Chapter 1 Exercise Solutions

1-1
There are numerous answers, but the following are provided as examples:

X-Ray technology

Patient Monitors

CT scanning

Artificial organs/skin

1-2
Computers in Biomedical Research 1960s
Computer-based Instruments 1970s
Artificial Intelligence 1980s
Medical Informatics 1990s
Bioinformatics 2000s

1-3
Genetic engineering does not imply an engineering function. First, via the development of specific research tools, it is possible to detect and monitor gene expression. By participating in studies to understand genetic configurations, BMEs can assist in the development of devices and/or methodologies to modify these genes.

1-4
The genome project offers the promise of developing biological markers that can be used for diagnostic purposes, as well as providing "personalized medicine" approaches that would meet the needs of specific individuals or populations once a diagnosis has been made.

1-5
In my crystal ball, the development of the computerized patient record that could enable patients to take it with them wherever they go would significantly impact health care delivery.

1-6
The Board of Trustees have overall financial control, and are responsible for electing the Chief Executive Office (CEO). Administrators are responsible for the daily operation of the hospital. The Medical Staff is primarily responsible for patient care. Clinical Engineers are essentially managers of medical technology responsible for the assessment and maintenance of medical technology.

1-7
Attributes of a clinical engineer should include:

technical knowledge

management skills

personnel supervision

1-8
Specific activities of clinical engineers include:

Technology assessment

Prepurchase evaluation

Repair of equipment

Preventative maintenance

Electrical safety

Budget management

Personnel supervision

1-9

a. Problem Solver – developer of the cardiac pacemaker, artificial heart, heart-lung machine, dialysis machine, sleep apnea monitors, physiological monitors, etc.
b. Technological Entrepreneur – biotechnology, i.e., new drugs and delivery systems, new materials, tissue, new imaging modalities.
c. Engineer Scientist – Bring about better understanding of physiological function.
d.

1-10

a.	Registered Nurse	Yes
b.	Biomedical Technician	Yes
c.	Respiratory Therapist	Yes
d.	Hospital Administrator	No

1-11

To practice BME one must develop a good understanding of mathematics, physics, engineering materials, and design. In addition, one must acquire good interpersonal and communication skills. Administrative skills can be best acquired as interns or in MBA programs.

1-12

The design of any specific prosthetic device should always be developed with the individual user in mind. As an example see the CHEETAH LEG shown on page 24.

1-13

To become a licensed prosthetician , one must complete an accredited undergraduate program in prosthetics and follow the guidelines specified by th AMERICAN BOARD for CERTIFICATION in ORTHOTICS, PROSTHETICS and PEDORTHICS.

1-14

To power a neural prosthetic device one can use the human body itself or some external source (see page 25).

1-15

The distinction between adult and embryonic stem cells are described in detail in page 28

1-16

As you search the internet, please note that the results from each state will vary.

1-17

Student Activity.

1-18

The BMES , a major BME Professional Society , is described on page 31

1-19
Student View.

1-20
Student View.

1-21
Student View.

Chapter 2 Exercise Solutions

2-1

Ethics refers to a certain part of study, whereas morality refers to the distinctive object of study. The morality of a person, nation, culture, etc. consists of a body of moral judgments, which are based on moral standards. Examples of moral judgments in a medical area are as follows:

- Active euthanasia is wrong.
- Humans should not be involved in experiments without their consent.
- Information contrived in medical records should be held in confidence between patient and physician.

Ethics would involve a study of each of these issues resulting in a list of pros and cons for consideration by the person, nation, culture, etc. Ethics is concerned chiefly with determining which moral judgments are valued in various circumstances.

2-2

Beneficence and Non Maleficence are two moral norms that have remained constant (see page 44 for details).

2-3

Controversial moral judgments include the following examples:

- Individuals should have the sole authority to accept or reject medical treatment.
- Patients needing dialysis should have full access to their treatment.
- Brain death is the criteria for the end of human life.

2-4

The end justifies the means.

2-5

Respect the patient's rights.

2-6

A code of ethics for Clinical Engineers provides guidance in making specific judgments related to the care of patients and the integration of medical devices used in that process.

2-7

Brainstem death, defined as total and irreparable loss of brain function, is when an individual is legally indistinguishable from a corpse and so may be legally treated as one. Therefore, mechanical sustenance of a person in a state of brainstem death is merely postponement of the inevitable. Neocortical death is defined as a present vegetative state. In this case, although severe damage to the brain has occurred, there is sufficient brain function to make mechanical sustenance of respiration and circulation unnecessary.

2-8

For brain death to occur the EEG must be a flat line. It is critical that each hospital develop the appropriate guidelines for these cases.

2-9

The distinction between active euthanasia and passive euthanasia rests on the difference between helping a person die and letting a person die. Involuntary euthanasia is distinguished by acts that hasten an individual's death for his or her own good, but against their wishes. Voluntary euthanasia, on the other hand, requires that substantial evidence of prior consent or patient willingness exists.

2-10
ABSOLUTRLY NOT .This decision is a personal one and should only be initiated and signed by the individual patient.

2-11
It should be honored. In the presence of a living will, there need not be any further discussion.

2-12
Human experimentation occurs when the overall aim of the treatment is to acquire new knowledge that will be useful to medical science. It is permissible only if an informed consent is attached.

2-13
The use of animal experimentation is solely dependent on the question / hypothesis being asked (see page 55). Animal research should be conducted only if it leads to new knowledge that would benefit society as a whole (see page 38).

2-14
Risk/Benefit is a critical tradeoff. All treatment should follow low risk/high benefit principles.

2-15
The place to begin is with the health care professionals in charge of the care for their patient.

2-16
The steps include the following:

1. Proof of concept
2. Prototype development
3. Small Scale test to prove feasibility
4. Larger study to determine statistical accuracy
5. Refinement as a clinical device
6. FDA approval
7. Clinical use

2-17
Practice – devices accepted and approved by the FDA for clinical use.
Research – exploratory efforts to develop a new medical device (see Section 2.8.2).
Non-validated practice – patients volunteer to partake in a novel use of a medical device (see section 2.8.3).

2-18
(see Section 2.8.1)

2-19
Informed Consent provides the opportunity for self determination (see Section 2.8.1). The patient must receive full disclosure of all information.

2-20
A feasibility study would take place in a single institution, involve no more than ten patients, and be limited to investigation of new uses or modifications of either existing devices or temporary and permanent implants.

Emergency use, on the other hand, is the use of a device to save the life of a patient under circumstances where no alternative is available.

2-21
Student View.

Chapter 3 Exercise Solutions

3-1

Relationship between mouth and left ear

The left ear is lateral to the mouth.
The mouth is medial to the left ear.

Relationship between mouth and nose

The nose is superior (cranial) to the mouth.
The mouth is inferior (caudal) to the nose.

Relationship between mouth and right big toe

The mouth is superior (cranial) to the right big toe.
The mouth is medial to the right big toe.
The right big toe is lateral to the mouth.
The right big toe is inferior (caudal) to the mouth.

3-2

Position of the Stomach in the Body & Relative to the Hearth

The stomach is located medially within the body and can be found within the abdominopelvic cavity.
The stomach is inferior (caudal) to the heart.
The heart is located in a different cavity of the body, i.e. the thorax.
Both are located in the ventral body cavity

3-5

Name	Examples	Functions
Carbohydrates	glucose, fructose, sucrose, lactose, maltose	Energy source; energy storage; structural role (when attached to lipids or proteins).
Lipids	fatty acids, waxes, triglycerides, sterols, cholesterol	Energy source; energy storage; insulation; structural components of cell membranes; chemical messengers; physical protection.
Proteins	myoglobin, hemoglobin, keratin, enzymes	Catalysts for metabolic reactions; structural components; movement; transport; buffers, defense; control & coordination of activities.
Nucleic Acids	DNA, RNA, ATP	storage and processing of genetic information; energy transfer.

3-6

Molarity = 0.5 M (0.5 mole of $CaCl_2$ per liter of solution)
Osmolarity = 1.5 Osm (0.5 M of Ca^{++} and 1 M of Cl^- per liter of solution)

$$1.0\frac{moles}{1liter}\times 6.023\times 10^{23}\frac{molecules}{mole}\times 1liters = 6.023\times 10^{23} molecules$$

3-7

Cell : **0.2 Osm**.
0.05 M $CaCl_2$ solution: **0.15 Osm**.

The $CaCl_2$ solution is hypotonic relative to the osmolarity inside the cell. Since none of the particles (protein, Ca^{++}, and Cl^-) can cross the membrane, water will move into the cell until the osmolarity inside the cell is 0.15 Osm.

$$C_1V_1 = C_2V_2$$
$$\frac{0.2Osm}{0.15Osm} \times 2nl = V_2$$
$$2.7nl = V_2$$

3-8
The principle of electrical neutrality is related to the electrical balance within a cell. It requires the over all concentrations of cations and anions inside a cell to be equal.

3-9
While initial osmolarities for both inside and outside of the cell are the same, the concentration gradient favors the movement of urea from outside the cell to inside the cell. Since the extracellular volume is infinite compared to the intracellular volume, urea will continue to move into the cell until the concentration is the same on both sides of the cell membrane, i.e. 0.2 M. If nothing else happened, the osmolarity inside the cells would be 0.4 M due to the original proteins and the accumulation of urea. Since the cell would no longer be in osmotic balance with the extracellular environment, water would move into the cell with the urea to maintain a total internal osmolarity of 0.2 M. At equilibrium, the final osmolarity of the cell will be 0.2 Osm and its volume will be 4 nl.

3-10
synthesized in **ribosomes** ---> modified inside the **rough ER** --->
packaged into vesicles by the **smooth ER** ---> attached to the **Golgi apparatus** where they are modified, repackaged, and released into new vesicles ---> leave the cell by means of exocytosis when the vesicles fuse to the plasma membrane

3-11
The mitochondria are the powerhouses inside a cell. They generate the energy required by the cell in the form of ATP. Containing the process within the mitochondria makes it possible to use relatively small amounts of enzymes because they are all located in the same area. In addition, the double compartment environment inside a mitochondrion makes it possible to generate the electrochemical gradient that is used to produce ATP.

3-12
Microtubules, intermediate filaments, and microfilaments are the main components of the cytoskeleton, which gives cells their internal organization, overall shape, and capacity to move. These 3 components of the cytoskeleton are formed by protein subunits. Cell movements can be achieved when actin and myosin interact. These are the protein subunits for microfilaments.

3-14
During transcription (versus replication),

1) only a certain stretch of DNA, i.e. a single gene, acts as the template and not the whole strand.

2) different enzymes are used.

3) only a single strand (RNA) is produced while replication produces a double-stranded DNA.
4) U pairs with A instead of T pairing with A since RNA, not DNA, is produced.

3-15

Processes called transcription and translation are used to make specific proteins determined by the genetic code. Transcription transfers genetic information from the DNA in the nucleus to mRNA, which provides the template for making proteins on the ribosomes (outside the nucleus). Translation is the actual process of making specific proteins by using the genetic information delivered by the mRNA.

Steps of Transcription

1. The sequence of nucleotides in a gene that codes for a protein is transferred to a primary transcript through complementary base pairing of the nucleotide sequence in the gene. For example, a DNA sequence of **TACCGCTTCGAT** will be changed to **AUGGCGAAGCUA** in mRNA. Areas, i.e. introns, that are not used to produce the needed protein are removed while exons, those areas that are expressed in the protein, remain. The primary transcript is now called messenger RNA, mRNA.

2. The mRNA moves out into the cytoplasm through the nuclear pores and binds to ribosomes.

3. Translation begins.

Steps of Translation

1. Transfer RNA (tRNA) delivers amino acids to the growing polypeptide chain in accordance with the codons (AUG, GCG, AAG, GUA) specified by the mRNA.

2. Peptide bonds are formed between each newly delivered amino acid and the previously delivered one.

3. The amino acid bound to the growing chain is released from the tRNA.

4. The tRNA moves off into the cytoplasm and joins with another amino acid specified by its anticodon. (UAC, CGC, UUC, CAU for anticodon in tRNA while the codon in mRNA is AUG, GCG, AAG, GUA.)

5. This process continues until a stop codon (UAA, UAG, or UGA) is reached on the mRNA.

6. The protein is either released into the cytoplasm or further modified by the rough ER.

3-16

The amino acid, methionine, always signals the starting place for translation which makes its codon the initiator codon. Therefore, it is essential that there can be only one. Otherwise, the tRNA will not know where to start the process of producing proteins (translation).

3-17

mRNA codons from Table 3.1.

	Threonine (Thr)	**Proline (Pro)**	**Lysine (Lys)**	**Alanine (Ala)**
mRNA codon	AC(A, G, U, or C)	CC(A, G, U, or C)	AAA or AAG	GC(A, G, U, or C)
DNA	TG(T, C, A, or G)	GG(T, C, A, or G)	TTT or TTC	CG(T, C, A, or G)
tRNA anti-codon	UG(U, C, A, or G)	GG(U, C, A, or G)	UUU or UUC	CG(U, C, A, or G)

3-19
The red blood cell will flow through venules and then veins in the right hand and arm until it reaches the right subclavian vein. From there, it will flow into the superior vena cava and then into the right atrium of the heart. It will flow through the tricuspid valve to the right ventricle and then through the pulmonary valve to the pulmonary trunk. The cell will then move into the right pulmonary artery and into the right lung. In the right lung, it will move into arterioles, capillaries, and venules. In the capillary bed of the lung, carbon dioxide will leave and oxygen will be delivered from the alveoli of the lungs. The red blood cell will then flow to the left atrium of the heart through the right pulmonary vein. The cell will move through the mitral valve into the left ventricle and then through the aortic valve into the aorta. From the aorta, it will flow into the right subclavian artery, other arteries, and arterioles before returning to the capillary bed of the right hand where oxygen will be delivered to the tissues and carbon dioxide will be removed.

3-20
Use Figures 3.17, 3.18, 3.19, and 3.21.

3-22
R waves have sharper peaks that are easier to detect as fiducial points than the more rounded peaks of T waves. This makes it easier to select the same relative point in the ECG for each beat to determine the time at which the beat occurred.

3-23
If the heart rate (HR) is know, then the stroke volume (SV) can be found from the following equation for cardiac output (CO):

$$CO = SV \times HR$$
$$\frac{CO}{HR} = SV$$

3-24
The pulse pressure is defined as the difference between the systolic (145 mmHg) and disastolic (98 mmHg) pressures, which would be 47 mmHg in this case.

Mean arterial pressure is the average blood pressure in the arteries and is estimated as the diastolic pressure (98 mmHg) plus one-third of the pulse pressure (15.7 mmHg), which would be 113.7 mmHg.

3-25
From Figure 3.25, vital capacity (VC) is equal to the sum of the inspiratory reserve volume (IRV), tidal volume (TV), and expiratory reserve volume (ERV).

$$VC = IRV + TV + ERV$$
$$4.2l = IRV + 0.5l + 1.2l$$
$$2.6l = IRV$$

3-26
The vital capacity must also be known in order to determine the residual volume (RV) since

$$TLC = VC + RV$$

3-27

System	Components	Functions

Central Nervous System (CNS)	Brain and spinal cord.	Integrating and coordinating sensory data and motor commands.
Peripheral Nervous System (PNS)	All the neural tissues outside the CNS.	Connect the CNS and the rest of the body.
Somatic Nervous System (SNS)	Subdivision of the PNS.	Voluntary control over skeletal muscle contraction.
Automatic Nervous System (ANS)	Subdivision of the PNS.	Involuntary regulation of smooth muscle, cardiac muscle, and glandular activities.
Sympathetic Nervous System	Preganglion fibers from the thoracic and lumbar segments of the spinal cord. Division of the ANS	"Fight or flight" system. Produces increased alertness, a feeling of energy, increased cardiovascular and respiratory activity, and general elevation in muscle tone during a crisis.
Parasympathetic Nervous System	Preganglion fibers leave the brain and sacral segment of the spinal cord. Division of the ANS	"Rest and response" system. Focus is on relaxation, food processing, and energy absorption.

3-28

The heads of myosin molecules extend and attach to nearby actin molecules at cross-bridges. The myosin heads snap towards the myosin molecule and cause the actin to slide past the myosin. The cross-bridges are released and reform at a different point on the actin. This releasing and reforming of cross-bridges is like pulling a rope hand over hand and moves the myosin and actin filaments so that the distance between Z line (where actin molecules are attached) decreases. The sliding filament mechanism is driven by energy in ATP and results in shortening of the muscle, i.e. contraction of the muscle.

3-29

The skeletal system provides a rigid system that supports the muscles of the body. The muscular system attaches to the bones of the skeletal system and provides the driving force that is used to move the bones and joints of the body. The continual contraction of some skeletal muscles helps maintain the body's posture. A system of levers, which consist of rigid lever arms that pivot around fixed points, is used to move the skeleton. Bones act as lever arms, and joints provide a fulcrum. The resistance to be overcome is the weight of the body part that is moved, and the applied force is generated by the contraction of a muscle or muscles.

3-30

Use Figure 3.40 as a model for the block diagram.