Step 7 Human Health

Here is a review of the main concepts of this step!

1 DNA and RNA, essential molecules for life

DNA, or deoxyribonucleic acid, is the molecule that contains all the instructions needed to direct the activities of the cells, the fundamental units of life. DNA is a type of nucleic acid composed of a backbone of alternating sugar (deoxyribose) and phosphate molecules. DNA contains four nucleobases: adenine, guanine, cytosine, and thymine. These bases pair (adenine with thymine, and cytosine with guanine) to form a double helix structure. DNA stores genetic information in the sequence of these bases.

RNA, or ribonucleic acid, differs from DNA in that it has ribose sugar and the nucleobase uracil instead of thymine. RNA is typically single-stranded and plays a crucial role in translating genetic information from DNA into proteins.

There are three main types of RNA:

- Messenger RNA (mRNA) carries genetic information from DNA to ribosomes, where proteins are synthesized.
- Ribosomal RNA (rRNA) is a component of ribosomes and catalyzes peptide bond formation.
- Transfer RNA (tRNA) transports amino acids to ribosomes during protein synthesis.

DNA and RNA are essential for encoding, transmitting, and expressing genetic information, and are vital for all living organisms. DNA acts as a blueprint for constructing cellular components, while RNA facilitates protein synthesis and various biochemical reactions.

2 Protein synthesis

Protein synthesis is the process by which cells create proteins using genetic information stored in DNA, and it occurs in two main stages: transcription and translation.

Transcription

The DNA double helix unfolds, and RNA polymerase uses one strand as a template to synthesize messenger RNA (mRNA). The DNA sequence in genes is copied into mRNA, which then migrates from the nucleus to the cytoplasm.

Processing mRNA

In eukaryotes, the initial mRNA, called pre-mRNA, undergoes processing to become mature mRNA. This involves:

- **Splicing:** Removal of introns (non-coding regions) from pre-mRNA, leaving only exons (coding regions).
- **Editing:** Alteration of nucleotides in mRNA, potentially creating different protein forms.
- **Polyadenylation:** Addition of a poly-A tail to the mRNA, aiding in mRNA stability, export from the nucleus, and protection from degradation.

Translation

- **Ribosome binding:** Occurs in the cytoplasm where ribosomes bind to the mRNA at the start codon.
- **Elongation:** Ribosomes facilitate the sequential binding of tRNA (transfer RNA) molecules, each carrying an amino acid. The tRNA anticodon pairs with the complementary mRNA codon.
- **Protein formation:** Ribosomes move along the mRNA, adding amino acids one by one to form a polypeptide chain according to the sequence dictated by the mRNA.
- **Termination:** A release factor binds to the stop codon, ending translation and releasing the complete polypeptide.

This intricate process ensures that genetic information is accurately translated into functional proteins, essential for various cellular functions.

3 The human body

The human body is composed of several biological systems, each performing specific functions necessary for daily life. These systems are interconnected and rely on each other to maintain normal body function.

- **The circulatory (cardiovascular) system** includes the heart, blood, and blood vessels (arteries and veins). It circulates blood to transport nutrients, gases, and other molecules throughout the body.
- **The respiratory system** comprises the trachea, diaphragm, and lungs. It facilitates breathing by allowing the intake of oxygen and expulsion of carbon dioxide.
- **The lymphatic system** consists of lymph nodes, ducts, and vessels. It produces and circulates lymph, containing white blood cells to fight infection, and removes excess lymph fluid from tissues.
- **The endocrine system** is made up of eight major glands that secrete hormones into the blood to regulate metabolism, homeostasis, growth, and sexual development.
- **The immune system** provides defense against pathogens through components such as lymph nodes, spleen, bone marrow, lymphocytes (b cells and t cells), thymus, and leucocytes.
- **The nervous system** controls voluntary and involuntary actions by sending signals throughout the body. It includes the central nervous system (brain and spinal cord) and the peripheral nervous system (nerves connecting the body to the central nervous system).
- **The musculoskeletal system** comprises about 650 muscles and 206 bones, along with tendons, ligaments, and cartilage. It supports movement, produces blood cells, and stores calcium.

- **The digestive system** involves organs like the mouth, esophagus, stomach, intestines, liver, and pancreas. It breaks down food, absorbs nutrients, and eliminates waste.
- **The excretory system** consists of kidneys, ureters, bladder, sphincter muscles, and urethra. It removes waste products (urea), regulates electrolyte balance, and maintains blood volume, pressure, and pH.
- **The reproductive system** includes sex organs that facilitate reproduction. During conception, sperm fertilizes an egg, leading to the development of a fertilized egg in the uterus.
- **The integumentary system** encompasses skin, hair, and nails. It protects against external pathogens, regulates body temperature, and eliminates waste through sweat.

4 A complex network defending the body: the immune system

The immune system defends the body against diseases and harmful environmental influences through its two main components: the innate and adaptive immune systems. The innate immune system provides a general defense against pathogens, using immune cells like scavenger and killer cells to fight bacterial infections. The adaptive immune system, on the other hand, adapts to specific pathogens through previous exposure, making it a learned or specific immune response. This system can also adapt to combat bacteria and viruses that evolve over time.

The immune system has several primary tasks: neutralizing and removing pathogens such as bacteria, viruses, parasites, and fungi; recognizing and neutralizing harmful substances from the environment; and combating the body's own cells that have become altered, such as cancerous cells.

For the immune system to function properly, various cell groups must work together to form alliances against any pathogen. Illness can occur if the immune system is compromised, if the pathogen is particularly aggressive, or if the body encounters a pathogen for the first time, as seen with the recent SARS-CoV-2 virus and its variants.

The immune system must identify foreign cells, organisms, and substances known as antigens, which include proteins on the surfaces of bacteria, fungi, and viruses. It memorizes the defense processes it activates to be prepared to defend against known pathogens in the future. Typically, the immune system recognizes the body's own cell proteins as 'self' and does not attack them. However, an autoimmune reaction occurs when the immune system mistakenly identifies its own cells as 'non-self' and attacks them.

5 Dangerous microorganisms: pathogens

Pathogens are microorganisms that cause diseases. The human body encounters pathogens daily, but the immune system usually destroys them before they can cause harm. When pathogens enter the body, they can cause infections, leading to diseases. Pathogens include viruses, bacteria, and fungi.

Viruses are small infectious agents that replicate only in living hosts. They depend entirely on the host to thrive and multiply, causing diseases ranging from colds to serious conditions like hepatitis and AIDS. The SARS-CoV-2 virus, responsible for the Covid-19 pandemic, is a coronavirus that likely originated in animals and mutated to infect humans.

Bacteria are microscopic organisms that can be rod-shaped, spherical, or spiral. They often attack after a viral infection has weakened the body's defenses. Bacteria are larger than viruses and can cause serious diseases like pneumonia, meningitis, urinary tract infections, and strep throat.

Fungi are ubiquitous microorganisms, with about 1.5 million species on Earth, but only around 300 are known to cause diseases in humans. Fungal diseases often come from fungi commonly found in the environment, both outdoors and indoors, and on human skin. While most fungi are beneficial, some can be harmful. Cryptococcosis is a potentially fatal fungal disease caused by inhaling fungal spores, leading to symptoms like fever, mental confusion, and headaches.

6 Vaccines: a protection against pathogens

Vaccines are crucial in protecting against pathogens by stimulating the immune system to produce antibodies. These antibodies recognize and neutralize disease-

causing germs, providing immunity that prevents future infections. Vaccines contain killed or weakened microbes or parts of them, which mimic infections and prompt the immune system to react and produce antibodies.

Community immunity, or herd immunity, occurs when a significant portion of a population is vaccinated against a contagious disease. This reduces the likelihood of outbreaks, protecting even those who are not vaccinated. Vaccination has effectively controlled diseases like influenza, measles, mumps, whooping cough, and pneumococcal disease, preventing serious illnesses and their complications, which can include severe disabilities or death.

The COVID-19 pandemic accelerated the development of vaccines that have been pivotal in fighting the global spread of COVID-19, emphasizing the importance of widespread vaccination to achieve community immunity and prevent future pandemics.

7 Balance is the key: homeostasis

Homeostasis is crucial for maintaining stability within the human body's internal environment. This self-regulating process continually adjusts to optimize internal conditions despite external changes. Disruptions in homeostasis, such as those leading to hypertension or diabetes, can result in disease.

A primary example of homeostasis is body temperature regulation, which typically fluctuates around 37°C (98.6°F). The hypothalamus in the brain plays a key role in this process, receiving feedback from the bloodstream regarding temperature fluctuations. Adjustments like altering breathing rates, blood sugar levels, and metabolic rates help maintain temperature within a stable range.

To manage heat, the body employs mechanisms like reduced activity, perspiration, and heat exchange near the skin's surface. Conversely, insulation, decreased skin circulation, and external sources of warmth reduce heat loss. This interplay establishes a homeostatic plateau, ensuring life-supporting conditions.

8 Pharmaceutical drugs

Pharmaceutical drugs encompass substances that alter bodily functions physically or psychologically when consumed through various methods like ingestion, inhalation, or injection.

These medications, derived from organic synthesis or plant extraction, are used to treat, prevent, diagnose diseases, or enhance well-being. Antibiotics, such as penicillin, are crucial for combating bacterial infections by inhibiting bacterial growth or reproduction. However, they are ineffective against viral infections like colds and flu. Overuse of antibiotics has led to antibiotic resistance, limiting their effectiveness and necessitating prudent use. Antibiotics can be administered orally, intravenously, or topically, with potential side effects including vomiting, indigestion, and rare severe allergic reactions.

9 Psychoactive drugs and addiction

Psychoactive drugs affect the central nervous system, altering perception, mood, or consciousness. They include legal substances like alcohol, caffeine, and tobacco, as well as illegal drugs such as cannabis, ecstasy, cocaine, and heroin. Often used for recreational purposes, these drugs can lead to addiction despite initial beliefs otherwise. They are categorized as depressants (e.g., alcohol), stimulants (e.g., caffeine), and hallucinogens (e.g., LSD), with some drugs exhibiting properties of multiple categories. Addiction is characterized by compulsive drug use despite negative consequences, often due to persistent changes in the brain. Treatment for drug addiction is complex and ongoing, tailored to individual responses and needs, addressing withdrawal symptoms and the risk of relapse.