure 1, p. 483 shows how the immune system responds to first and second exposure of a microbe antigen
- helper T cells identify the weakened antigen and signal B cells to reproduce antibodies against them
- a vaccination is successful if the antibodies produced by the B cells to fight the "twin" , weakened, or dead microbe antigen, "fit" or are just as effective on binding to the virulent and harmful microbe antigen
- the smallpox vaccination was the first vaccination ever used (p. 483 – "Smallpox and the First Vaccine") – a less severe cowpox virus was introduced to people so that they developed immunity to smallpox as well

- the rabies vaccination was a weakened, dormant version of the more virulent, less dormant strain
- when the weakened version was introduced to the body, it stimulated antibodies to be produced, which were effective in binding to both weakened and virulent strains
- the polio vaccination is one where the virus is actually killed, or permanently inactivated, and then injected as a dead virus into the system

B. Chemical Controls

- there are certain chemical substances that go straight to the pathogenic organisms at which they are aimed and leave host cells undamaged – so called "magic bullets"
- these chemicals don't operate like vaccinations – instead, they attack the organism directly
- they basically act as "blockers" of normal metabolic pathways that are essential for bacteria to survive
- the chemical becomes a competitive inhibitor of enzymatic operations (see Figure 4, p. 485)

Antibiotics

- these chemicals originate from living organisms
- the principle behind their effective functioning is interspecific competition – competition between organisms of different species
- quite often, the toxins produced by one organism prevent another from surviving or being successful in the same living space
- Fleming discovered that agar plates inoculated with bacteria had become contaminated with mould, and that wherever the mould was, there was not bacterial growth
- the mould secreted a bacterial-destroying agent, that is now known as penicillin
- penicillin interferes with bacterial cell walls, weakening them and causing the cell to burst as if fills with water
- even though antibiotics are very specific in killing bacteria, they do cause side effects…
    - sometimes helper T cells identify antibiotics as foreign agents and set off an inappropriate attack on them by the immune system
    - allergies to an antibiotic can sometimes result in more life threatening results than the bacteria
    - stomach upset
    - harm to developing fetus

Antibiotic-Resistant Bacteria

- since bacteria have a relatively fast reproductive rate, they can evolve much faster than any immune system can keep up with

- a typical spoonful of soil contains over one billion bacteria, 5 million of which are mutant strains
- this high variation causes bacteria to have a large advantage against antibiotic attack
- random mutations have allowed bacteria to become resistant to penicillin and a wide range of many other antibiotics
- over use of antibiotics causes a selective pressure on bacteria to survive
- any mutant or variant strain that survives an antibiotic, will thrive since it has no chemical control
- the result is that the antibiotic becomes obsolete and a new one must be developed to counter the “evolved” bacteria

Guided Missiles: Monoclonal Antibodies

- the antibodies produced by B cells to attack a particular microbial antigen are not all identical
- the immune system releases several varieties of the same basic shape in hopes that at least one kind will do the job
- to ensure that all the antibodies that are made are pure, and effective, a technology, developed by Kohler in 1975, is used
- an antibody-producing cell from a mouse is fused with a cancer cell – the new cell, called a **hybridoma**, inherits the characteristics of the two individual cells – it produces antibodies like a lymphocyte, while reproducing at the rate of a cancer cell (see Figure 7, p. 487)
- this makes a large number of antibodies in pure form called **monoclonal antibodies**
- this means that specific antibodies for specific diseases can now be farmed – they can be cultured in tissue, collected, and given to people who have a specific bacterial infections or cancers……
    - cultured antibodies can be used for binding to specific cancer cells (radioisotope markers)
    - guided chemotherapy – cultured antibody binds and induces an attack on cancer cells only, or binds to the toxins or poisons that are made by certain cancer cells, while not causing any harm to healthy tissues

Biological Warfare

- the use of deadly organisms, such as bacteria or viruses, as weapons of defence is known as biological warfare
- what makes these organism an ideal candidate for being an effective weapon are the following criteria:
    - the spores are deadly and live for long periods of time
    - the spores are highly contagious
    - the spores are highly resistant to environmental factors and antibiotics
- for example, the bacteria *Clostridium botulinum* produces a deadly poison and is highly contagious – one kg of this dropped in a stream could kill up to 50 000 people, 60% of which would die in 24 hours

- sometimes only antibiotic resistant genes are used
- for example, if deadly antibiotic resistant genes are spliced into a harmless microbe, like friendly intestinal *E. coli*, the body's defence mechanisms wouldn't even recognize them as deadly, and doctors wouldn't be able to diagnose the problem, let alone find a cure

Advanced Drug Delivery Systems

- this is a type of delivery system that involves the targeting and release of a drug at optimum rates and at optimum levels in the body – it operates like a natural regulatory system
- examples are "patch" drugs like nicotine, nitroglycerine, female contraception
- polymers are made that have specific antibodies incorporated into their surface
- when these antibodies bind to antigens of particular foreign molecules, that may be present in the body at certain times, the antibody-antigen complex triggers the release of a drug that is held within the polymer capsule that counteracts the foreign molecule
- certain treatments such as hormones, and insulin, which need to be administered at exactly the correct time and level, are now being taken as "slow release capsules" that time the release of the aiding chemical automatically

Homework: **1-8, p. 490**