Human Body Systems

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Learning Outcomes

- Identify major human body systems (e.g., integumentary, respiratory, nervous) and their critical functions.
- Understand the role of specific cell types, such as pneumocytes and erythrocytes, in maintaining life and how they interact with chemical agents.
- Recognize the physiological impact of damage to specific systems, such as the collapse of alveoli or interruption of oxygen transport.

Reading

- Foundations of Spiritual and Physical Safety: with Chemical Processes; Chapter 3, Sections 1-2 (Chemical Lethality).

This section provides an overview of human body systems and toxicology, which are essential for understanding how injuries occur. It covers the major body systems, some of their functions, and how they can be affected by chemical exposures.

1 Major Human Body Systems

nervous system

The nervous system consists of the brain, spinal cord, and nerves. It controls and coordinates body activities. Damage to the nervous system can lead to loss of sensation, paralysis, or death.

circulatory system

The circulatory system includes the heart, blood vessels (arteries and veins), and blood. It transports oxygen, nutrients, and waste products throughout the body. Damage to this system can result in hemorrhage, shock, or organ failure. Typical blood volume is 5 liters (1.3 gallons). It takes 20 - 60 seconds for a red blood cell (one of

20-30 trillion) to make a full circuit of the body. Starting in the right atrium it then moves to the right ventricle, pulmonary artery, lungs (to pick up oxygen), pulmonary vein, left atrium, left ventricle, aorta, arteries, capillaries (to deliver oxygen), veins, and back to the right atrium.

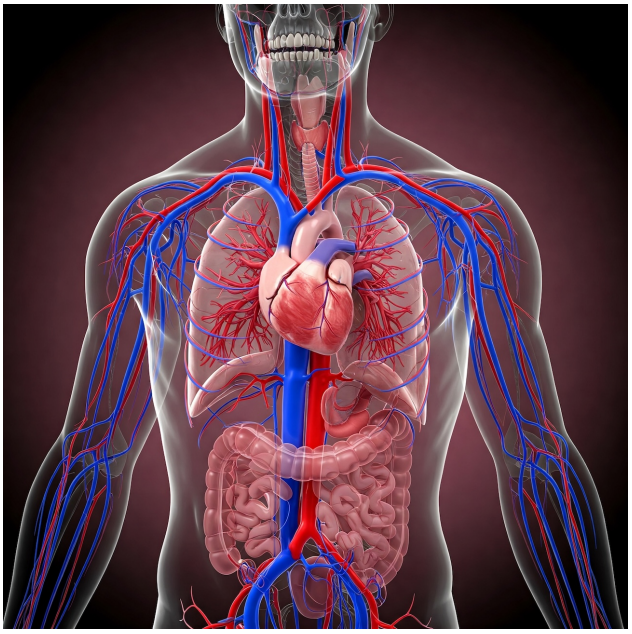


Figure 1: AI generated image of parts of the circulatory, respiratory, and digestive systems.

Figure 2: AI generated image of the heart where blood flows through the chambers and valves. Oxygen-deficient blood enters the right atrium from the superior vena cava, moves to the right ventricle, and is pumped to the lungs via the pulmonary artery. Oxygen-rich blood returns to the left atrium, moves to the left ventricle, and is pumped out to the body through the aorta. Heart vessels (not shown) supply the heart muscle with oxygen and nutrients.

skeletal system

The skeletal system is made up of bones, cartilage, and ligaments. It provides structural support, protects internal organs, and facilitates movement. Damage to the skeletal system can lead to fractures, dislocations, or impaired mobility.

muscular system

The muscular system consists of muscles that enable movement and maintain posture. It works in conjunction with the skeletal system. Damage to muscles can result in strains, tears, or loss of function.

digestive system

The digestive system includes the mouth, esophagus, stomach, intestines, liver, and pancreas. It breaks down food into nutrients that the body can absorb. Damage to this system can lead to malnutrition, dehydration, or systemic toxicity.

respiratory system

The respiratory system comprises the lungs, trachea, bronchi, and alveoli. It facilitates the exchange of oxygen and carbon dioxide. Damage to the respiratory system can result in impaired gas exchange, respiratory distress, or failure.

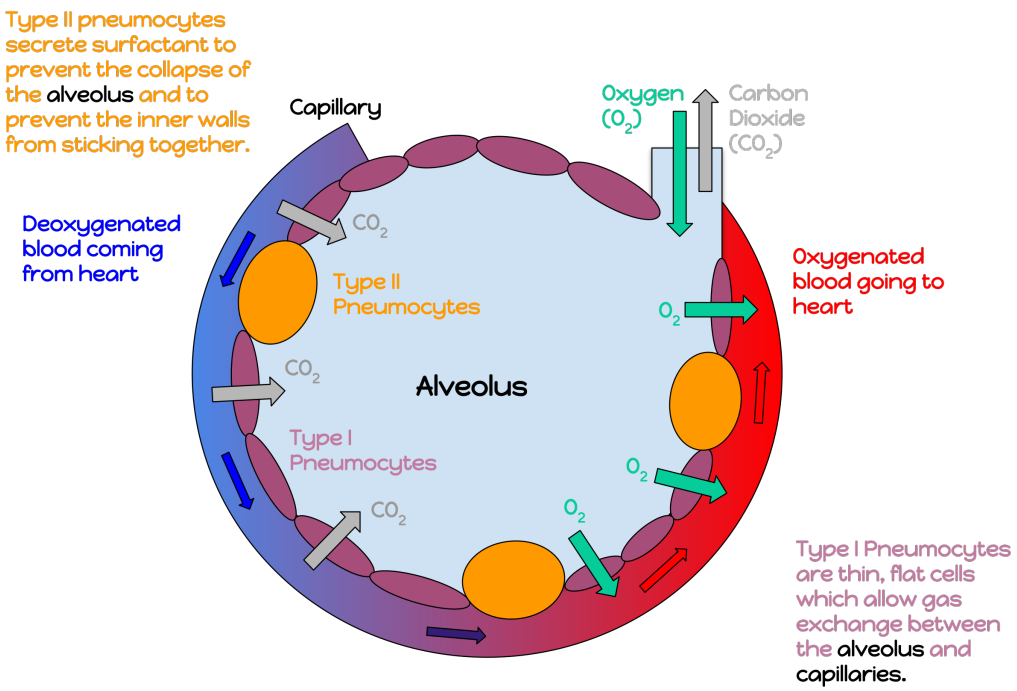


Figure 3: Un adapted image of an alveolus: a 200 micron diameter air sac found in the bronchi of the lungs. Credit to Katherinebutler1331, used per the Creative Commons Attribution-Share Alike 4.0 International license.

2 Cell Types and Functions

3 Injury Modes

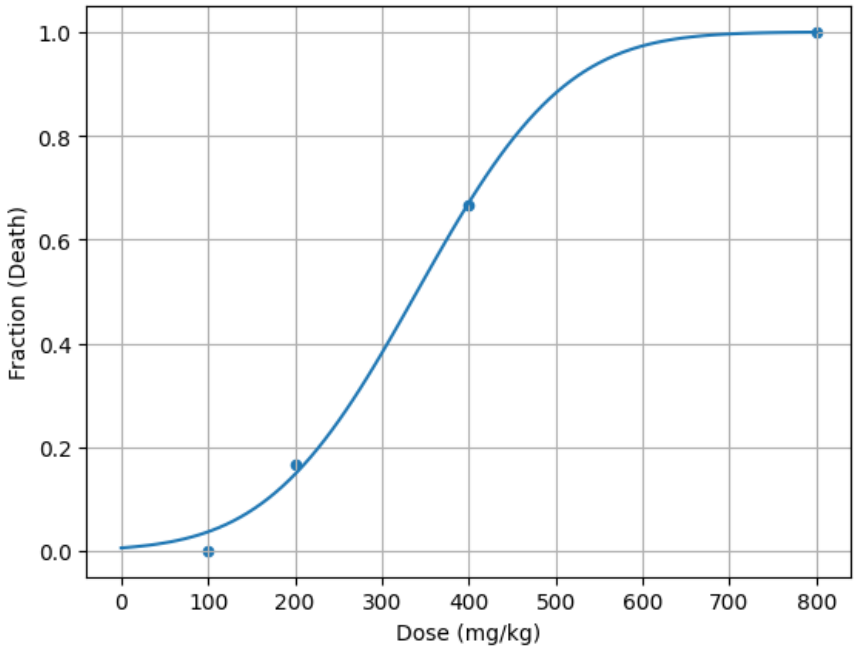
Human Body System	Common Injury Modes
Muscular, skeletal	Slips, trips, falls, heavy or awkward lifting of objects, falling objects, machine crushing or cutting, high-speed or high-energy debris, blast or pressure waves, or blast fragment
Integumentary (skin, ears, eyes)	Cuts, thermal burns, chemical burns, noise, damage to eyes
Nervous, circulatory, digestive, respiratory, excretory, endocrine, reproductive, lymphatic, microbiome	Chemical interactions upon absorption through the skin, inhalation, ingestion, or injection

4 Chemical Lethality

```
import numpy as np; import pandas as pd
import matplotlib.pyplot as plt
from scipy.optimize import curve_fit
from scipy.stats import norm
#create a dataframe with the data
```

```
df = pd.DataFrame([100,200,400,800], columns=['Dose (mg/kg)'])
df['Fraction (Death)'] = [0/6,1/6,4/6,6/6]
#set function for fitting with curve_fit
def cumulative_gaussian(x, mu, sigma):
    return norm.cdf(x, mu, sigma)
# fit a cumulative gaussian to the data
popt, pcov = curve_fit(cumulative_gaussian, df['Dose (mg/kg)'], df['Fraction (Death)'],p0=[350, 100])

x = np.linspace(0, 800, 100)
y = cumulative_gaussian(x, *popt)
#plot the data and the fit
df.plot(x='Dose (mg/kg)', y='Fraction (Death)', kind='scatter')
plt.plot(x, y, label='fit'); plt.grid()
plt.show()
```



$Y = \text{scipy.stats.norm.ppf}(f) + 5$

where Y is the probit value and f is the mortality fraction of probability.

4.1 Thought Experiment

Roll two dice (you can do that virtually here: https://www.calculator.net/dice-roller.html) with the following criteria and plot the results:

- Roll the dice 5 times and count how many times you get a sum less than 3
- Roll the dice 5 times and count how many times you get a sum of 3 to 5
- Roll the dice 5 times and count how many times you get a sum 5 to 12

Plot the results.

Action Items

1. Pick a human cell type mentioned in the sources (e.g., pneumocytes or erythrocytes) and research its function; write three paragraphs discussing its specific role in the body and the potential consequences if these cells were damaged by chemical exposure.
2. Explain the pathway through which a chemical entering the respiratory system eventually interacts with cells throughout the body.
3. Plot the linearized version of the plot given in the Figure above.