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Geography

Hadley Cell

HADLEY CELL

+ Inter-Tropical Convergence Zone [ITCZ]
+ Sub-Tropical High Pressure Belt [STHP]
+ Trade Winds

Important to note!

ALL WINDS TRAVEL FROM A REGION OF

HIGH PRESSURE

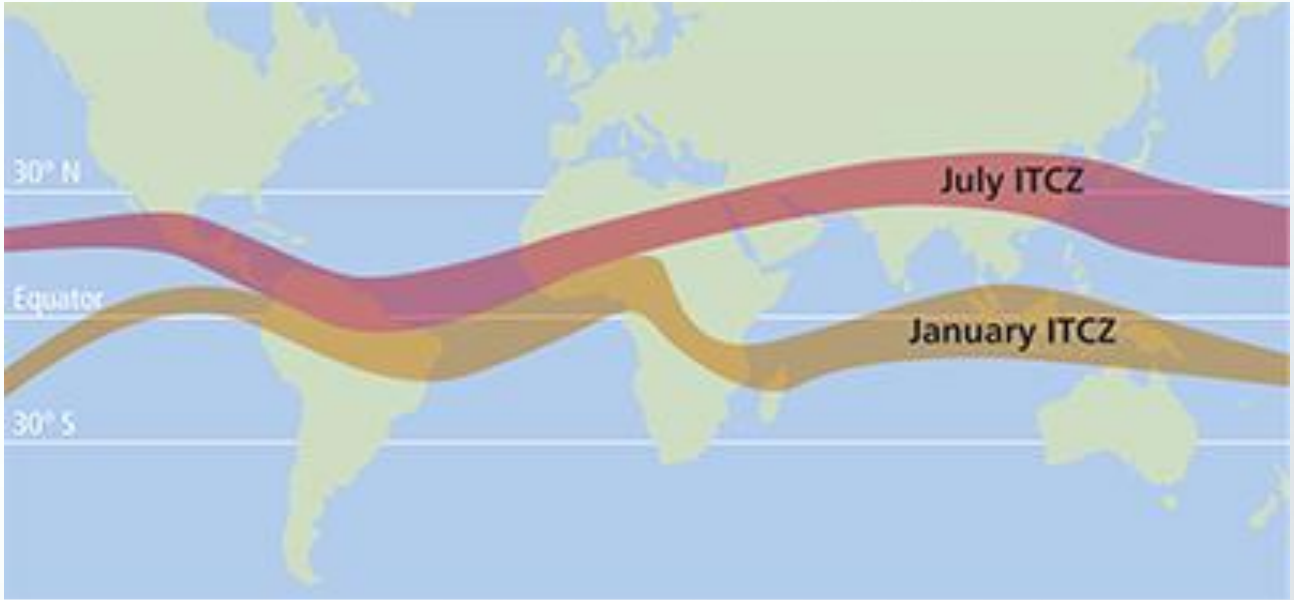
TO

LOW PRESSURE

Inter-Tropical Convergence Zone [ITCZ]

+ a **LOW PRESSURE** belt
+ A driver of trade winds as they move from a region of high to low pressure [zone of convergence of TWs from SH and NH].
+ Follows the position of the overhead sun
+ Line of maximum insolation
+ Rapid, rising moist warm air → High amount of convectional rainfall

ITCZ in different months



Position of ITCZ

June/July: Found in Asia due to Asia being summer period, found near 23.5 degrees north [Tropic of Cancer] → ITCZ can go up to 30-40 degrees North.

December/January: Found in 23.5 degrees south [Tropic of Capricorn] → goes **no** more than 5 degrees due to small continent of Australia.

Sub-tropical High Pressure Belt [STHP]

+ A **HIGH PRESSURE** BELT
+ It is where sinking air is found due to high pressure → Extremely dry.
+ Follows the **MOVEMENT** of ITCZ.
+ Trade winds are generated here and moves towards ITCZ [Low Pressure]

TRADE WINDS

- Known as the **surface winds** as air moves back towards the equator/ITCZ.
- Moves from STHP to ITCZ.
- Follows the **MOVEMENT** of ITCZ.
- Drops rain on land before coming to ITCZ when the trade winds converge as they force air to rise and reach dew point temperature.

Exam Requirements

- Hadley Cell question types can come out as the bigger mark questions [i.e. 16 or 20m essays].
- Such questions require you to make a **judgement** on the **influence of ITCZ/STHP** relative to other factors.
- Hence, ways you can make such a judgement is through the use of criteria → For instance, ITCZ affects all climates due to its **global/macro influence** as compared to other factors which may only be **localised**.

Sample A Level Question

Qn. To what extent is ITCZ the most important factor in influencing rainfall in the tropics? [20]

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Geography

Monsoon Winds

Monsoon Winds

- SouthWest Monsoon
- NorthEast Monsoon

Special Cases:

- Asian Monsoon
- African Monsoon

Important to note!

ALL MONSOON WINDS TRAVEL FROM A REGION OF

<u>HIGH PRESSURE</u>

TO

<u>LOW PRESSURE</u>

Main Causes of Monsoon Winds

+ **Coriolis Force/Effect** → Responsible for where MWs travel to [Deflected rightwards in NH and leftwards in SH]
+ Due to changes in **season**
+ **Eurasian Continent** → Causes a large pressure gradient between the NH and SH.

SouthWest Monsoon Winds

+ *Easy Way to remember*: Since '**SOUTH**' comes first, winds must travel from **SOUTH** to **NORTH**.
+ Occurs in **June/July**.
+ Generated due to a differences in **season** → SH experiencing **Winter** while NH experiences **Summer** due to relative position of OHS.
+ As winds pass the equator, beyond 5°N, it experiences the Coriolis force hence winds will be deflected rightwards resulting in the **southwest** monsoon winds.

NorthEast Monsoon Winds

+ Easy Way to remember: Since **'NORTH'** comes first, winds must travel from **NORTH** to **SOUTH**.
+ Occurs in **Dec/Jan**.
+ Generated due to a differences in **season** → NH experiencing **Winter** while SH experiences **Summer** due to relative position of OHS.
+ As winds pass the equator, beyond 5°S, it experiences the coriolis force hence winds will be deflected rightwards resulting in the **NORTHEAST** monsoon winds.


Earth's Oceans
Arctic Ocean
North Pacific Ocean
North Atlantic Ocean
North Pacific Ocean
South Pacific Ocean
South Atlantic Ocean
Indian Ocean
Southern Ocean
JC
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ASIAN Monsoon – India

+ **June/July:** SW Monsoon → India has high levels of rainfall as moisture comes from the Indian Ocean.
+ **Dec/Jan:** NE Monsoon → India is dry → Monsoon winds coming from Eurasia bypasses the Himalayas mountain → Rain is only deposited at the windward side → India receives no rain [Known as the **DRY** monsoon winds]

AFRICAN Monsoon – West Africa

- **June/July:** SW Monsoon → high levels of rainfall as moisture comes from the Atlantic Ocean.
- **Dec/Jan:** NE Monsoon → West Africa is dry → Due to continental effect as monsoon winds generated over land do not absorb as much moisture to bring heavy rain.

AFRICAN Monsoon – East Africa

- **June/July:** SW Monsoon → high levels of rainfall as moisture comes from the Indian Ocean.
- **Dec/Jan:** NE Monsoon → East Africa is wet → Due to transition between seasons which bring rainfall due to ITCZ from the Indian Ocean.

Exam Requirements

- Monsoon Wind question types can come out as the bigger mark questions [i.e. 16 or 20m essays] or smaller marks.
- Such questions require you to make a **comparison** on the **influence of monsoon winds** relative to other factors.
- Hence, ways you can make such a judgement is through the use of criteria → For instance, Monsoon wind affects all climates due to its **regional influence** as compared to ITCZ which may only be **global** hence smaller influence.

Sample A Level Question

Qn. To what extent are monsoon winds the most important factor in influencing rainfall in the tropics? [20]


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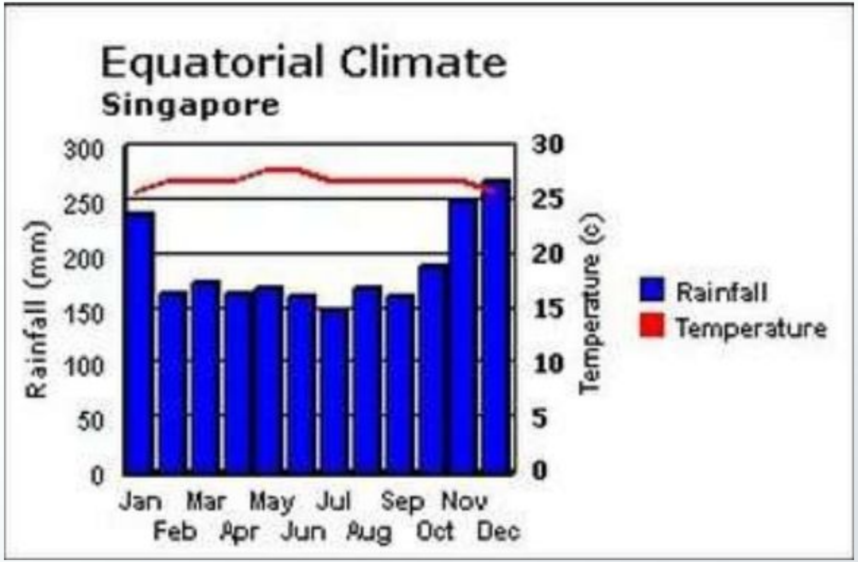
Geography

Koppen-Geiger Climates

Tropical Rainforest (Af)

- Found at equator → 0-5°N/S.
- Around **2000-3000 mm** of **UNIFORM** rainfall annually.
- High temperature of around **27°C** annually.
- High rainfall due to **dominance** of ITCZ.

Climograph of Af climate



Tropical Monsoon (Am)

- Found beyond 5°N/S → Requires coriolis effect.
- Around **2000-2500 mm** of **SEASONAL** rainfall annually.
- High temperature of around **25°C** annually.
- High seasonal rainfall due to **dominance** of monsoon winds.

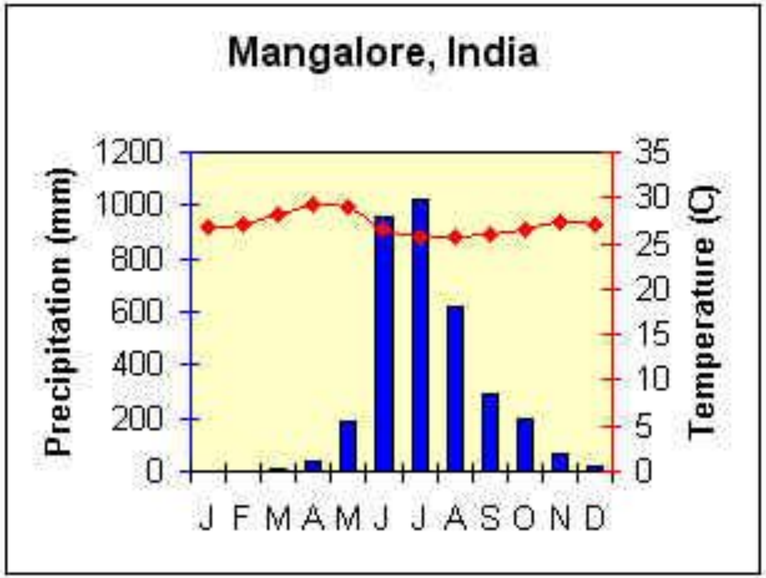
Tropical Monsoon Climates

- Important to take note of the **2** different monsoons and how each brings different dryness or intensity of rainfall.
- Different countries/continents would also be affected differently → Look at **Asia** and **African** Monsoon case studies [*In Monsoon video*]

SouthWest Monsoon: June/July

NorthEast Monsoon: December/January

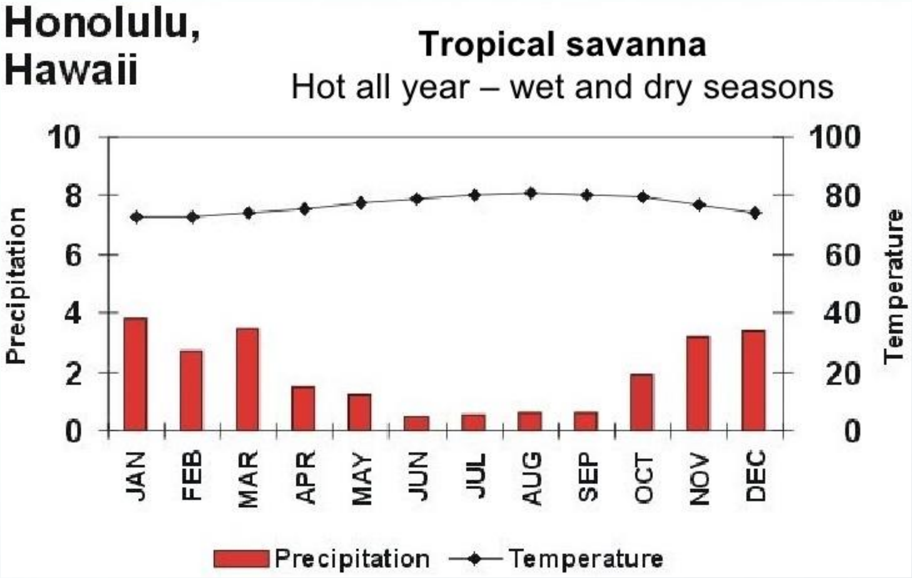
Climograph of Am climate



Tropical Savannah (Aw)

+ Found around 10-15°N/S.
+ Around **900-1500 mm** of annual rainfall.
+ 6 months of rain only.
+ High temperature of around **26°C** annually.
+ seasonal rainfall due to Movement of ITCZ → Trade winds .

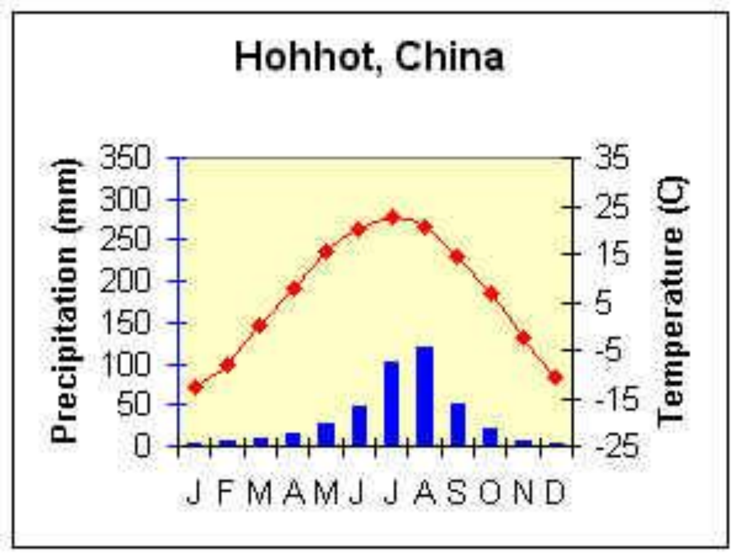
Climograph of Aw climate



Tropical Steppe (Bsh)

- Found Around 20°N/S.
- Around **100 mm** of **LOW** rainfall annually.
- **3-4** months of rain all year round.
- High temperature of around **25°C** annually.
- Low rainfall due to movement of STHP → Brings dryness.

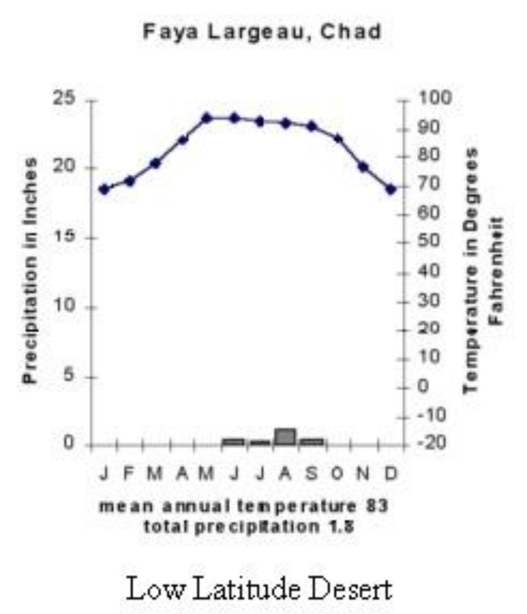
Climograph of Bsh climate



Tropical Desert (Bwh)

- Found at 30°N/S.
- Around **0-10 mm** of **EXTREME LOW** rainfall annually.
- High temperature of around **30°C** annually.
- Diurnal temperature varies greatly due to cloud cover.
- Low/No rainfall due to **dominance** of STHP → Brings dryness.

Climograph of Bwh climate



Exam Requirements

- Koppen Climates act as a form of justification in terms of **CONTEXT**.
- More applicable to Data-Response Questions [**DRQs**]
- Requires you to understand the **underlying reasons** behind the different climatic characteristics of different regions → ITCZ, STHP, Trade Winds, Monsoon Winds, Continentality Effect.

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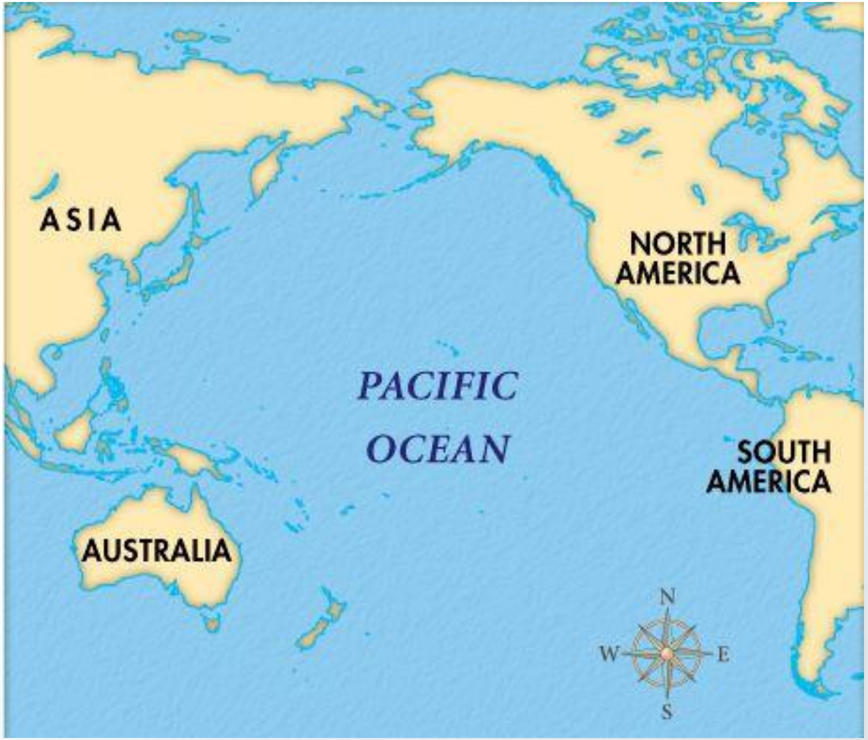
Geography

Walker Circulation

What is the Walker Circulation?

- The *Walker Circulation* is a phenomenon that takes place all-year round in the **Pacific Ocean**.

- It is the NORMAL SITUATION while the UNUSUAL ONE is known as EL NINO (next video)


ASIA
NORTH AMERICA
PACIFIC OCEAN
SOUTH AMERICA
AUSTRALIA
N
W
E
S

Walker Circulation – direction [warm air/water]

- East-West surface circulations of **warm air and water** between *Western & Eastern Pacific.*

- Trade Winds blow from **East to West** → Brings warm ocean water towards *Indonesia & Australia*

Piling of warm water here

Walker Circulation – direction [cold air/water]

- Cold ocean water will rise up to the surface along the coast of *Peru and Chile* → Resulting in the **upwelling** of cold nutrient-rich deep ocean water.

- This is known as the **PERUVIAN CURRENT**.

Walker Circulation processes

Warm ocean water at Western Pacific

=

Region of **low pressure**

Walker Circulation processes

Cold ocean water at Eastern Pacific

=

Region of **high pressure**

Walker Circulation processes

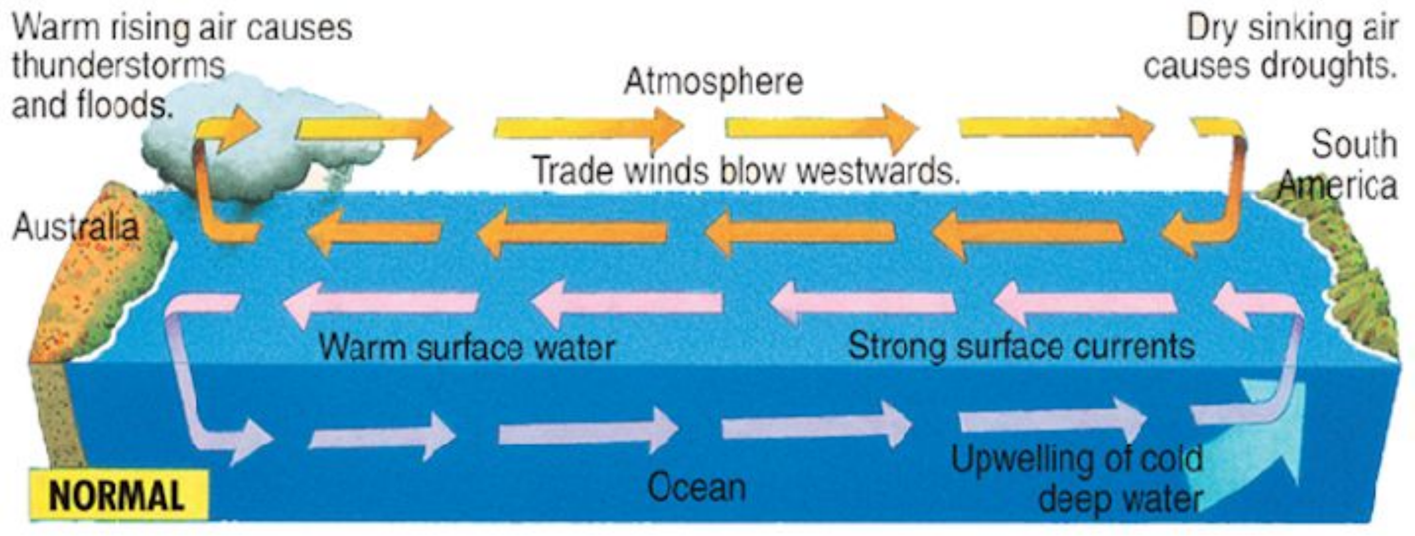
- **ACTIVE CONVECTION** due to low pressure takes place in the air above Indonesia and Australia [*Western Pacific*].

- This results in high rainfall and thunderstorms, **WET WEATHER**.

Walker Circulation processes

- On the other hand, high pressure due to lower temperature over Eastern Pacific results in **DRY WEATHER.**

Walker Circulation



Exam Requirements

- In the exam, **Walker Circulation** usually comes in conjunction with **El Nino** [Next video].
- They tend to take the form of either **12m essay** questions or in the **Data Response Question** [DRQ] section.

- As for DRQ, data would require you to **DESCRIBE** the pattern of Walker, **EXPLAIN** the Walker or **EVALUATE** the impacts of Walker Circulation and El Nino [*Next video will show an example of such data*]

Key Concepts to ALWAYS include for this topic

You **NEED** to quote these key concepts when answering questions on Walker Circulation and El Nino.

- Trade Winds [*Easterly TWs*]
- Piling of Warm Water
- Upwelling of Deep, Cold Ocean Water: Peruvian Current
- Active Convectional Activity [*High Temp vs Low Temp*]
- High or Low Pressure
- Eastern Pacific and Western Pacific [*Chile vs Australia*]
- Dry Weather vs Wet Weather

La Nina event

- The *La Nina* event is similar to the Walker Circulation, except that it brings more intense effects.

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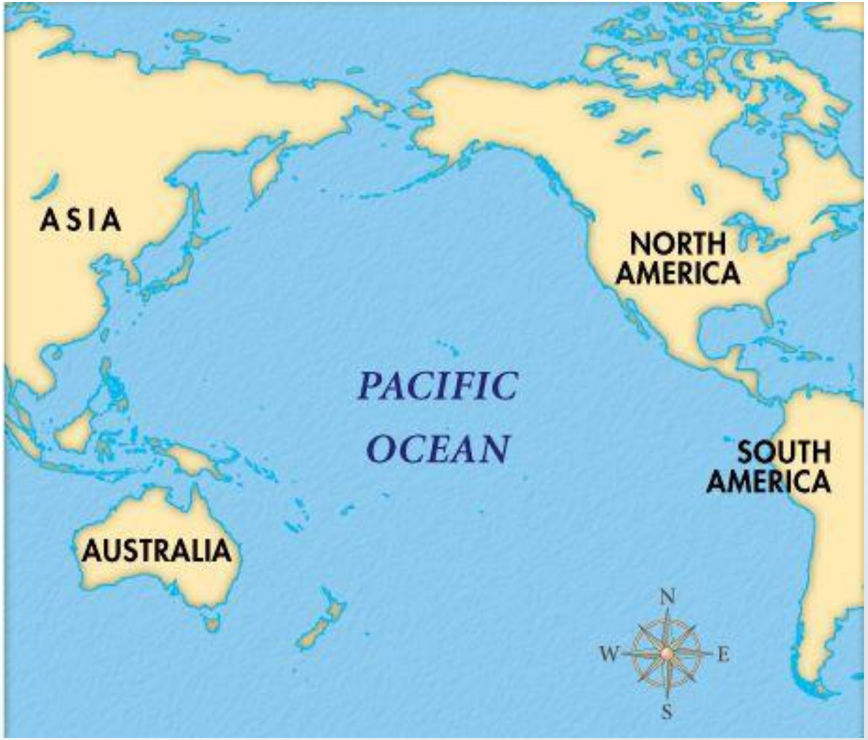
Geography

El Nino

What is the El Nino?

- The *El Nino* is a phenomenon that takes place once in a while in December in the **Pacific Ocean** when the Walker Circulation breaks down.

- It is the UNUSUAL SITUATION, the NORMAL ONE is Walker Circulation [*Previous video*]


ASIA
NORTH AMERICA
PACIFIC OCEAN
SOUTH AMERICA
AUSTRALIA
N
W
E
S

El Nino - direction [warm air/water]

- Easterly trade winds decline and weaken → Warm water moves across the Pacific Ocean, **SHUTTING OFF** the Peruvian Current.

- This produces a *warm ocean current* [**EL NINO**].

El Nino – Pressure Changes

High pressure which normally forms over the cold ocean
→ Replaced by **low pressure** over the <u>warmer ocean</u>
[*6-10 degreesC above normal*]

El Nino processes

Colder ocean water at Western Pacific

=

Region of **higher pressure**

El Nino processes

Warmer ocean water at Eastern Pacific

=

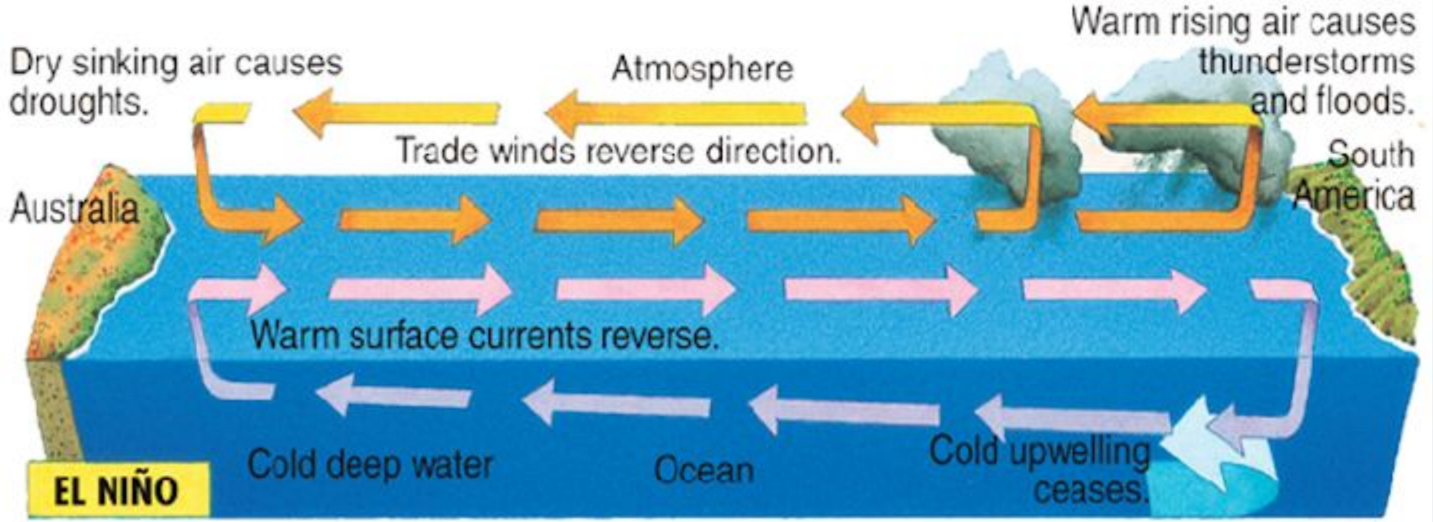
Region of **lower pressure**

El Nino outcome

- **Heavy Rainfall** on the usually arid coastline of *Eastern Pacific* [Peru] → **HEAVY FLOODING.**

- **Droughts** will occur on the *Western Pacific* [Indonesia] due to low pressure → **SEVERE DROUGHTS.**

El Nino



Warm rising air causes thunderstorms and floods.
Dry sinking air causes droughts.
Atmosphere
Trade winds reverse direction.
South America
Australia
Warm surface currents reverse.
Cold deep water
Ocean
Cold upwelling ceases.
EL NIÑO

Exam Requirements

- In the exam, **El Nino** usually comes in conjunction with **Walker Circulation** [Previous video].
- They tend to take the form of either **12m essay** questions or in the **Data Response Question** [DRQ] section.

- As for DRQ, data would require you to **DESCRIBE** the pattern of El Nino, **EXPLAIN** the El Nino or **EVALUATE** the impacts of Walker Circulation and El Nino [*Next video will show an example of such data*]

Key Concepts to ALWAYS include for this topic

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- Active Convectional Activity [*High Temp vs Low Temp*]
- High or Low Pressure
- Eastern Pacific and Western Pacific [*Chile vs Australia*]
- Dry Weather vs Wet Weather


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Geography

Convectional Rainfall

Convectional Rainfall

What is Convectional Rainfall?

- Essentially the most **common** form of rainfall.
- Common amongst the tropical Af/Am/Aw climates and warmer regions.

Formation of Convectional Rainfall

In warmer climates close to the equator

→ More intense heat/convection activity

→ Convection is the vertical heat transfer

→ Warm air rises and absorbs more water and can hold more water vapour

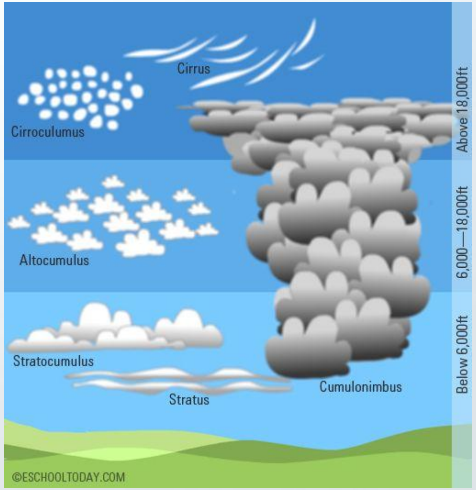
→ Heated air parcel expands

→ Reaches **dew point temperature**

Formation of Convectional Rainfall

→ Warm air condenses to form clouds such as **cumulonimbus** clouds

→ Brings about convectional rainfall.



Exam Requirements

- Understand the entire **process** of the formation of convectional rainfall.
- Understand the **areas** which convectional rainfall affect.
- Tends to be a good form of **ANALYSIS** in backing up any sort of explanation as to why there is high rainfall in Af/Am/Aw climates when you are explaining <u>climographs</u>.

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Geography

Orographic Rainfall

Orographic Rainfall

What is Orographic Rainfall?

- It is form of rainfall which is formed by moist air which has been physically **FORCED** over topographic barriers such as **MOUNTAINS**.
- It is not usually a result of intense convection activity.

Formation of Orographic Rainfall

In areas with the presence of a mountain such as trade wind latitudes

→ When moist air blows against a mountain range

→ The air is forced to rise on the windward slope of the mountain where there is higher elevation and lower pressure

→ Air parcel expands

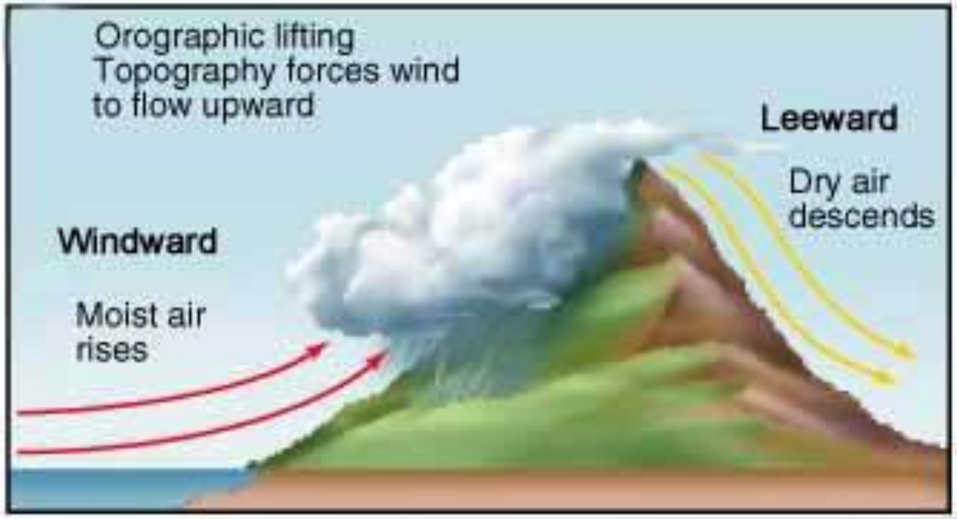
→ Temperature of air parcel falls

Formation of Orographic Rainfall

→ Clouds containing water vapour forms

→ Results in the heaviest amount of rainfall on **windward** side and little/no rainfall on **leeward** side.

Example of Orographic Rainfall



Exam Requirements

- Understand the entire **process** of the formation of orographic rainfall.
- Understand the **areas** which orographic rainfall affect.
- Tends to be a good form of **ANALYSIS** in backing up any sort of explanation as to why there is high rainfall in along mountains or linking to karst landscapes and the formation of its landscape.

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Geography

Drainage Basin Hydrology

[inputs, outputs, flows, storages]

The Basin Hydrological Cycle

- Drainage Basin is an **<u>OPEN SYSTEM</u>**.
  - There is a clearly defined input and output beyond the confines of the drainage basin.
  - Known as an area of land in which water flowing across the surface drains into a particular stream or river (naturalised).

Main **INPUT**: Precipitation

Main **OUTPUT(s)**: River runoff and evapotranspiration

Components

1. Inputs
2. Pathways/Flows/Transfers
3. Storages
4. Output

INPUT

- The ***main*** input of a drainage basin is **Precipitation**.
- It is the deposition of moisture on earth's surface from the atmosphere.
- Varies in terms of type (snow/rain/dew/etc.), quantity and intensity, duration.

Pathways/Flows

- The path in which moisture is being transported within the drainage basin.

Pathways/Flows – interception loss

<u>1. Interception loss</u>

- Refers to holding of raindrops by plants as the water falls onto leaves and stems of vegetation cover.
- Refers to a **<u>loss</u>** of water.
- Precipitation - Interception loss = water reaching ground surface.
- Amount of precipitation intercepted depends on *leaf type, wind speed, intensity of precipitation, etc.*

Pathways/Flows – Infiltration

2. Infiltration

- Transfer of rainwater entering a **permeable** surface.
- Contributes rainfall to ***soil moisture storage***.
- The *more permeable* the soil, the *faster the infiltration rate.*

ALWAYS Look at ***infiltration rate*** and ***infiltration capacity***

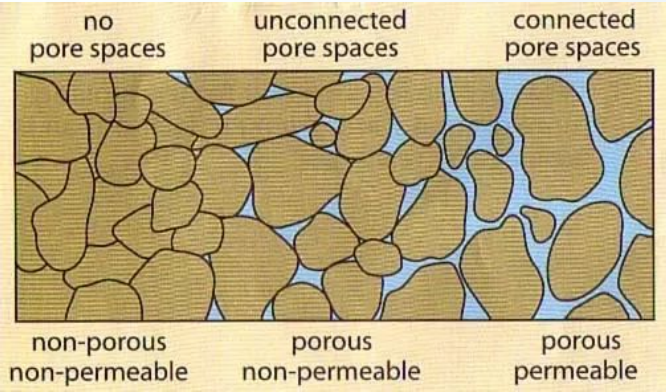
Pathways/Flows – Infiltration

Factors affecting infiltration

- Rainfall intensity [High intensity of rainfall → Surface will reach infiltration capacity faster → Less infiltration]
- Vegetation cover
  - High density of vegetation cover → slows down rainfall → Aids infiltration.
  - Layer of humus can hold rainwater → Aid in slowing down infiltration.

Pathways/Flows – infiltration

- Type of soil [Porosity and Permeability]
    - Impermeable layer of soil → lesser infiltration [*e.g concrete*]
    - More pore spaces → Increases infiltration



Pathways/Flows – percolation

2. Percolation

- Slower than infiltration (contributes to groundwater storage)
- It is the flow of rainwater, filtering downwards in the **subsurface** soil, through the joints and pore spaces of the soil.
- Rate of percolation **slows down** as it gets deeper (*because layers of soil and rock get more compact → pore spaces reduced*)

Pathways/Flows – percolation

Factors affecting percolation

- Volume of pore spaces in the soil and frequency of joints in the soil
  - More spaces means that the soil can hold more water
  - More cracks and fissures means that the water can pass through different layers easily.

Pathways/Flows – throughflow

3. Throughflow

- Horizontal flow of water in soil moisture storage moving towards river channel (storage)
- Viewed as excess flow of percolation.

Pathways/Flows – throughflow

<u>**4. Groundwater flow/Baseflow**</u>

- Groundwater flow is the horizontal flow of water in the groundwater storage, going towards the river channel (storage).
- Extremely slow due to **high saturation**.

Pathways/Flows – Overland Flow

5. Overland Flow

- The **FASTEST** flow, whereby a portion of water does not infiltrate the soil.
- Consists of **HORTONIAN** and **SATURATED** overland flow.
  - **HOF**: Rainfall intensity exceeds rate of infiltration
  - **SOF**: If soil is at its water holding capacity

Pathways/Flows – Overland Flow

<u>**Hortonian Overland Flow**</u>

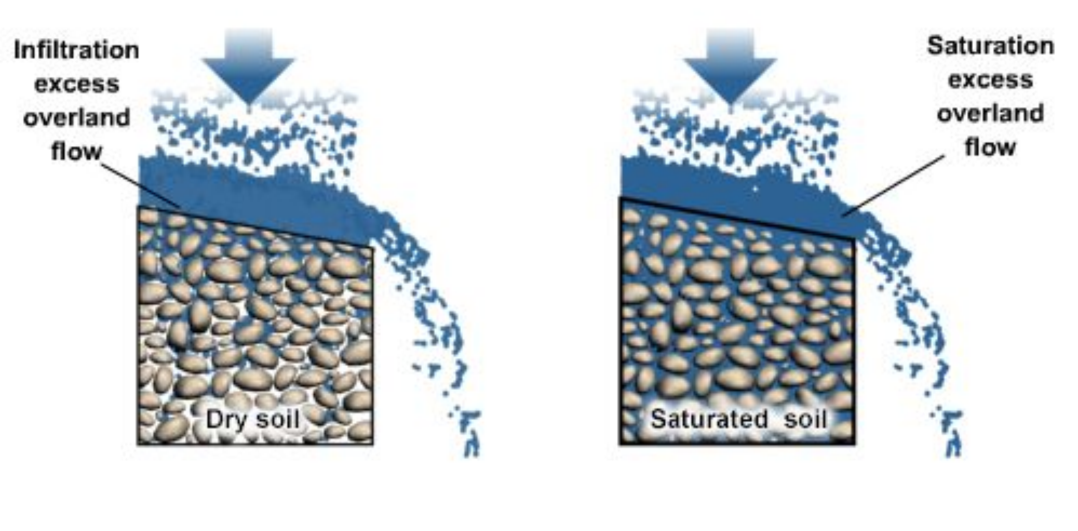
- Occurs after infiltration, when conditions impede infiltration and channel rainwater to overland flow.
- Occurs when **precipitation exceeds infiltration capacity or rate of infiltration, ground is frozen, steep slopes**.

Pathways/Flows – Overland Flow

Saturated Overland Flow

- When the ground is saturated and rainwater cannot infiltrate at all and flows on the surface.
- May develop when rainfall is heavy and takes place over a few day resulting in increase in height of water table, **high** soil antecedent moisture conditions.
- **HOF always takes place first before SOF**.
- Soil must be **near saturation** before SOF can occur.

Pathways/Flows – Overland Flow



Take a quick break before moving on to stores and output

Stores – Interception and biological water storage

1. Interception and biological water storage

- Refers to plant canopy on earth's surface, which hold a certain amount of precipitation.
- Can only be removed via **evaporation**.

Stores – soil moisture storage

2. Soil moisture storage

- Refers to the storage of moisture in the soil.
    - Areas above water table where the pore spaces are not saturated with water, filled with both water and air.

Stores – Groundwater storage

3. Groundwater storage

- Refers to the storage of water in the subsurface zone that is fully saturated, beneath the water table.

*Upper surface of the saturated zone (pore spaces completely filled with water) is called the **water table** (*an imaginary line*), separates the zone of aeration and zone of saturation in the subsurface layers.

Stores – Channel storage

<u>4. Channel storage</u>

- Refers to the **river channel**, a physical confine of a river, consisting of a channel bed and channel banks.
- Receives water **<u>indirectly through flows from other stores</u>** and **<u>directly from precipitation</u>** that drops into them.

Output(s)

1. River Runoff

- Water flowing from river channel towards sea, lost from drainage basin system.

2. Evapotranspiration

- Water lost due to evaporation and transpiration.

Exam Requirements

- Understand the entire drainage basin hydrology in terms of its input and output(s), flows, and storages.
- Be able to **explain** and **discuss** the function of the different parts of the drainage basin hydrology, and how they all work cohesively to form **one system**.
- Tends to come out as essay questions, and possibly identification in Data-Response/Case-Study questions.

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Geography

Drainage Basin Hydrology [factors] and Water Balance

Factors – climate

1. Climate

Rainfall → Determines amount of rainwater available and how much water will be transferred from each storage [*input*, *flows*, *storages*].

Temperature → Determines rate of evapotranspiration [*output*].

Factors – Vegetation Cover

2. Vegetation Cover

- Different characteristics of vegetation cover will influence amount of interception, evapotranspiration, infiltration and overland flow [*flows*, *storages*, *output*].
    - Surface area of leaves, density of vegetation, etc.

Factors – Soil Moisture conditions

3. Soil Moisture conditions

- Different antecedent moisture conditions affect infiltration, percolation and overland flow.
  - The **higher** the soil antecedent moisture → The lesser the available pore spaces → Reduces infiltration capacity and could lead to saturation hence reduces permeability as well.

Factors – Soil & Rock type

4. Soil and Rock type

- The extent of porosity and permeability will affect the sub-surface and overland flows.
    - The more porous the rocks → Greater infiltration capacity
    - The greater the permeability → Greater infiltration rate
- If the rocks/soil are **not porous** and **not permeable** → Leads to **greater overland flow**.

Factors – Anthropogenic (human) Activities

<u>5. Anthropogenic Activities</u>

- Otherwise known as human activities.
- **Urbanisation** → Such as concrete surfaces → Results in lower permeability → Lesser infiltration → Greater overland flow.
- **Water abstraction from ground (wells)** → Affect groundwater flow and hence affects channel flows.

"

The
Water Balance

Water Balance equation

- Determines the relationship between input and output(s).

Precipitation (P) =

Streamflow (Q) + Evapotranspiration (E) +/- Changes in storage (S)

$$P = Q + E +/- S$$

Water Balance equation

- The water balance equation can show surpluses and deficits in drainage basin hydrology.
  - E.g. When P>E → Surplus → May lead to more overland flows, more groundwater storage, etc.
  - E.g. When E>P → Deficit → May lead to low water table levels, lesser percolation, etc.

Exam Requirements

- Understand, explain and be able to discuss the various factors which affect drainage basin hydrology. Use **criteria** to discuss these factors (*covered in a previous video*).
- Understand the water balance equation and use it as a form of evaluation to **justify variations** in flows, stores, input and output when discussing the drainage basin hydrology.

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Geography

Fluvial Processes

[erosion, transportation, deposition]

3 MAIN FLUVIAL PROCESSES

1. Erosion
2. Transportation
3. Deposition

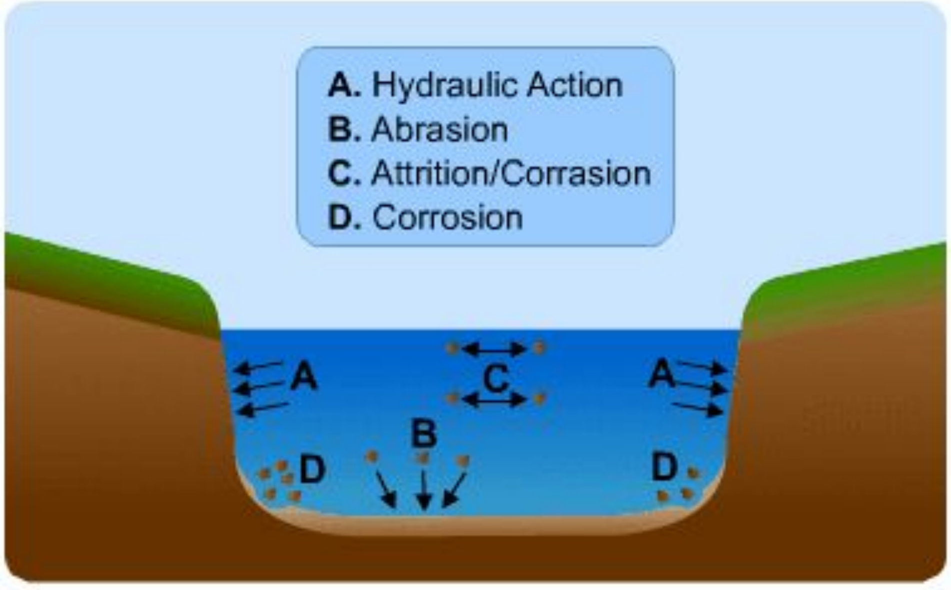
Erosion → Transportation → Deposition

Types of EROSION

- Breaking down of sediments.

1. Abrasion
2. Hydraulic Action
3. Attrition
4. Solution

Types of EROSION



EROSION TYPE: ABRASION

1. Abrasion

- Refers to the wearing away of mainly the ***river bed and sometimes river bank*** by load carried.
- Action type: **DOWN-CUTTING**.
- Most effective in upper course [*due to presence of large, coarse fragments of bedload*].
- Creates a V-shaped channel.

EROSION TYPE: HYDRAULIC ACTION

2. Hydraulic Action

- Refers to the sheer force of flowing water sufficient to dislodge particles or fragments of unconsolidated material into the channel → Results in the collapse and retreat of ***river banks***.
- Action type: **LATERAL erosion**.
- Widens river channel.

EROSION TYPE: ATTRITION

3. Attrition

- Attrition is the ***constant collision and grinding*** of sediment load against one another and wearing bedload to become smaller and smoother.
- Impacts efficiency of channel downstream, as erosion **reduces** the **size of load** hence **reducing the friction**.

EROSION TYPE: ATTRITION

4. Solution

- Solution is the removal of soluble rock minerals.
- This often happens in areas where the geology is limestone, which is soluble in slightly acidic water.
- Tends to work in-hand with the ***solution process of transportation***.

Types of TRANSPORTATION

- Downstream movement of load.

1. Solution
2. Suspension
3. Saltation
4. Traction

TRANSPORTATION TYPE: SOLUTION

1. Solution

- Eroded rock minerals being dissolved and carried along in water as individual ions.
- Always takes place despite river energy level.
- In the ***humid tropics***, chemical weathering of rocks is highly efficient, hence solution load is important.

TRANSPORTATION TYPE: SUSPENSION

2. Suspension

- Finer particles carried by water without touching river channel (river bed and river bank).
- More turbulent flow* = larger particles can be transported in suspension.

*More on turbulent flow in a bonus video!

TRANSPORTATION TYPE: SALTATION

3. Saltation

- The skipping motion of middle-sized rocks along the river bed.
- It is a cumulative process - when one rock hits others, the rest will also skip.

TRANSPORTATION TYPE: TRACTION

4. Traction

- Transports coarse bedload via sliding, rolling or hopping motions.
- Only happens when stream energy levels are high due to energy required to move the coarser and heavier bedload.

DEPOSITION

- Dropping of particles that were transported in water.
- Load is deposited according to their size → Sorted out according to size and weight.
- Occurs due to a sudden decrease in gradient, slower velocity, decrease in volume of water, etc.

Exam Requirements

- Understand and be able to explain each erosion, transportation and deposition process.
- Identify the type of process which produces different channel patterns (*to be covered in another video*).

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Factors affecting channel morphology

FACTORS AFFECTING CHANNEL MORPHOLOGY

1. Channel Discharge
2. Channel Velocity
3. Quantity and Size of sediment load

Channel Discharge

- Channel Discharge is the **volume of water** flowing through a river channel, measured in terms of the volume of water passing a point in the river channel in a **unit of time**.
- Determines the river's ability to erode its channel.
- Has a **direct influence** on potential and kinetic energy of the river → Higher discharge = Higher energy levels.

Channel Discharge

$$Q = A \times V$$

Q: Discharge

A: Cross-sectional Area

V: Velocity

Channel Discharge

From upper to lower course:

- Discharge increase because upper course has a smaller basin, while lower course can have a basin size two times bigger.

At lower course:

- More tributaries combine and contribute to the main river channel → Increase in Q

Channel Velocity

- Channel velocity **increases** from upper to lower course.
- The greatest velocity occurs where friction is the least [*affected by sediments*].
- Also determines how much kinetic energy the river possesses.

$$KE = \frac{1}{2} mv^2$$

- The **greater the velocity**, the **more the energy** to perform tasks (ie fluvial processes).

Channel Velocity – Manning's equation

$$V = R^{2/3} S^{1/2} / n$$

V: Velocity

R: Hydraulic Radius

S: Channel Slope

n: Coefficient of Roughness

Sediment size and load

- Sediment Load refers to the amount of sediment carried by the river.
- Sediments are obtainable from weathering and mass movements and from its own channel bed and banks.
- Works hand-in-hand with fluvial processes.
- The **finer/lighter the sediment**, the more sediments picked up, and lesser friction.
- Heavier sediments result in **lower river efficiency** due to increased friction.

Sediment size and load

Size/Type	Characteristics
Bedload	- Large rock fragments that roll/slide along the channel bed. - Found at upper course
Suspended Load	- Fine and lightweight - Greater velocity = more picked up. - Found at lower course
Dissolved Load	- Dissolved rock material in water.

Exam Requirements

- Understand the various factors affecting channel morphology and how they lead to changes in fluvial processes.
- Be able to explain and discuss these factors, while applying the mentioned-equations for higher level answers.


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Geography

Drainage Density

Formula of drainage density

Dd =

Total Stream Length / Total Basin Area

High Drainage Density

- High overland flow → Higher flood risk
- Greater amount of tributaries
- Lesser infiltration
- Lesser groundwater storage

Low Drainage Density

- Low overland flow
- Lesser amount of tributaries
- More infiltration
- More groundwater storage
-

Exam Requirements

- Understand the concept of drainage density and what a high/low drainage density entails.

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Geography

BRAIDED RIVERS

Braided River:

Waimakariri
River,
South Island
of New Zealand

Formation

4 stages:

1. High level of discharge
2. Low levels of discharge
3. High level of discharge
4. Low levels of discharge

STAGE 1: HIGH LEVEL OF DISCHARGE

- During a period of high rainfall → High input → High discharge in the river channel → Increase in velocity and discharge leads to an increase in overall energy → Channel banks are eroded → Results in a huge supply of bedload.

STAGE 2: LOW LEVEL OF DISCHARGE

- During a period of low rainfall → Low input → Drop in velocity and discharge of the river → Fall in river energy → Not enough energy to carry the heavy load brought about by high input season → Sediments deposited → Coarser sediments are unloaded first and will act as nuclei → Finer sediments deposit around the nuclei → Overtime, this leads to the formation of **elongated shaped mid-channel bars** [*Main river flow is diverted to smaller channels on either side of the bar and causes accelerated bank erosion*].

STAGE 3: HIGH LEVEL OF DISCHARGE

- During a period of high rainfall → High input → High discharge and velocity once again → Some mid-channel bars will be eroded away via attrition. On the other hand, some will be stabilised with vegetation with the high rainfall (favourable for vegetation) → Traps more sediments (these bars become **permanent features**)

STAGE 4: LOW LEVEL OF DISCHARGE

- Drop in river discharge during low input season → Mid-channel bars formed prior will be exposed to the surface.
- At the same time, some new mi-channel bars will be formed.

Conditions for BRAIDED rivers to form

- Larger variation in input (braided rivers form in areas with seasonal climate).
- Higher amount of sediment load
- Bigger and coarser sediment load
- Steeper slope, usually forms at upper course.

Exam Requirements

- Be able to explain fully the formation of a braided river.
- Discuss the factors affecting the formation of a braided river (usually climate is the most important since it is a macro factor and is the one to determine the outcome/shape of the river).
- Discuss in relation to meandering rivers (if asked by the question).

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MEANDERING RIVERS

Meandering River:

Amazon River

Formation

<u>4 stages</u>:

1. Alternating bars of sediment
2. Pools and Riffles
3. Alternate sequence of pools and riffles
4. River cliff and Point bars

Stage 1: Alternating Bars of Sediment

- Pre-existing alternating bars of sediment in channels formed by deposition in lower velocity areas → This deflects thalweg (a line connecting the lowest points of successive cross-sections along the course of a valley or river)

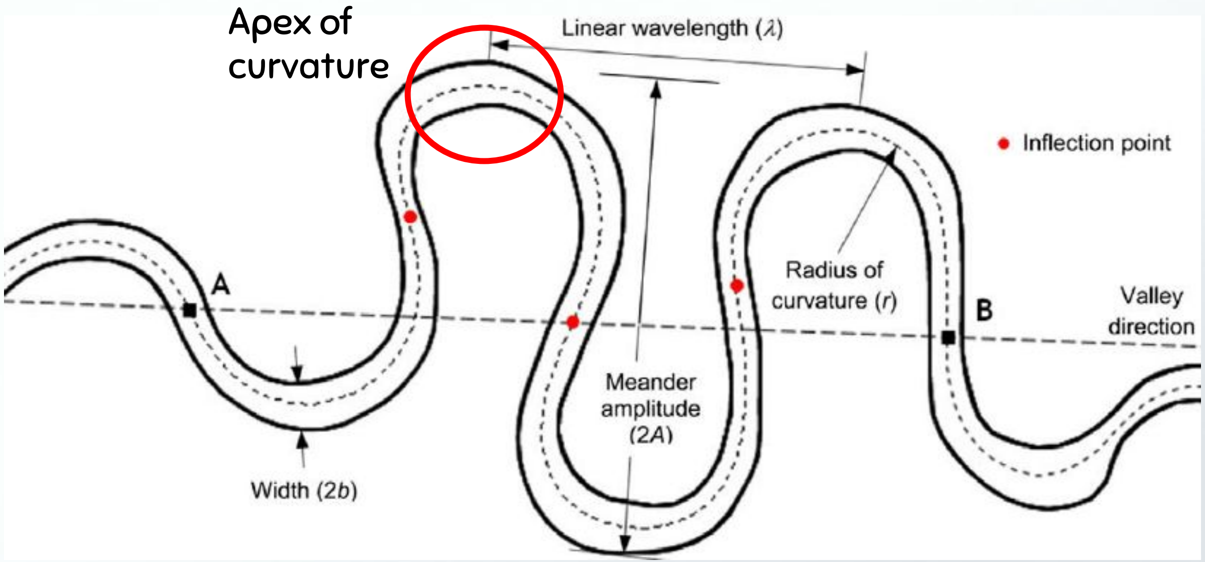
Stage 2: Pools and Riffles

- Deposition bars deflect thalweg to the opposite bank → Initiates erosion process (**abrasion**) → Develops a sequence of pools and riffles.

Pools: Depressions formed at the apex on curvature, on the river bed.

Rifles: Deposition of sediments, with turbulence flow, at the point of inflection with low velocity ((deposits coarser sediments).

Apex of curvature and Point of inflection



Stage 3: Alternate sequence of pools and riffles

- Overtime → Swinging of thalweg and alternate deposition and erosion will form a well-developed alternate sequence of pools and riffles spaced apart → This causes thalweg to swing in a more uniform pattern → Results in a **slight channel curvature**

Stage 4: River cliff and Point bars

- As a result of the slight channel curvature → Helicoidal flow is created → Causes water to pile up against the outer bank → produced a hydraulic gradient → This causes erosion of outer bank → Increased sediment load in the river → Causes current/velocity to weaken at the inner bank → Formation of bars of coarse sediments → **Point bars** formed.
- On the other hand → At the outer bank → erosion causes collapse of bank → forms steep river cliffs.

stage 4: River cliff and Point bars

- Repeated cycle of collapsed river cliffs and point bars result in a full developed meandering river (headed downstream).

Conditions for MEANDERING rivers to form

- Lower levels of discharge
- Lower amount of sediment load
- Smaller and finer sediment load (sand-silt grade for erosion and deposition)
- Gentler slope, usually forms at mid-lower course

Exam Requirements

- Be able to explain fully the formation of a meandering river.
- Discuss the factors affecting the formation of a meandering river (usually climate (hence discharge) is the most important since it is a macro factor and is the one to determine the outcome/shape of the river).
- Discuss in relation to braided rivers (if asked by the question).

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Geography

River Equilibrium and Longitudinal Profile

River Equilibrium

- River equilibrium is reached when the river has achieved a balance of water flow and sediment transport.
- Rivers tend to reach a state of equilibrium by the processes of erosion and deposition.
- There should not be an overload of sediments in the river, yet sufficient erosion and deposition should be taking place.
- River Efficiency will be able to aid in showing if the river is in a state of equilibrium.

River Efficiency

- The calibre and amount of sediment that the river can carry is measured by its competence and capacity.

Competence: Measure of the largest rock particle the river can transport.

- A river with a higher velocity, higher energy will have a higher competence level.
- Turbulent flow will also aid in competence as it allows larger particles to move with greater ease.

River Efficiency

Capacity: Measure of the amount of sediment the river can transport.

- A higher volume of discharge would mean a higher river capacity.

Longitudinal Profile

- The longitudinal profile characterizes the river slope/gradient, as well as the spacing of the river channel, caused by pools and riffles, etc.
- Can be further classified into V-shaped and U-shaped profiles.
  - V-shaped: Upper course, where turbulent flow is present and more down-cutting of river.
  - U-shaped: Mid-Lower course, lower velocity, gradual erosion of banks and bed.

Exam Requirements

- Understand the definitions of river equilibrium and longitudinal profile and apply them to different types of rivers (where applicable).

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Geography

Physical Weathering

Definition of Physical Weathering

- Disintegration of rocks and minerals.
- Alters the physical structure but not chemical composition of the rock.
- Produces more surface area on which chemical weathering can operate.
- More prevalent in cold and dry regions.

Types of Physical Weathering

1. Frost Weathering
2. Salt Weathering
3. Pressure Release
4. Thermal Weathering

1. Frost Weathering [block disintegration]

- Comprises of Freeze-thaw action, frost wedging and frost shattering, ice crystallisation.

Conditions: Requires existing joints, daily/seasonal freeze-thaw cycle (Deserts).

Process: Freeze Thaw → Frost-Wedging → Frost Shattering

- Repeated expansion causes strength of rock to weaken hence repeated fluctuations breaks down the rock.

2. Salt Weathering

Conditions: Hot arid regions with high rates of evaporation.

Process: Rainwater percolating through a rock contains dissolved salt minerals → High rates of evaporation would leave salt crystals which grow → Generates stress on the rock and forces mineral grains apart → Granular disintegration of rock.

Outcome: Large boulders.

3. Pressure Release

Conditions: Occurs in places that have moderate rainfall, so as to support erosion and transportation.

Process: Overtime, erosion removes overlying layers of rock or regolith and expose intrusive rocks.

- Dilation and Exfoliation occurs resulting in the peeling off of rocks in layers.

Outcome: Continued weathering causes slabs produced by exfoliation to break off → Forms exfoliation domes.

4. Thermal Weathering

Conditions: Large diurnal temperatures such as the desert.

Process:

- With large diurnal temperatures → Rock will weather and weaken [*outer layers expand faster than inner layers*].
- At night → Outer layer cools and contracts faster than inner layers.
- Repeated uneven contraction and expansion creates stress on the rock.

Outcome: Granular disintegration and peeling off of rock in layers.

A lil' note

Physical Weathering takes place

BEFORE

Chemical Weathering takes place.

Exam Requirements

- Understand the various physical weathering processes.
- Physical Weathering can come out as a **12** mark question, usually asking you to explain with *chemical weathering* processes.
- Alternatively, it acts as prerequisite knowledge for the topic on **Karst** and **Aeolian** landscape based essays.

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Geography

Chemical Weathering

Definition of Chemical Weathering

- Chemical Alteration or Decomposition of rocks and minerals.
- Alters the chemical composition of the rock.
- Always in the presence of water.
- More prevalent in warm, wet tropical climates.

Types of Chemical Weathering

1. Carbonation
2. Solution
3. Oxidation
4. Hydrolysis
5. Reduction

1. Carbonation

Conditions: Limestone areas. Cool environments abundant with carbon dioxide and water.

Process:

- Rainwater + Carbon Dioxide = Carbonic Acid
- Carbonic Acid and Calcium carbonate forms limestone which can be easily eroded/weathered.

Outcome: Results in Karst Landscapes.

2. Solution

Conditions: Occurs in humid and hot climates, common in limestone areas.

Process: Water will remove and carry soluble minerals from the rock → Results in a weaker rock structure → Granular disintegration.

Outcome: Rocks with holes are left behind (granular disintegration)

3. Oxidation

Conditions: Tropical regions with high temperature and precipitation, rocks with IRON and ALUMINIUM.

Process: Chemical reaction between metallic minerals.

- Iron + Oxygen in air + Water = Browning

Outcome: Rusting → Removal of iron from rocks → Disrupts granular structure → More susceptible to further weathering and granular disintegration.

4. Hydrolysis

Conditions: Presence of common silicate like feldspar.

Process: Chemical reaction between rock minerals (silicate) + Hydrogen from rainwater → Forms clay → Further breakdown of rock because interlocking crystal network is weakened → Turns white.

Outcome: Produces clayey material → Causes rock to whiten slowly.

5. Reduction

Conditions: Waterlogged conditions.

Process: Removal of oxygen → Change in rock colour to grey/blue.

Outcome: Rock takes on a blue/grey tinge.

Let's emphasize this again.

Physical Weathering takes place

<u>BEFORE</u>

Chemical Weathering takes place.

Chemical Weathering will exploit the cracks caused by Physical Weathering.

Exam Requirements

- Understand the various chemical weathering processes
- Chemical Weathering can come out as a **12** mark question, usually asking you to explain with *physical weathering* processes.
- Alternatively, it acts as prerequisite knowledge for the topic on **Karst** and **Aeolian** landscape based essays.

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EROSION BY WATER

2 WAYS IN WHICH EROSION BY WATER TAKES PLACE

1. Erosion by Unbconcentrated Flows
2. Erosion by Concentrated Flows

Erosion by UNCONCENTRATED flows

1. Rainsplash

- Raindrops striking rock and still surfaces → Resulting impact will **compress** and **spread** sideways.
- Spreading causes instantaneous stress on the rock or soil that **detaches particles from the surface** → Some particles may be entrained by water from the raindrop.
- Rainsplash releases particles for **entrainment** (picking up) and transportation by overland flows.

Erosion by UNCONCENTRATED flows

- Rainsplash releases particles for **entrainment** (picking up) and transportation by overland flows.
- Repeated cycles of rainsplash results in continual erosion of rock/particles.

Erosion by UNCONCENTRATED flows

<u>2. Sheet wash (overland flow) / Rainwash</u>

- **Sheet wash**: The entrainment of loose particles by runoff water.
- **Sheet flow**: Refers to the shallow overland flow when loose particles are displaced → Results in the removal of soil particles.

Overland Flow [OLF]:

- Hortonian OLF: ppt > infiltration rate, where soils are thin.
- Saturated OLF: When groundwater table sits at ground surface

Erosion by UNCONCENTRATED flows

<u>Overland Flow</u>:

- Hortonian OLF: ppt > infiltration rate, where soils are thin.
- Saturated OLF: when groundwater table sits at ground surface.

- Sheet wash and sheet flow are erosional in nature and are **<u>BROUGHT ABOUT</u>** by overland flow.
- Overland flow is the **mechanism** responsible for erosional processes of sheet wash/flow.

Erosion by CONCENTRATED flows

<u>1. Rill Flow/Rill Wash</u>

- Hillslope process that occurs when rainwater is heavy to carve out **small channels** on hillslopes. Able to do erosion as **sediments on the hillslopes get detached and removed by action of water**.
- Erodes deeper and occur at a faster speed than shee wash/flow → Forms **RILLS**.

[Rills: Small, shallow hillside channels]

EROSION BY CONCENTRATED FLOWS

2. Channel Flow (erosion)

- Fluvial erosional processes: Abrasion, Hydraulic Action, Attrition, Solution.

Erosion by CONCENTRATED flows

3. Spring

- An outlet for groundwater storage before it reaches the river.
- Occurs when the water table meets Earth's surface.
- Once spring flows, it causes a dip in water table that causes a pressure gradient → Encourages more groundwater to move to the spring.
- As more groundwater moves underground through cracks, fissures, joints → Does more underground/subsurface erosion.

Exam Requirements

- Explain the various erosional processes by water (Splash erosion, Rainwash, Rillwash and more as optional points).
- Apply the erosional processes to the various landscapes in the tropics (if required).

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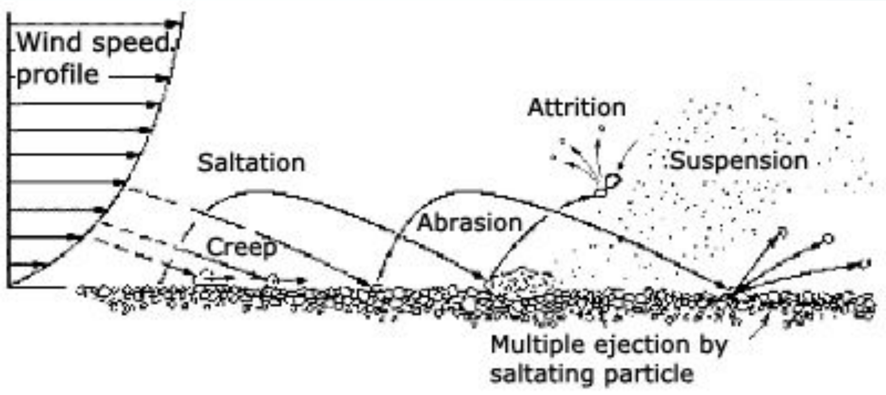
Erosion by Wind

2 MAIN TYPES OF EROSION PROCESSES BY WIND

1. Deflation
2. Abrasion



Deflation

- The **picking up** of dust, sand and loose rock fragments.
- The entrainment of **loosened materials** by wind, overtime, lowers ground → Wind directly lifts and removes the loose particles from the surface.
- Operates on a **LOCALISED** scale, since it takes a very long time to move sand great distances.

Deflation

- Fine materials (silt, clay) are often pre-weathered by salt weathering before going through deflation.
- Erosion is shown as **particles are eroded**, and also with the **lowering of ground**, until the water table is reached.

Abrasion

- Abrasion refers to the **mechanical wear of rock** or sediments by the **impact of particles** in **saltation**.
- Bouncing particles commonly dislodge other grains when they strike the surface.
- Number of particles diminishes with height.
- **Repeated contact/collision** of sediments would cause abrasive friction to take place and hence results in **deformed sediments/rocks**.

Exam Requirements

- Explain the various erosional processes by wind (Deflation and Abrasion).
- Apply the erosional processes to the various landscapes in the tropics (if required).

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Geography

Rocks

THE 3 TYPES OF ROCKS

1. Igneous Rocks
2. Sedimentary Rocks
3. Metamorphic Rocks

IGNEOUS ROCKS

- Distinctive due to their **crystalline** texture.
- Formed by cooling and solidification of molten rock (magma).
- There are **2** subtypes of Igneous rocks (Intrusive vs Extrusive)

IGNEOUS ROCKS

- Intrusive Rocks: Coarse-grained, large size, slow rate of cooling and felsic in mineral composition. E.g. Granite
- Extrusive Rocks: Fine-grained, small size, faster rate of cooling due to fine texture, mafic in mineral composition. E.g. Basalt

SEDIMENTARY ROCKS

- Distinctive due to their **GEOLOGIC STRUCTURE** of different layers (**STRATA**).
- Layered accumulations of mineral particles from weathering and erosion of pre-existing rocks.

SEDIMENTARY ROCKS – FORMATION

2 ways in which sedimentary rocks are formed:

1. **Compaction**: Occurs over time when the weight of overlying material compresses the deeper sediments. Reduces pore spaces hence compaction.
2. **Cementation**: Occurs when cementing materials are carried in solution by groundwater, fills the pores and joins sediments together.

METAMORPHIC ROCKS

- Distinctive due to their **<u>FOLIATED</u>** or **<u>NON-FOLIATED</u>** rock structure.
- Goes through the process of **metamorphism** - Process where sedimentary/igneous rocks are altered in composition and structure under extreme **heat and pressure** hence forms larger crystals as they *<u>re-crystallise</u>*.

METAMORPHIC ROCKS – METAMORPHISM

3 types of metamorphism: Regional, Contact, Dislocation metamorphism.

Agents of metamorphism:

1. **Heat**: Provides energy to drive chemical reactions.
2. **Pressure**: Tends to be force exerted by load above.

Exam Requirements

- Understand the different rock types and its structures.
- Usually rocks will appear in **DRQ** questions, where they may ask you to identify the rock type (2 marks).

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Soil Profile

The 4 soil forming processes

Translocation: Movement of dissolved materials from one horizon of the soil to another.

Eluviation: When particles held in suspension are removed (washed away).

Illuviation: When particles are accumulated/deposited.

Leaching: Complete removal of soluble components of soil column.

The 3 pedogenic processes

Lateralization: Occurs in humid tropics, where there is movement of large amounts of water (results in eluviation and leaching). Forms **laterites**.

Calcification: Occurs in areas where evapotranspiration exceed precipitation. Results in dry upward movement of alkaline soils hence **calcretes** formed.

Salinisation: A more intense version of Calcification.

Humid Tropics [Lateralization]

O-horizon: **No** O-horizon as the **decayed matter** is used up by vegetation + decomposed into humus very quickly due to the high temperatures in the Humid Tropics → Forms **humus** in A-horizon.

A-horizon: **Thin** A-horizon, due to the humus being quickly used up by plants in the form of fertile soil. With the ***abundance of moisture*** in humid tropics, leaching will occur → The minerals from the A-horizon will be **eluviated** and **translocated** to the B-horizon, resulting in a thicker B-horizon.

Humid Tropics [Lateralization]

B-horizon: **Thick** B-horizon, also known as the **zone of illuviation** → Due to the minerals and particles from A-horizon such as clay, which were held in suspension are deposited in the B-horizon. Accumulation of oxides minerals are iron-rich rocks known as laterite, B-horizon will tend to be **reddish** in colour due to the laterites.

C-horizon: **Thick** C-horizon. In the tropics, there is the presence of high rainfall → There is the occurrence of ***deep chemical weathering*** at a deep depth due to increased percolation leading to an increased amount of **saprolite and regolith** in the C-horizon. Thus, this results in a thick C-horizon.

Aw/BSh Tropics [Calcification]

O-horizon: <u>No</u> O-horizon, mainly due to a ***lack of flora and fauna*** since there is constantly high temperatures and lack of rainfall which are not favourable to the formation of flora and fauna.

A-horizon: <u>Slightly thick</u> → Due to the presence of occasional flora and fauna which die and decompose. Hence, this leads to a **buildup of humus** overtime, hence, a slightly thick A-horizon.

Aw/BSh Tropics [Calcification]

B-horizon: Thinner → Due to chemical weathering processes occurs rather shallow in arid climates as seen by *Strakhov's diagram*. During the dry season, in areas with low precipitation, the air has a high amount of alkali dust due to increased ***physical weathering*** in the arid tropics under high temperatures → When it rains during occasional wet seasons → Alkali dust is brought to the B-horizon as the water ***infiltrates and percolates*** to the B-horizon → Over a prolonged period of time, the calcium-carbonate enriched dust concentrates in B-horizon, forming hard layers of **caliche**.

Additionally, during the dry season, there is also an upward movement of water due to **capillary action**, hence, water will start to deposit calcite in B-horizon, leading to the formation of a hardened white layer of calcretes.

Aw/BSh Tropics [Calcification]

C-horizon: Thin. Due to the absence of deep chemical weathering, C-horizon tends to be found at a much shallower depth, hence, the dry soils are also known as **azonal** soils.

BWh Tropics [Salinisation]

- **Extreme dry conditions** → Groundwater brought up to the surface via **capillary action** → Evaporation leaves sal deposits and calcium carbonate in the topsoil layer → Forms hardpan (*white*).
- Salinisation results in **solonetz** soils, essentially a hard alkaline layer beneath the surface.
- General term for such soil is **pedocals**.

Exam Requirements

- Understand the the different pedogenic processes of **Lateralization**, **Calcification** and **Salinisation**.
- Tends to be a **12** mark question requiring you to explain the pedogenic processes in conjunction with the soil profile/column [O, A, B, C horizons].

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