DP IB Environmental Systems & Societies (ESS): SL

Your notes

Introduction to Water Systems

Contents

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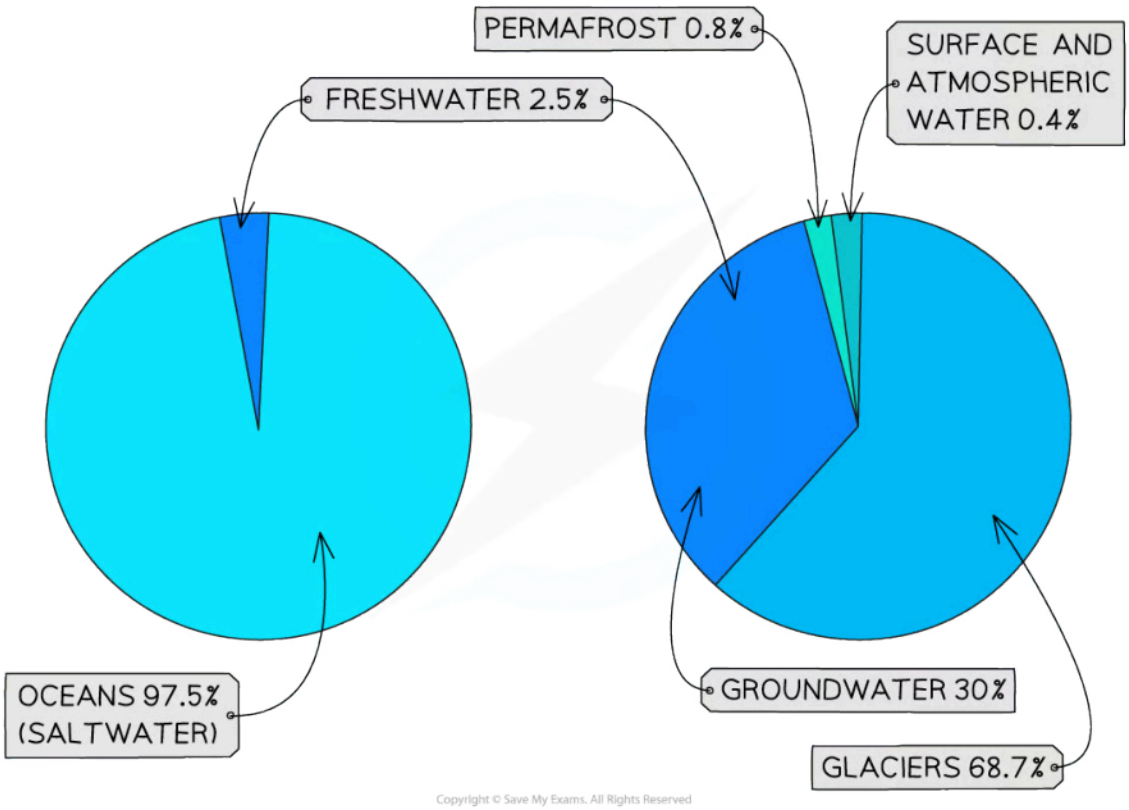
The Hydrological Cycle

Water on Earth

- Fresh water only makes up a small fraction (approximately 2.5% by volume) of the Earth's water storages
- Of this fresh water, approximately 68.7% is stored in glaciers and ice sheets and 30% is stored as groundwater
- The remaining 1.3% of freshwater is in rivers, lakes and the atmosphere
- All water is part of the **hydrological cycle**



Sources of water on Earth

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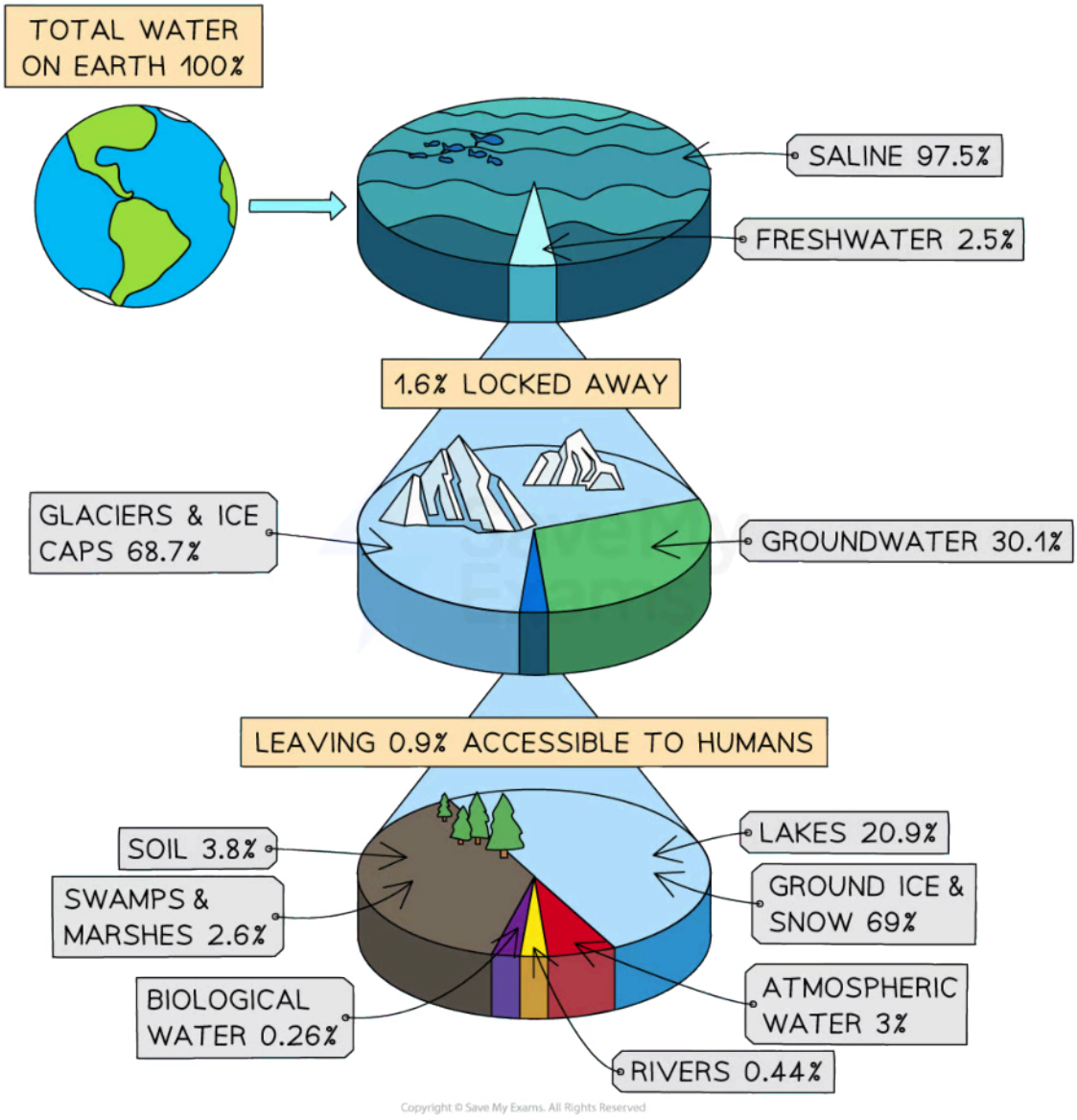

Comparison of the world's freshwater stores

Hydrological Cycle

- The hydrological cycle is a **closed system**
- Within the hydrological cycle, there are **stores** and **flows**
- The hydrological cycle is a series of processes in which water is constantly recycled through the system

- The cycle also shapes landscapes, transports minerals and is essential to life on Earth
- The main flows occurring within the hydrological cycle are:
  - **Transformations**:
    - Evaporation - the sun evaporates surface water into vapour
    - Condensation - water vapour condenses and precipitates
  - **Transfers**:
    - Water runs off the surface into streams and reservoirs or beneath the surface as ground flow
- These processes **move** the water on Earth from one **store** to another (river to ocean or ocean to atmosphere)
- The hydrological cycle involves energy exchange, leading to local **temperature fluctuations**
  - As water evaporates, it absorbs energy from its surroundings
  - This effectively cools the environment
  - The reverse happens when water condenses (heat is released)
  - This heat exchange influences the **local climate**


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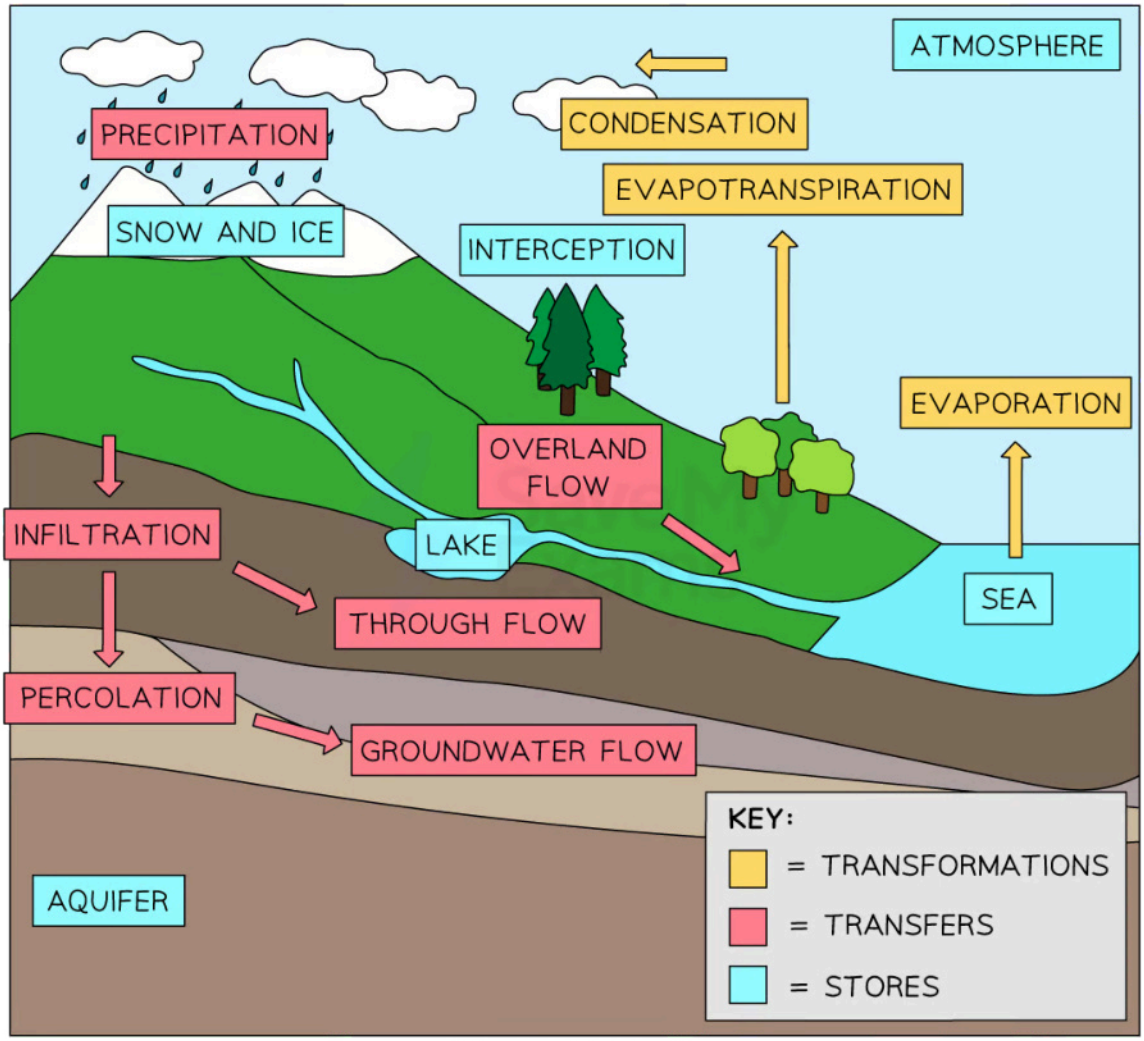

The hydrological cycle

Storages

- Storages in the hydrological cycle include:
  - Rivers, lakes and oceans
  - Groundwater (**aquifers**)
  - Soils
  - The atmosphere

- Glaciers and ice caps
- Organisms (e.g. trees)


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Flows

- Flows in the hydrological cycle include:
  - Evapotranspiration (transformation)
  - Sublimation (transformation)
  - Evaporation (transformation)
  - Condensation (transformation)
  - Melting (transformation)
  - Freezing (transformation)
  - Advection (transfer)
  - Precipitation (transfer)
  - Flooding (transfer)
  - Surface run-off (transfer)
  - Infiltration (transfer)
  - Percolation (transfer)
  - Stream-flow or currents (transfer)

Flows in the Hydrological Cycle

Flow	Description
Evaporation	The process by which liquid water changes into a gaseous state (water vapour) and enters the atmosphere from water bodies such as oceans, lakes, and rivers
Transpiration	The process by which plants absorb water from the soil through their roots and release it as water vapour through tiny openings called stomata in their leaves
Evapotranspiration	The combined process of water vaporisation from the Earth's surface (evaporation) and the release of water vapour by plants through transpiration

Sublimation	The direct transition of water from a solid (ice or snow) to a vapour state without melting first
Condensation	The process in which water vapour in the atmosphere transforms into liquid water, forming clouds or dew, as a result of cooling
Advection	The horizontal movement of water vapour, clouds, or precipitation caused by the prevailing wind patterns
Precipitation	The process of water falling from the atmosphere to the Earth's surface in the form of rain, snow, sleet, or hail
Melting	The process by which solid ice or snow changes into liquid water due to an increase in temperature
Freezing	The process by which liquid water changes into a solid state (ice or snow) due to a decrease in temperature
Flooding	The overflow of water onto normally dry land, often caused by heavy rainfall, melting snow, or dam failure
Surface run-off	The movement of water over the Earth's surface, typically occurring when the ground is saturated or impermeable, leading to excess water
Infiltration	The process of water seeping into the soil from the surface, entering the soil layers and becoming groundwater
Percolation	The downward movement of water through the soil and underlying rock layers, eventually reaches aquifers or groundwater reservoirs
Stream-flow or currents	The movement of water in streams, rivers, or other water bodies, driven by gravity and the slope of the land, ultimately leads to oceans or lakes

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Examiner Tips and Tricks

Remember that percolation and infiltration are not the same. Percolation happens after the water has infiltrated the soil.

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Human Impact on the Hydrological Cycle

- Human activities, such as agriculture (specifically irrigation), deforestation, and urbanisation, have significant impacts on the hydrological cycle, altering the natural processes of **surface run-off** and **infiltration**

Photo by Przemyslaw Stroinski on Unsplash

Agricultural irrigation has an impact on the hydrological cycle

The impact of agriculture and irrigation on the hydrological cycle

- Irrigation is the process of artificially supplying water to agricultural crops
  - It has a direct impact on the hydrological cycle by modifying the water distribution and availability in a region
- Increased irrigation leads to artificially high evapotranspiration rates as more water is supplied to plants than would occur naturally, resulting in increased atmospheric moisture levels
- This can lead to localised **increases in precipitation** downwind of irrigated areas, altering rainfall patterns in the region
- Additionally, excessive irrigation can result in **increased surface run-off**
  - When water is applied faster than the soil can absorb it, it flows over the surface, carrying sediments, fertilisers, and pesticides, leading to **water pollution** and **nutrient imbalances**

The impact of deforestation on the hydrological cycle

- Deforestation refers to the clearing or removal of forests, primarily for agriculture, logging, or urban development purposes
- Forests play a crucial role in the hydrological cycle
  - They act like natural **sponges**, absorbing rainfall and facilitating infiltration, which helps **recharge groundwater** and maintain stream flows
- When forests are cleared, **surface runoff increases** significantly
  - Without the tree canopy and vegetation to intercept and slow down rainfall, more water reaches the ground surface, leading to higher surface runoff rates
- Deforestation also **reduces evapotranspiration** rates
  - As trees are removed, there is less transpiration and evaporation occurring, resulting in reduced moisture release into the atmosphere
- Overall, deforestation disrupts the balance between surface run-off and infiltration, leading to **increased erosion**, reduced groundwater recharge, and altered stream flow patterns

The impact of urbanisation on the hydrological cycle


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Photo by Chris Gallagher on Unsplash

Urbanisation has an impact on the hydrological cycle

- Urbanisation involves the transformation of natural landscapes into urban areas with buildings, roads, and infrastructure
- Urban development dramatically alters the hydrological cycle by replacing permeable surfaces (such as soil and vegetation) with **impermeable surfaces** (concrete, asphalt)
  - Impermeable surfaces **prevent infiltration**, leading to **reduced groundwater recharge**
  - Instead of infiltrating into the soil, rainfall quickly becomes surface runoff, resulting in **increased flooding** and diminished water availability during dry periods
- Urban areas typically have efficient drainage systems designed to remove the excess water quickly
  - This further accelerates surface runoff, which can **overload natural water bodies** and cause downstream flooding
- Urban areas often experience higher temperatures due to the urban heat island effect

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- This effect, caused by the concentration of buildings and paved surfaces, increases evaporation rates, altering local precipitation patterns


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Ocean Circulation

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Ocean Circulation

What Causes Ocean Circulation?

- Ocean circulation systems are driven by differences in **temperature** and **salinity**
- The resulting difference in water density drives the **ocean conveyor belt**, which distributes heat around the world and thus affects climate

Ocean Conveyor Belt

- Ocean currents **redistribute** heat energy around the globe
- The currents (warm or cold) act a bit like 'rivers' of water in the sea
- Cold currents move towards the **equator** and warm currents towards the **poles**
- Each ocean has its own pattern of currents
  - E.g. the warm Atlantic Ocean waters of the low latitudes are moved to **high latitudes** via the North Atlantic Drift
- All ocean currents are triggered by the **prevailing surface winds** created by global atmospheric circulation
- Ocean circulation is also maintained through **convection currents** driven by cold water freezing into ice at the poles
  - The polar cold waters contain **denser**, saltier sea water, which **sinks** to the ocean floor
  - Water then flows in above it at the surface, which forms a current
  - The deep ocean currents then flow towards Antarctica along the western Atlantic basin, before splitting off into the Indian and Pacific Oceans where the water begins to warm up
  - The warming makes the water **less dense** so it loops back up to the ocean **surface** in the South and North Atlantic Ocean
  - The warmed surface waters continue to flow around the globe and eventually return to the North Atlantic, where the cycle begins again
- This movement of water is known as the **thermohaline circulation** and drives the ocean conveyor belt

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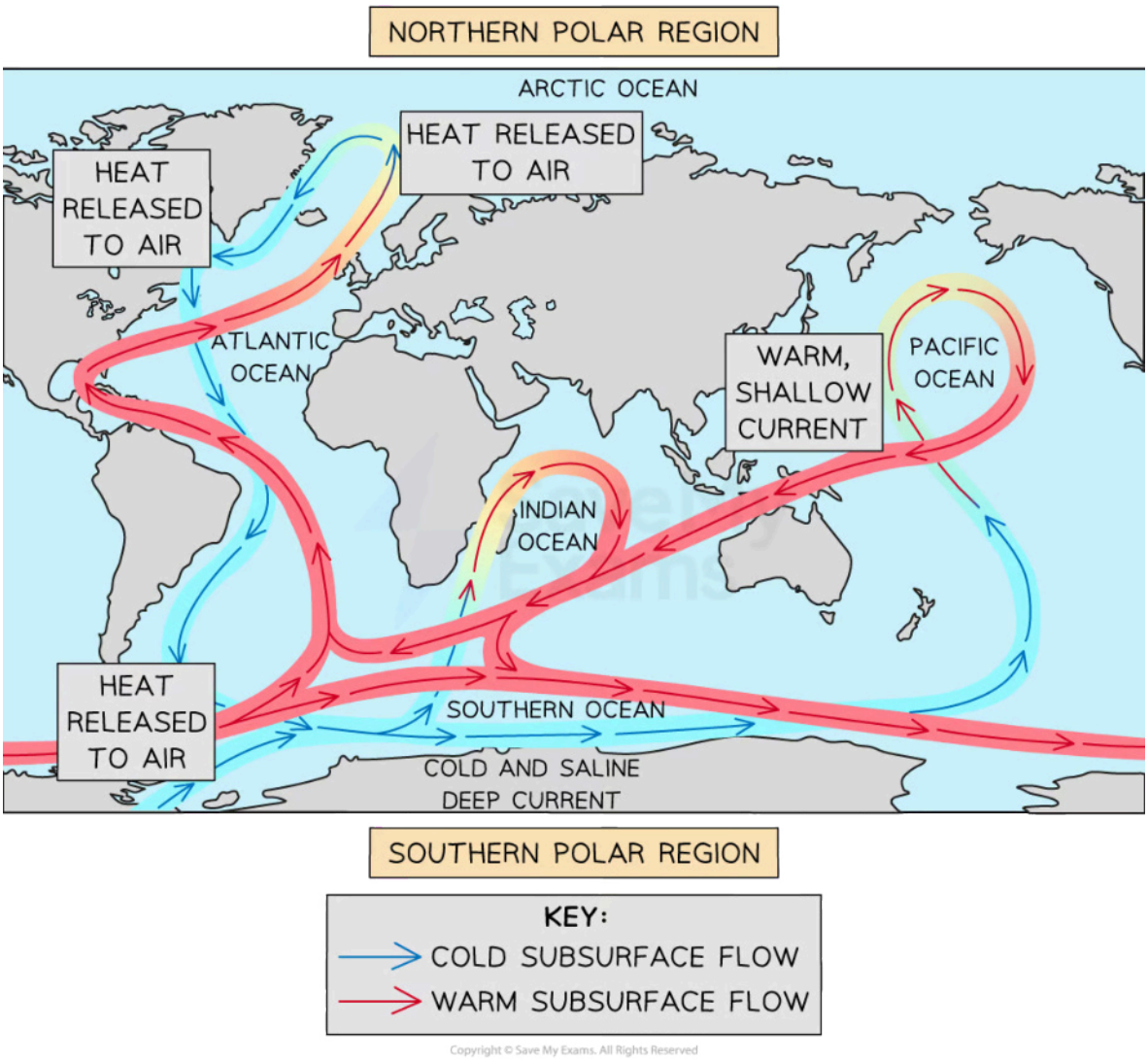

The ocean conveyor belt transports heat and energy around the world, affecting climate