Leaf Structure and Function

Leaf Functions

The primary functions of a leaf are:

- **Photosynthesis**: To produce glucose (food)
- **Gas Exchange**: To facilitate the intake and output of gases
- **Transpiration**: To allow water loss through the stomata

Stem Functions

The functions of the stem include:

- **Transportation**: Moving food to all plant parts via the phloem.
- **Water and Mineral Transport**: Transporting water and minerals from roots to leaves via the xylem.
- **Anchoring**: Providing support through roots and root hairs.
- **Storage**: Acting as a storage organ in some plants (e.g., potatoes and carrots).

Leaf Anatomy

The leaf consists of several key parts:

- **Petiole**: The stalk that attaches the leaf blade to the stem.
- **Midrib**: The central vein running along the length of the leaf blade.
- **Blade**: The broad, flat part of the leaf.
- **Margin**: The edge of the leaf blade.
- **Veins**: A network branching from the midrib that delivers water and salts to the leaf cells and carries away the food made by them, while also supporting the soft tissues of the leaf blade.

Internal Structure of a Leaf

Cuticle

A transparent, waxy layer on the surface of the leaf that helps reduce water loss.

Epidermis

A layer of cells on the upper and lower surfaces of the leaf, which are transparent to allow light to penetrate to the photosynthetic cells below.

Mesophyll

The middle layer of the leaf, where most photosynthesis occurs. It is divided into two types:

- **Palisade Mesophyll**: Consists of closely packed, elongated cells containing many chloroplasts, located just below the upper epidermis.
- **Spongy Mesophyll**: Located below the palisade layer, with irregularly shaped cells and large air spaces to facilitate gas exchange.

Veins

Situated in the mesophyll layer, they transport water and minerals via **xylem vessels** and transport food and nutrients via **phloem vessels**.

Lower Epidermis

A single layer of cells on the underside of the leaf containing **stomata**.

Stomata

Pores in the lower epidermis that allow for gas exchange. Each stoma is flanked by two **guard cells** that regulate the opening and closing of the pore.

Gas Exchange in Leaves

Night

Process	Description
Respiration	Leaf cells use oxygen, leading to a lower oxygen concentration in the spongy mesophyll layer.
Oxygen Diffusion	Oxygen diffuses into the leaf from the outside air (high concentration to low concentration).
Carbon Dioxide	Carbon dioxide is produced during respiration, resulting in a higher concentration of carbon dioxide inside the leaf. Consequently, carbon dioxide diffuses out of the leaf.

Daylight

Process	Description
Photosynthesis	During the day, photosynthesis occurs, using carbon dioxide and producing oxygen.
Oxygen Concentration	The oxygen concentration inside the leaf increases due to photosynthesis, causing oxygen to diffuse out of the leaf.
Carbon Dioxide Diffusion	Carbon dioxide from the air diffuses into the leaf for photosynthesis.

Stomata Functionality

Guard Cells

> The only cells in the epidermis with chloroplasts. They regulate the opening and closing of the stomata.

- **Turgid Guard Cells**: When guard cells are turgid (full of water), the stoma opens, facilitating gas exchange.
- **Flaccid Guard Cells**: When guard cells lose water and become flaccid, the stoma closes to prevent further water loss.

Photosynthesis Equation

$$CarbonDioxide + Water \xrightarrow{LightEnergy} Glucose + Oxygen$$

Wilting

If leaves lose water, the guard cells become flaccid, causing the stomata to close, which helps prevent excessive water loss.

Gaseous Exchange in Humans

Necessity of Gaseous Exchange

All bodily processes such as growth and reproduction require energy, which is obtained from food. Aerobic respiration requires oxygen and produces carbon dioxide as a waste product, necessitating a constant supply of oxygen and removal of carbon dioxide.

Why Not Skin?

Gaseous exchange does not occur through the skin in humans because:

- Surface Area to Volume Ratio: Humans have a small surface area to volume ratio, making diffusion too slow to meet oxygen demands.
- Impermeable Skin: Human skin minimizes water loss, which makes it impermeable to gases.

The Respiratory System

Lungs

> Provide a large, moist surface area suitable for gas exchange.

Pathway of Air

1. **Nose/Nasal Cavity**: Air enters through the nose, where sticky mucus and hairs trap large particles like dust and bacteria, filtering the air.
2. **Trachea**: The windpipe that connects the mouth to the lungs.
3. **Bronchi**: The trachea divides into two smaller tubes called bronchi, which enter the lungs.
4. **Bronchioles**: The bronchi further divide into smaller branches called bronchioles.
5. **Alveoli**: The bronchioles terminate in air sacs called alveoli, where gas exchange occurs.

Mechanism to Remove Dust Particles and Bacteria

Goblet cells produce mucus, and ciliated epithelial cells move this mucus up to the throat to be swallowed, removing any trapped particles.

Alveoli

> Tiny air sacs surrounded by capillaries where gas exchange occurs.

The Process of Gaseous Exchange

1. **Deoxygenated Blood**: Blood arrives at the capillaries surrounding the alveoli via the pulmonary artery. This blood is low in oxygen.
2. **Oxygen Diffusion**: Oxygen-rich air in the alveoli causes oxygen to dissolve in the moisture lining the alveoli and diffuse into the blood through the thin membrane.
3. **Oxygenated Blood**: Blood becomes oxygenated and is carried to the heart via the pulmonary vein to be pumped to the rest of the body.
4. **Hemoglobin**: Oxygen combines with hemoglobin in red blood cells for transport.
5. **Carbon Dioxide Diffusion**: Blood arriving in the capillaries contains a high concentration of carbon dioxide, which diffuses from the blood into the alveoli.
6. **Exhalation**: Carbon dioxide is removed from the body during exhalation.

Inhalation and Exhalation

Inhalation

1. Diaphragm Contraction: The diaphragm muscles contract, causing the diaphragm to flatten and pull down.
2. Intercostal Muscles Contract: The intercostal muscles contract, pulling the rib cage upwards and outwards.
3. Volume and Pressure Changes: The volume of the thorax increases, decreasing the internal pressure in the lungs, allowing air to be drawn in through the nose and trachea.

Exhalation

1. Diaphragm Relaxation: The diaphragm muscles relax, allowing the diaphragm to return to its domed shape.
2. Intercostal Muscles Relax: The intercostal muscles relax, causing the ribs to be pulled downwards.
3. Volume and Pressure Changes: These movements decrease the internal volume and increase the internal pressure, forcing air out of the lungs.

Composition of Inhaled and Exhaled Air

Gas	Inhaled Air (%)	Exhaled Air (%)
Oxygen	High	Decreases
Carbon Dioxide	Low	Higher
Nitrogen	Same	Same

Additional points

- Nitrogen: The percentage of nitrogen remains the same, indicating it is not used or produced during respiration.
- Lung Capacity and Breathing Rate: Breathing rate varies based on activity level. A normal breathing rate at rest is about 16 breaths per minute.

Exercise and Fitness

Pulse Rate and Fitness

An **unfit person** tends to have a higher pulse rate before, during, and after exercise compared to a fit person. The rate at which breathing and heart rate increase during and after exercise indicates fitness levels.

> **Recovery Time**: The time it takes for the pulse to return to normal after exercise. A fit person has a faster recovery time than an unfit person.

A fit person's pulse will be lower, reducing the chances of diseases and prolonging life.

Smoking and Its Effects

Nicotine

Nicotine is an addictive substance that raises blood pressure and heart rate. It narrows blood vessels, potentially leading to heart attacks or strokes.

Carbon Monoxide

Carbon monoxide, produced when a cigarette burns, reduces the oxygen-carrying capacity of red blood cells (hemoglobin). This causes smokers to experience shortness of breath.

If a smoker is pregnant, the reduced oxygen delivery to the fetus can slow down its growth.

Emphysema

> **Emphysema**: An incurable disease caused by smoking, characterized by frequent coughing that damages the alveoli in the lungs.

Damaged alveoli result in less surface area for gas exchange, making breathing difficult.

Respiratory Surfaces

Characteristics of Respiratory Surfaces

All respiratory surfaces share the following characteristics:

- **Large surface area**: Allows for a large volume of gases to be exchanged quickly.
- **Thin**: Reduces the distance gases need to diffuse.
- **Moist**: Enables gases to dissolve and diffuse efficiently.
- **Good blood supply**: Maintains a concentration gradient for efficient gas exchange.

Gas Exchange

The many branching air passages increase the surface area. The short diffusion distance and the ventilation of the lungs maintains the concentration gradient.

Oxygen diffuses from the air in the alveoli or gills into the blood capillaries. **Carbon dioxide**, a waste product of respiration, is removed from the body through these respiratory surfaces.