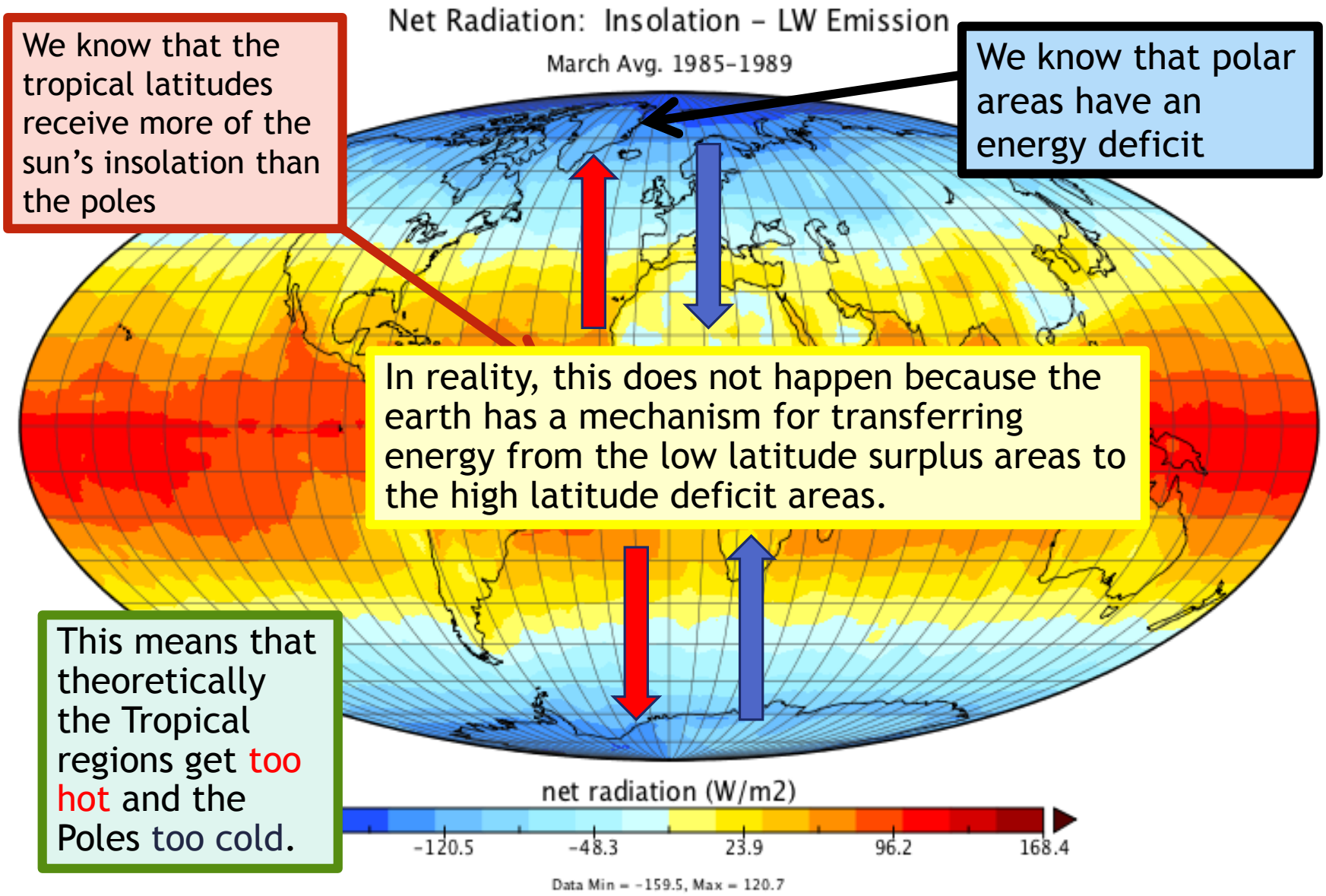
CfE Higher Geography
Physical Environments

Energy Transfer and Atmospheric Circulation

What do we know about the energy balance

We know that the tropical latitudes receive more of the sun's insolation than the poles

We know that polar areas have an energy deficit



In reality, this does not happen because the earth has a mechanism for transferring energy from the low latitude surplus areas to the high latitude deficit areas.

This means that theoretically the Tropical regions get too hot and the Poles too cold.

This transfer is known as ATMOSPHERIC CIRCULATION

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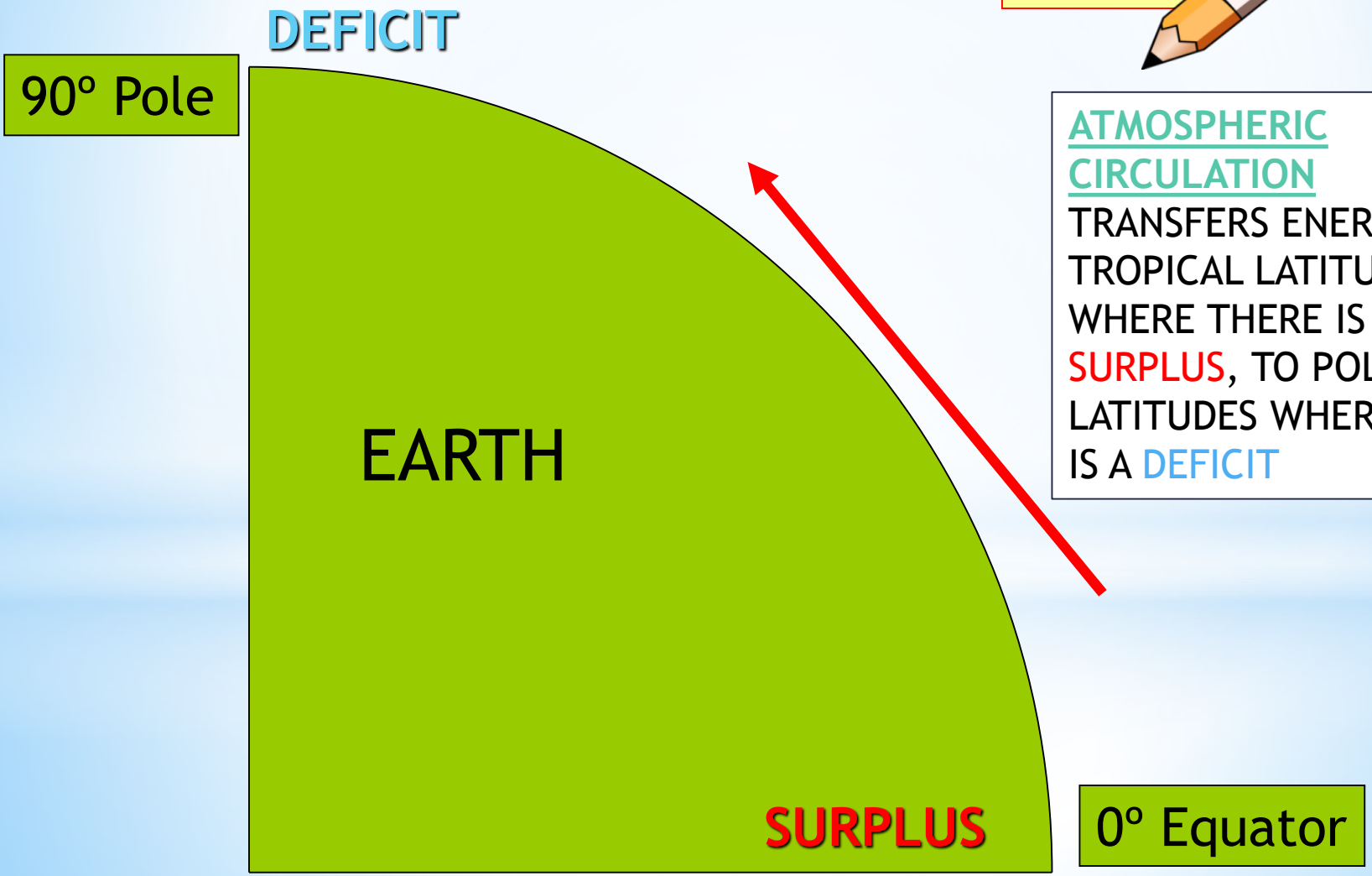


ATMOSPHERIC CIRCULATION TRANSFERS ENERGY FROM TROPICAL LATITUDES WHERE THERE IS A SURPLUS, TO POLAR LATITUDES WHERE THERE IS A DEFICIT

Part 1: Understanding the Role of Air Pressure

*Explaining Atmospheric Circulation

Atmospheric Pressure

Atmospheric pressure is an important influence on the redistribution of energy over the globe.

Basically, it is the weight of the gases in the atmosphere as they press down on the earth's surface.

oxygen

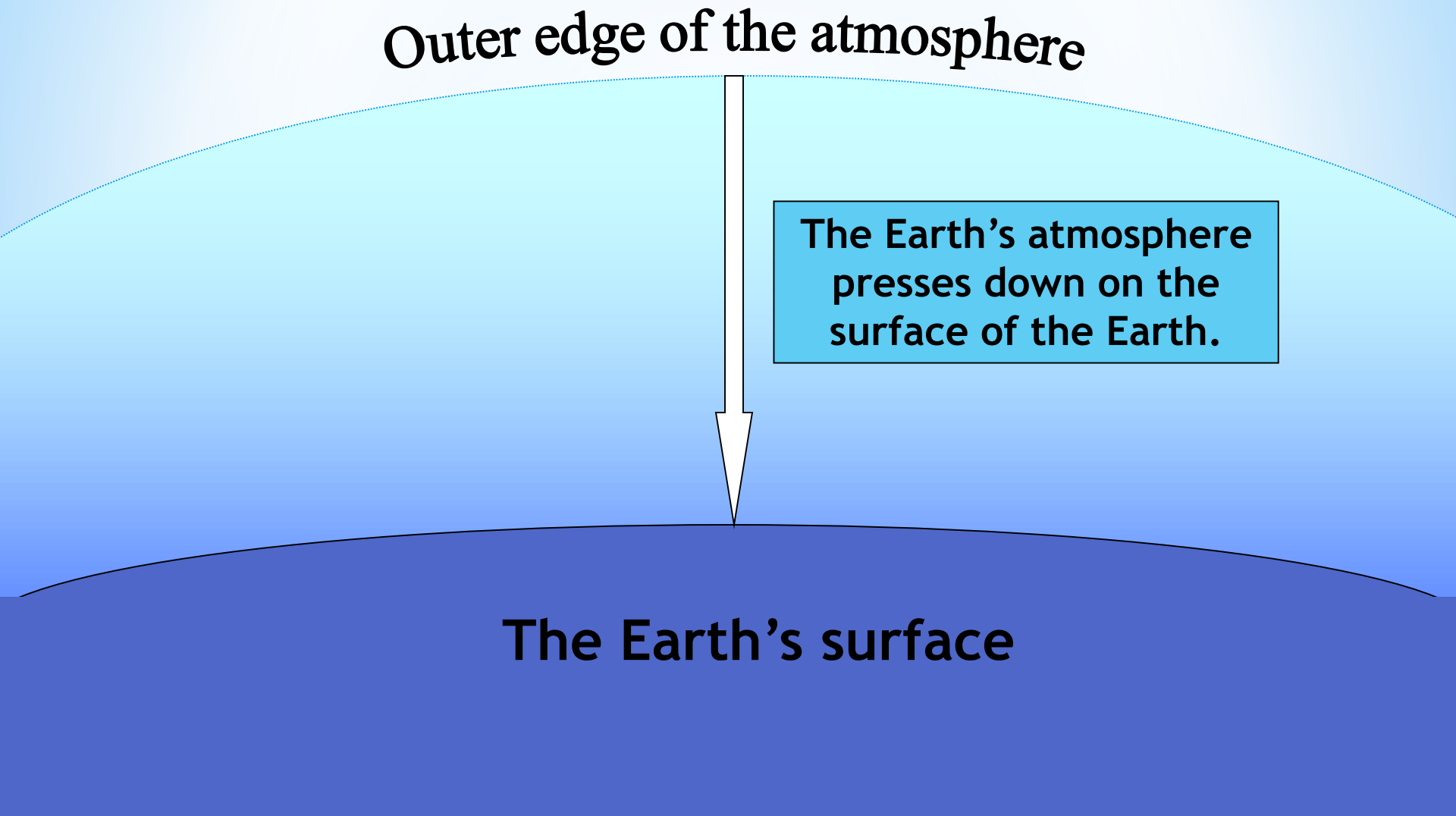
nitrogen

carbon dioxide

It is measured in MILLIBARS, and average pressure is around 1000mb.

Write a definition for air pressure

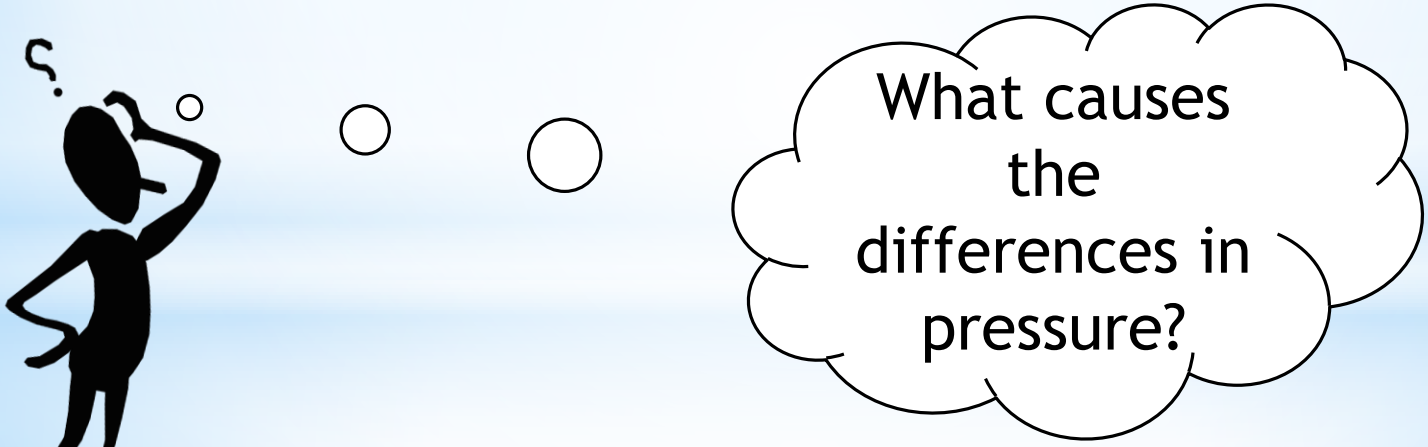
Atmospheric Pressure



Changes in Atmospheric Pressure

* Sometimes atmospheric pressure is higher than average. We call this **high pressure.**

* Sometimes atmospheric pressure is lower than average. We call this **low pressure.**



Low Pressure

- If air is ***heated*** it rises away from the Earth's surface.
- Rising air **reduces** the weight of air pressing down on the Earth's surface.
- This means that air pressure is ***low***.

Explain the cause of low air pressure

Clouds form…

It cools as it rises…

Warm air rises…

Sun heats the air at the earth surface

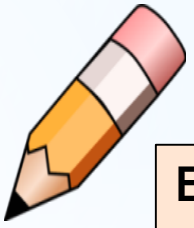
The air pressure decreases

High Pressure

- When air is cold, high up in the atmosphere it falls towards the earth's surface.
- Falling air **increases** the weight of air pressing down on the Earth's surface.
- This means that air pressure is ***high***.

Cold Air sinks towards the earth's surface…

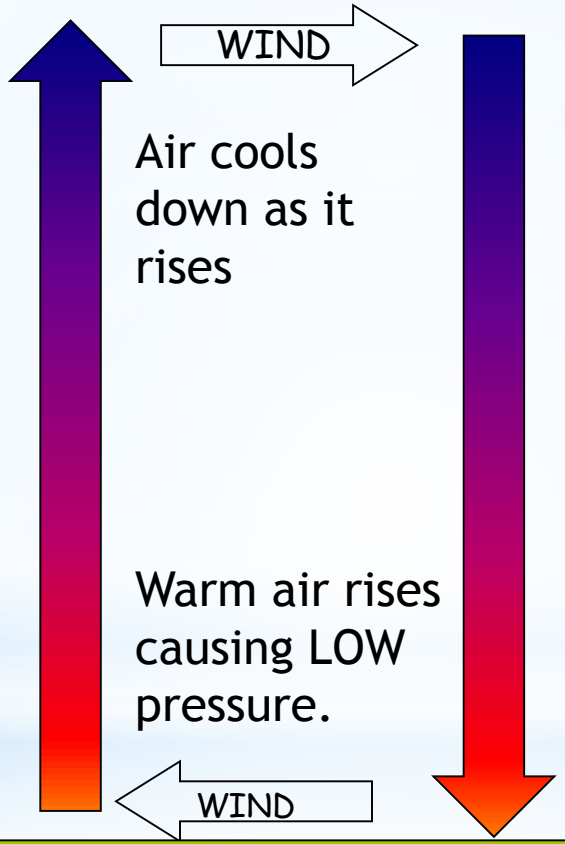
Air pressure increases



Explain the cause of high air pressure

High and Low pressure together

High and low pressure together create a cell-like movement of air. This is the basis for ATMOSPHERIC CIRCULATION



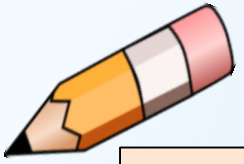
Air cools down as it rises

Cold air is dense and heavy so sinks back towards the earth's surface

Warm air rises causing LOW pressure.

Cold air falling causes HIGH pressure.

Sun heats the earth's surface



Make a copy of the diagram to show the link between high and low pressure

Part 2: The Role of Atmospheric Circulation

*Explaining Atmospheric Circulation

*The Single Cell Model

In 1735, scientist George Hadley proposed that energy was transferred to higher latitudes by WINDS generated from TROPCAL HEAT. He suggested that:

*The sun heats the air at the Equator

*This warm air rises into the atmosphere creating a LOW PRESSURE zone at the Equator.

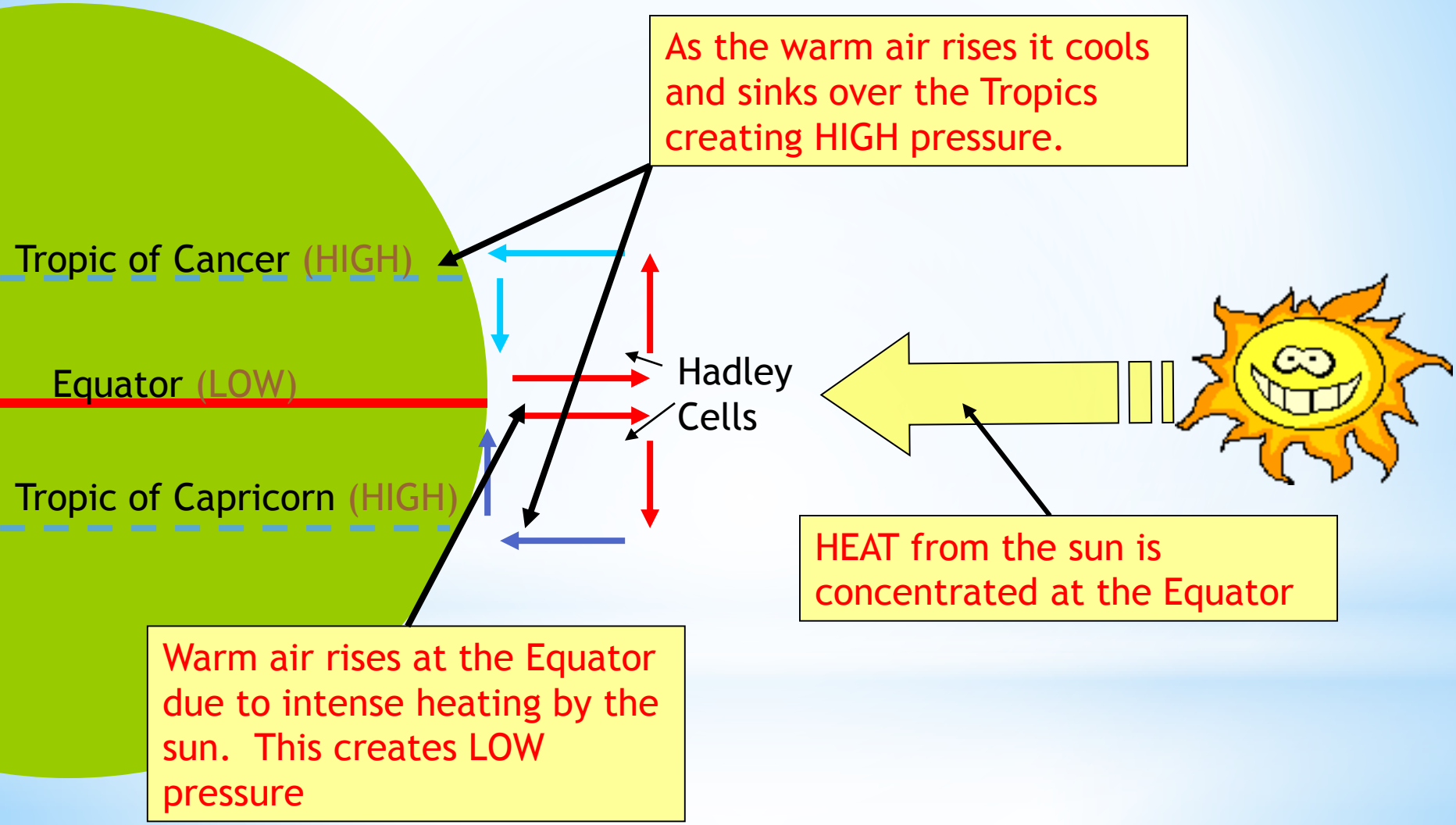
*It is then transferred northwards and southwards by the atmospheric winds.

*As it cools, it sinks back down to earth over the Tropics, creating HIGH PRESSURE zones.

*The cooler air then moves back towards the Equator.

*This movement of air between the Equator and Tropics was termed THE HADLEY CELL.

HADLEY CELLS



BUT

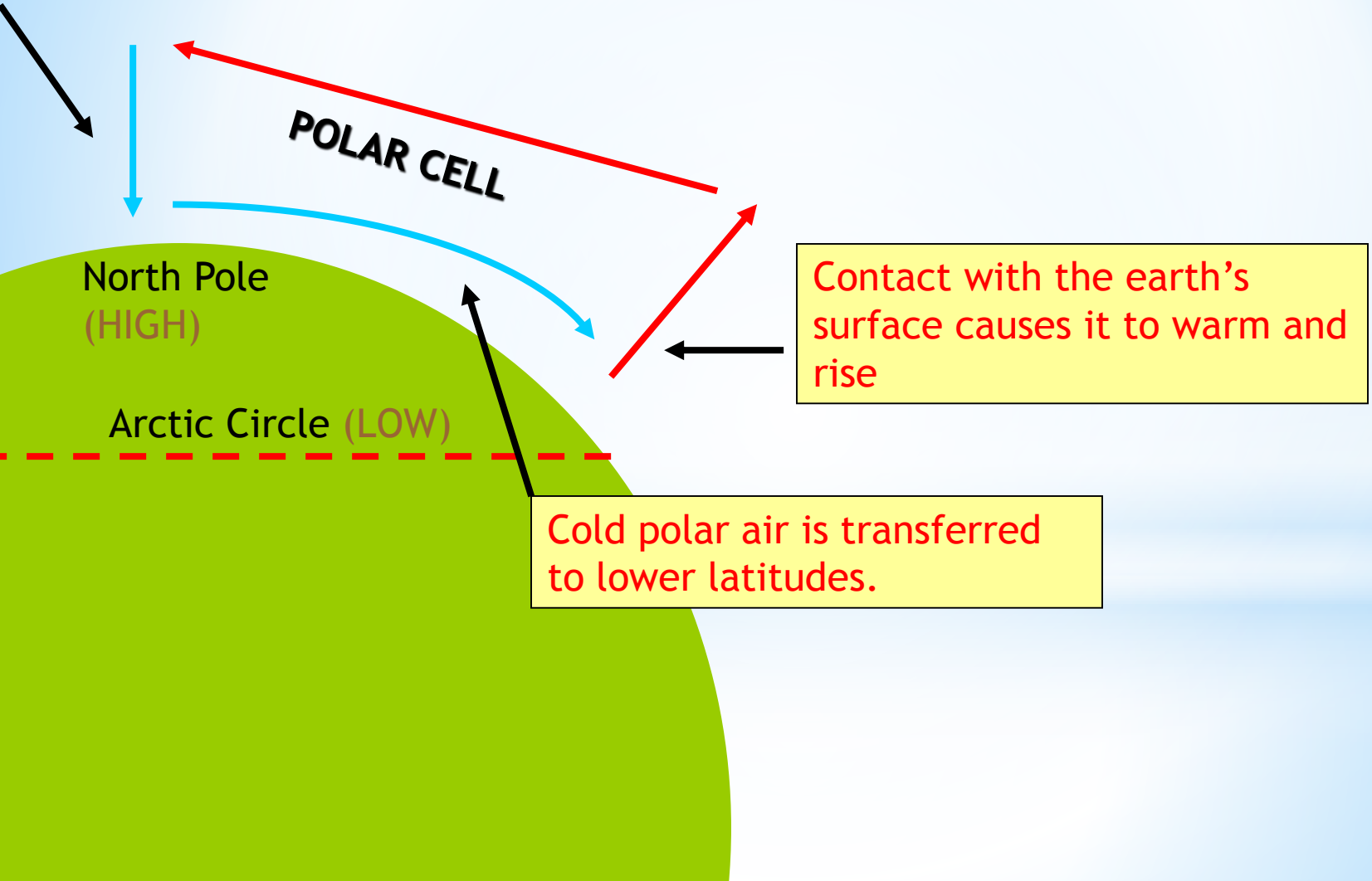
Hadley was very vague about what was happening between the POLES and the TROPICS, so in 1856 a THREE-CELL MODEL was formulated by William Ferrel.

Ferrel's Three-Cell Model of Atmospheric Circulation

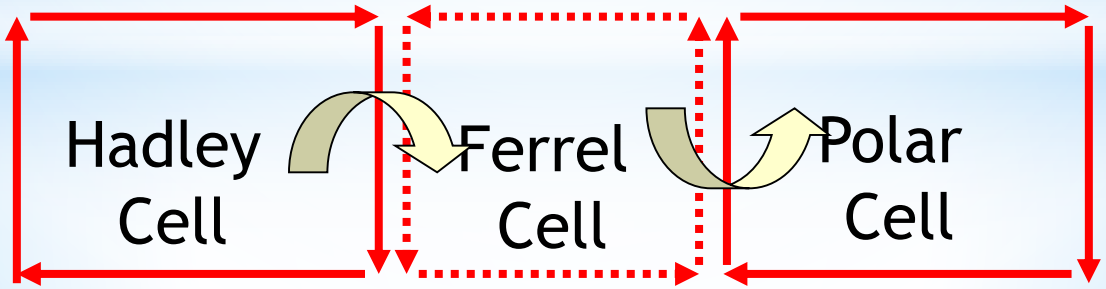
Ferrel proposed the following:

- He included the HADLEY CELL in his model; warm air rising as the Equator due to intense heat, creating a low pressure zone. As the air rises it cools and sinks over the Tropics creating High pressure areas.
- He also suggested that at the Poles the air is cold and constantly sinks, creating HIGH pressure.
- This cold air is transferred by surface winds to lower latitudes.
- As it is transferred across the earth's surface it warms and rises at the subtropics.
- This warm air is then returned to the Poles by atmospheric winds.
- Ferrel called this the **POLAR CELL.**

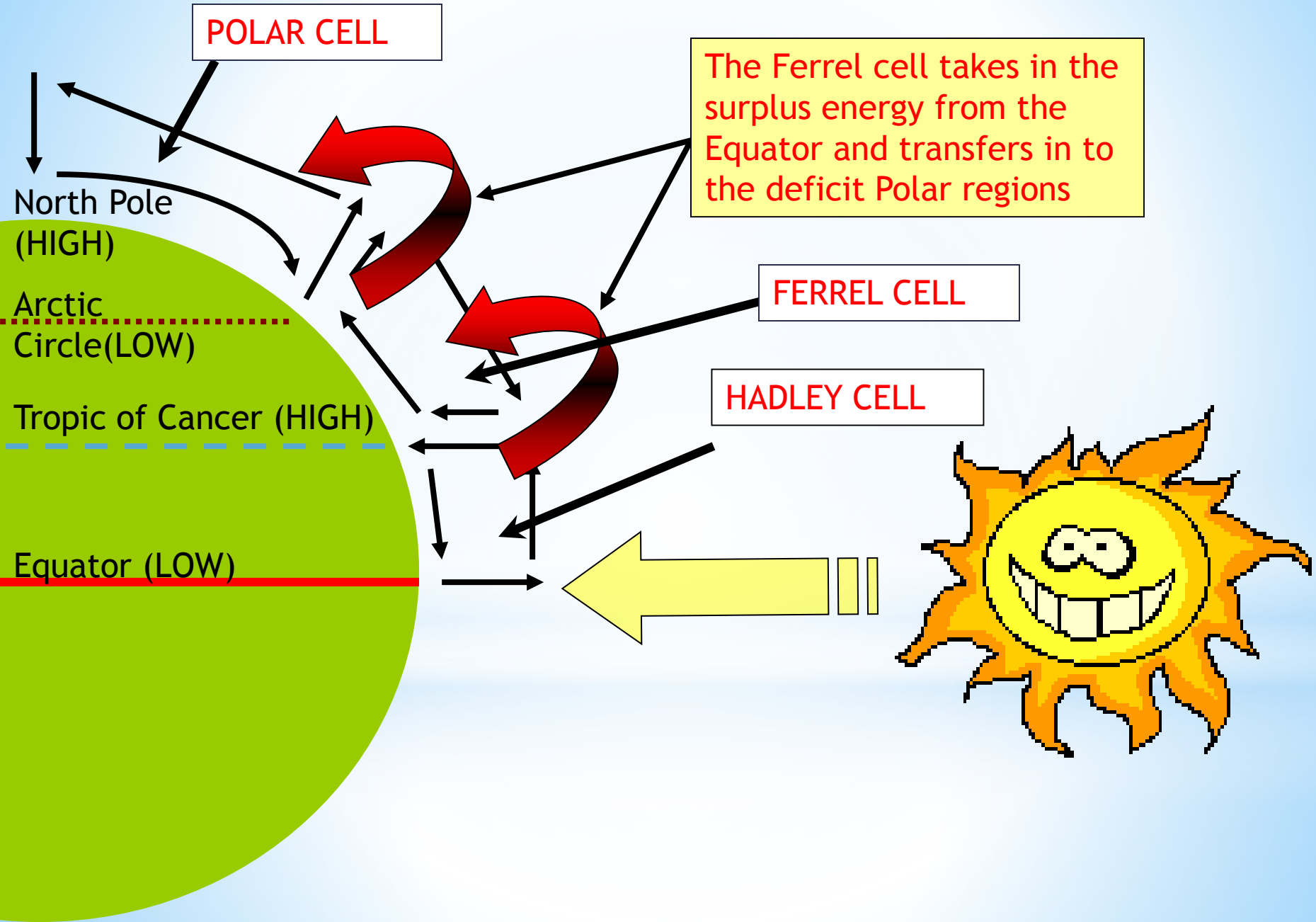
THE POLAR CELL



* Finally, Ferrel proposed a third cell, situated between the HADLEY and POLAR cells.
* This cell, called the FERREL CELL, forms as a result of temperature differences between the Hadley and Polar Cells.
* Warm air from the Hadley cell feeds into the Ferrel cell, and finally from the Ferrel cell into the Polar cell.
* In this way heat is transferred from the Equator where there is an energy surplus to the Poles where there is an energy deficit.



The Three-Cell Model of Atmospheric Circulation



*Test Your Understanding!

1) George Hadley proposed a single cell model of atmospheric circulation. What did he suggest happened to:

a) Air at the Equator

b) Air at the tropics

2) What effects did these movements of air have on the air pressure at the Equator and Tropics?

3) Describe and explain the Hadley cell in detail.

4) Why was Hadley's single cell model criticised?

5) Ferrel included the Hadley cell in his model of atmospheric circulation, but added **two other cells**.

a) Describe in detail how the Polar Cell Cell operates.

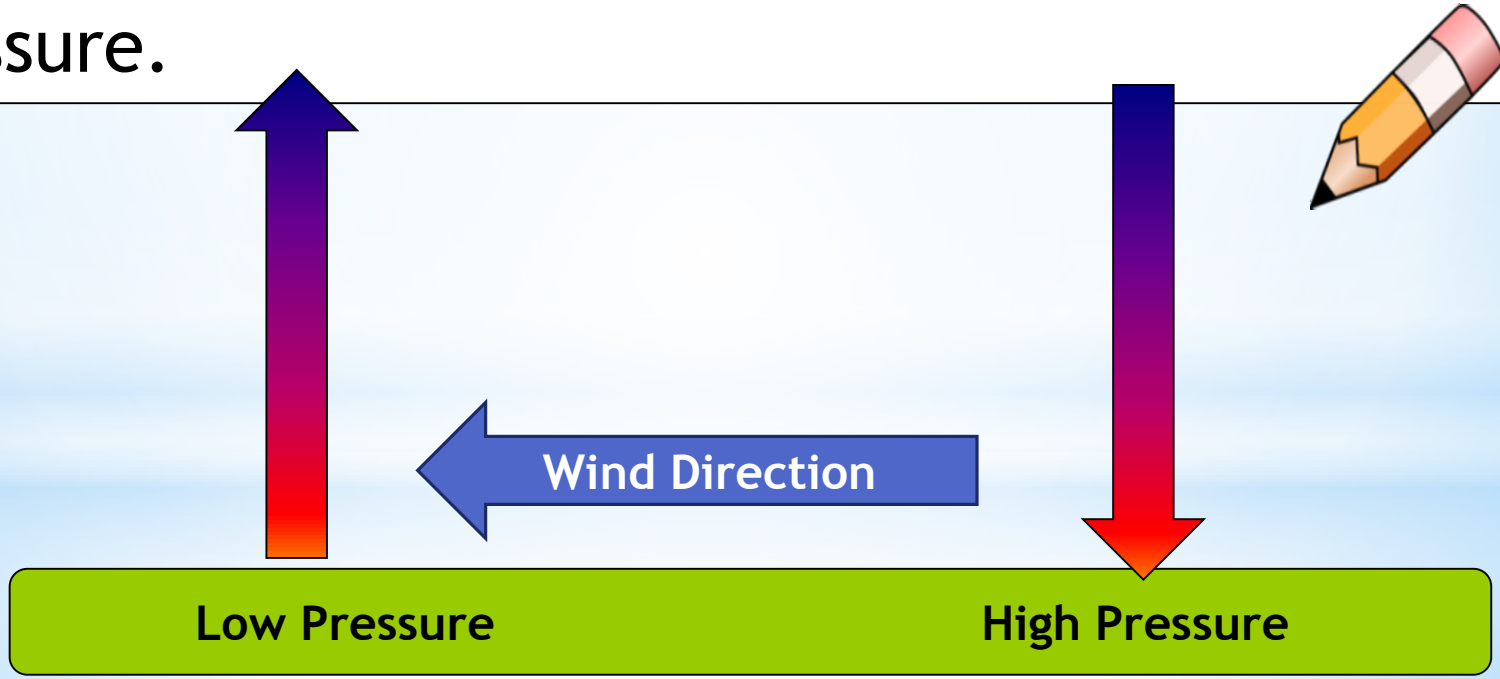
b) Explain how the Ferrel Cell helps to transfer energy.

Part 3: The Role of Surface Winds

*Explaining Atmospheric Circulation

*Surface Winds

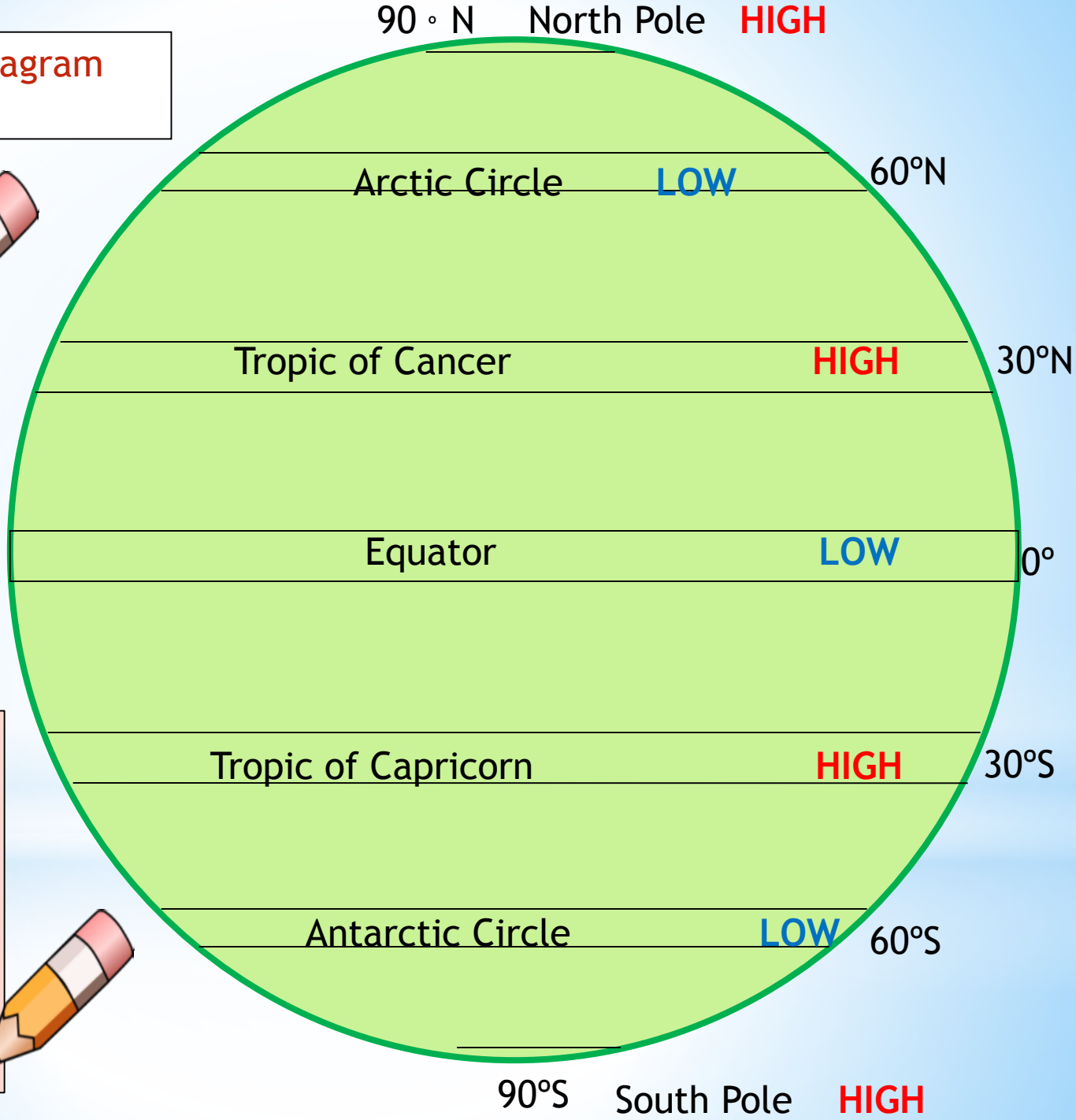
Winds are the movement of air from one place to another. Winds will always blow from areas of HIGH air pressure to LOW air pressure zones. Winds do this to balance out the difference in air pressure.



Glue a copy of this diagram into your notes

Now add the names of the different latitudes:
Equator
Tropic of Cancer, Tropic of Capricorn, Arctic Circle, Antarctic Circle, North Pole, South Pole

Now add the words HIGH or LOW to each latitude to represent the air pressure. You might need to look back at your 3 cell model notes



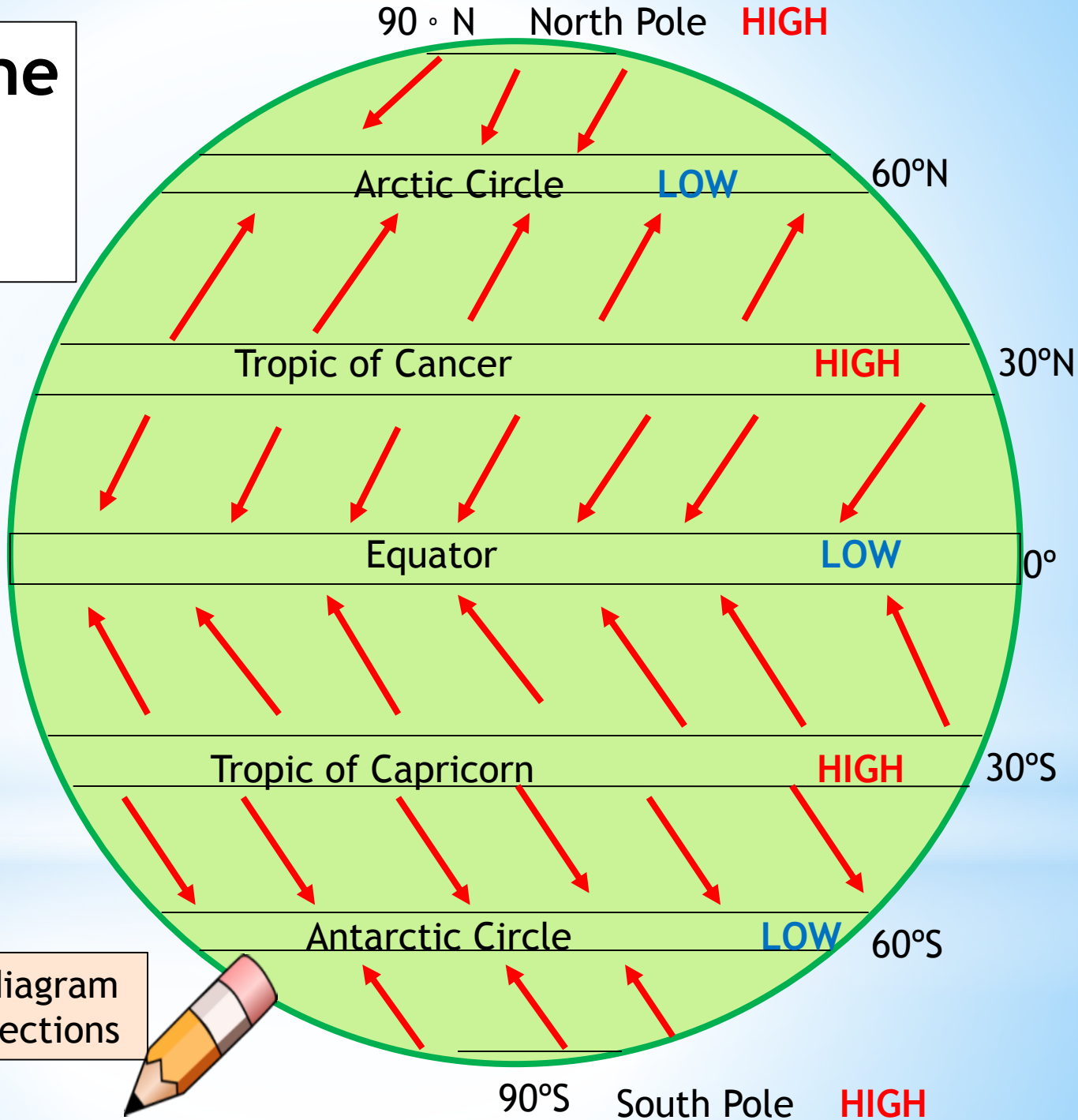
Work Out the Wind Direction

Wind Rule: **from HIGH to LOW.**

Which way will winds blow between

a) the Equator and tropics
b) The Tropics and the Subtropics
c) The subtropics and the Poles?

Add arrows to your diagram to show the wind directions



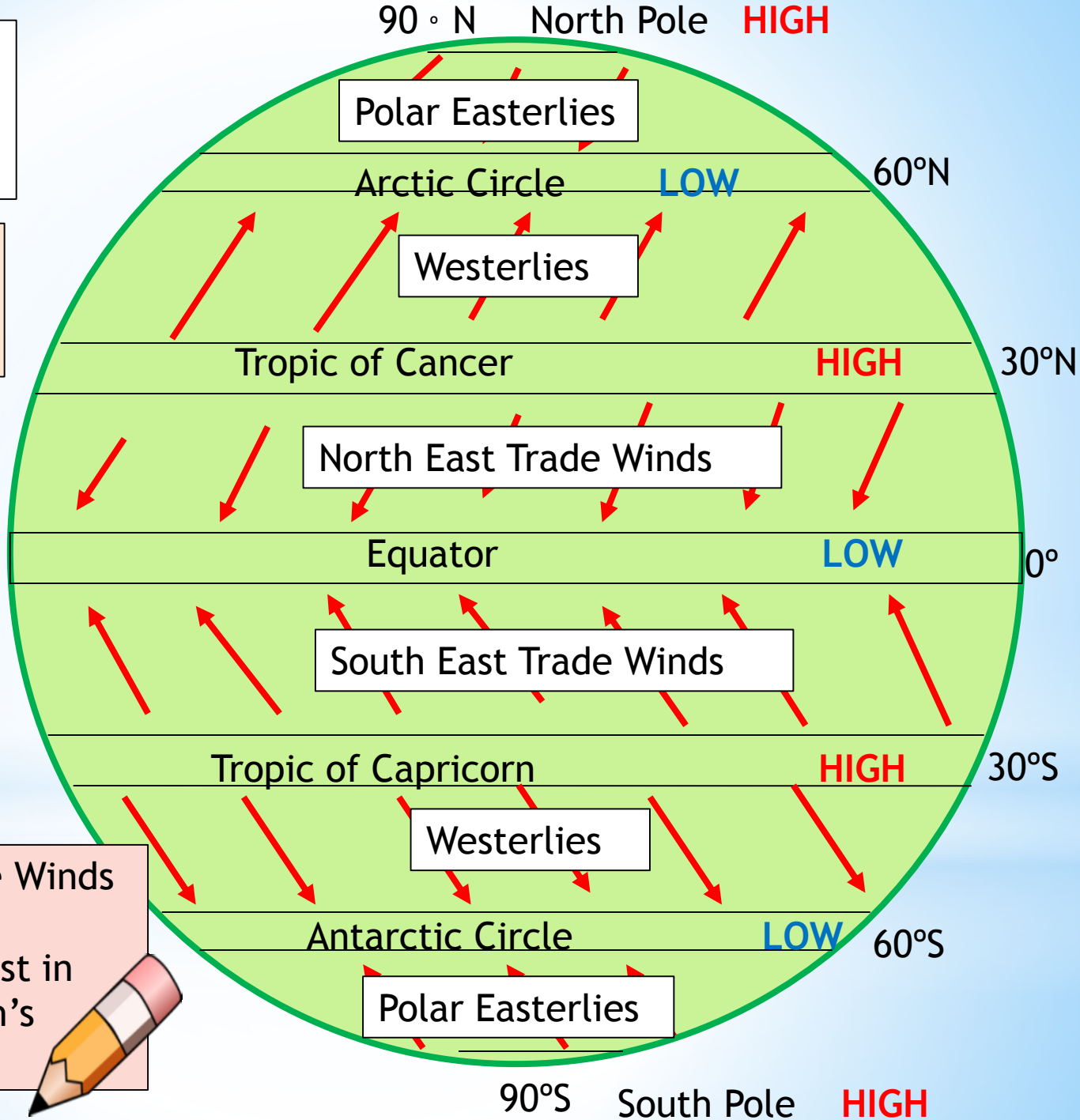
Name the Winds

The trade winds blow between the Tropics and Equator.

The Westerlies blow between the Tropics and Subtropics

The Polar blow between the Poles and Subtropics

Add the names of the Winds to your diagram.
Explain how they assist in maintaining the earth's energy balance

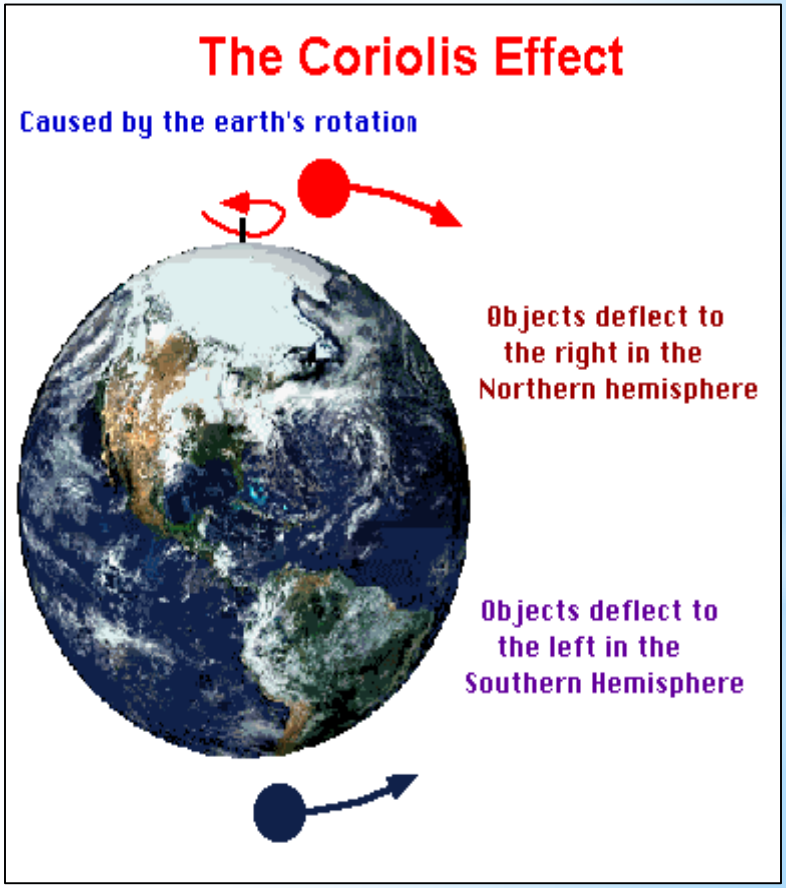


*Idealised Winds: A Reality Check!

These wind belts and patterns are often termed "idealised" because they are not quite so straightforward in reality. Let's see why!

Coriolis Effect

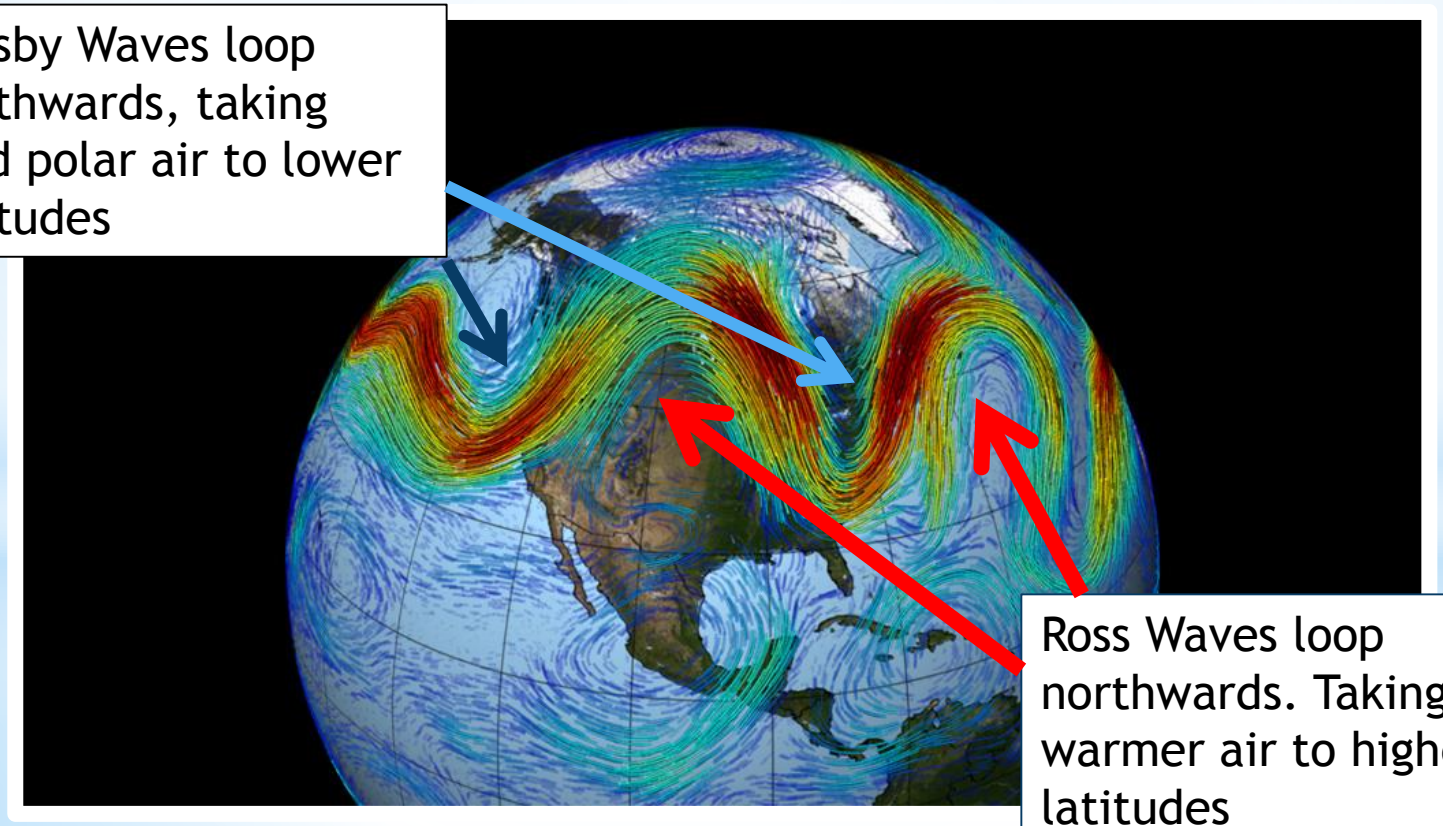
Winds blowing from high to low pressure are deflected by the spinning of the earth. In the northern hemisphere winds are deflected to the right. In the southern hemisphere they are deflected to the left.
Sometimes winds are deflected to such an extent that they flow almost horizontally creating a Geostrophic wind.



Rossby Waves

Are wave-like patterns found within the westerly wind belts. They form as a result of temperature and pressure differences. By looping southwards cold polar air is transferred to lower latitudes, and by looping northwards warm tropical air is transferred to higher latitudes.

Rossby Waves loop southwards, taking cold polar air to lower latitudes

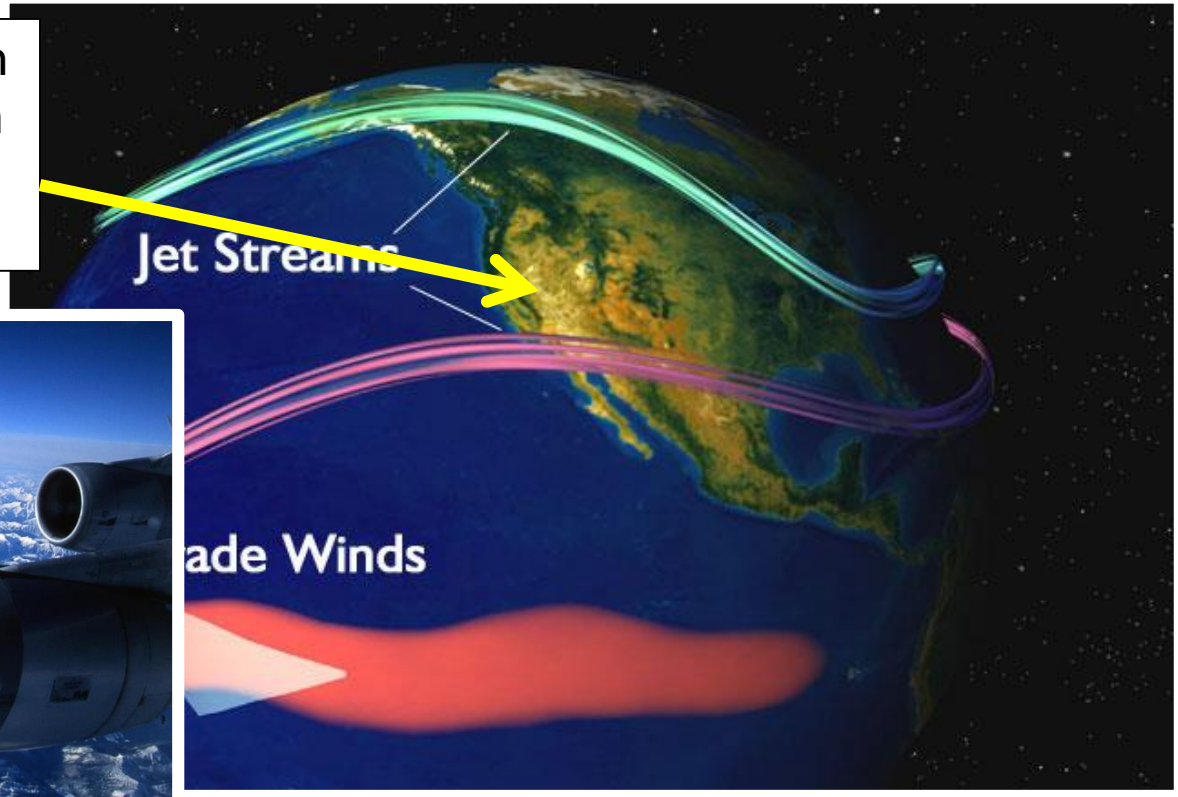


Ross Waves loop northwards. Taking warmer air to higher latitudes

Uneven Land Surface

The relief of the land can disrupt the generalised pattern of surface winds, with mountain ranges obstructing and deflecting the wind belts. The Rocky mountains for example deflect the westerly winds.

Rocky Mountains on North America's West Coast can interrupt and deflect the Westerly Winds



Test Your Understanding!

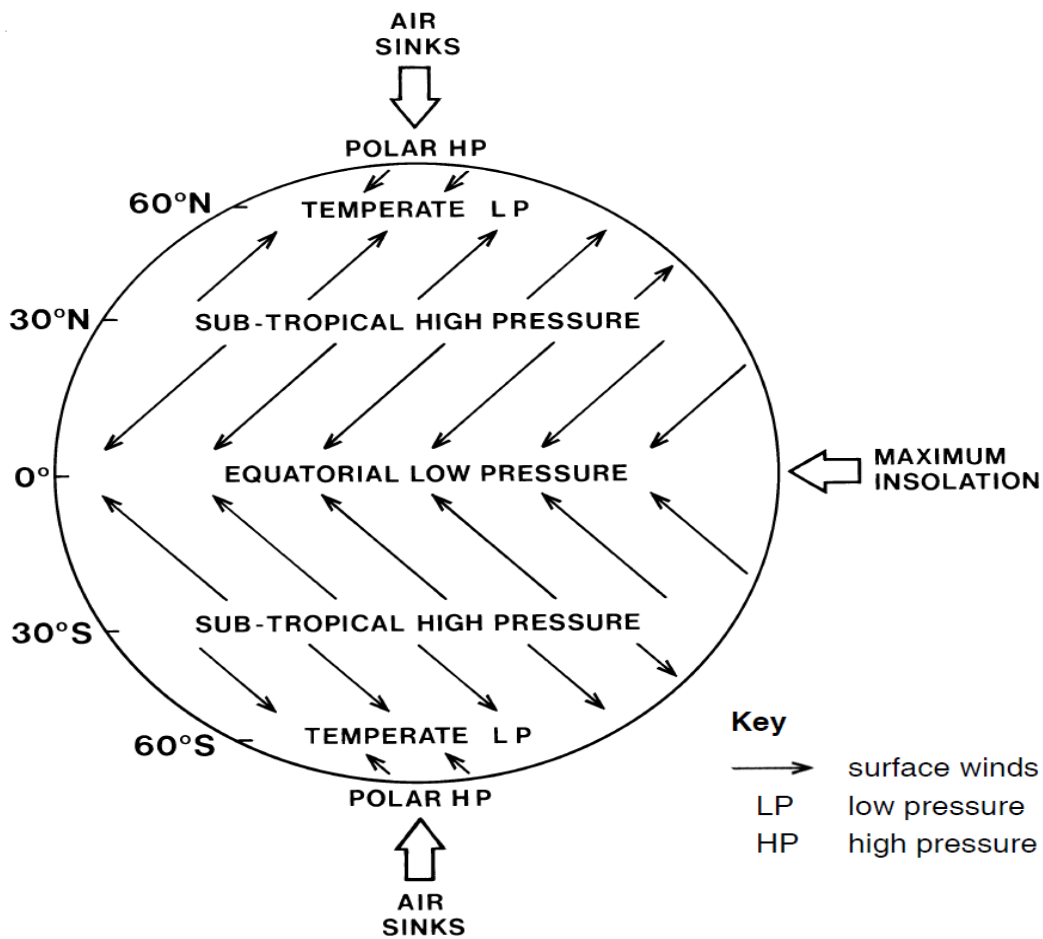
1) Between which type of pressure do winds always blow?
2) How do the 3 atmospheric cells contribute to the generalised pattern of surface winds?
3) Name and locate the earth's 3 main wind belts.
4) Convergence is the name given to the point where different winds meet or descend on a low pressure zone (where air comes together). The Equator is one zone of convergence. Name the other 2.
4) Divergence is the name given to a zone where air moves away from a High pressure. (where the wind blows from a High pressure Zone). Name the main zones of divergence.
5) How does the coriolis effect impact upon the generalised pattern of surface winds?
6) How do Rossby Waves help to transfer energy from low latitude surplus areas to high latitudes deficit areas?
8) How can an uneven land surface affect surface winds?

Exam practice!

Study Reference Diagram Q5 which shows surface winds and pressure zones.

(*b*) **Explain** how circulation cells in the atmosphere and the associated surface winds assist in the transfer of energy between areas of surplus and deficit. 5

Reference Diagram Q5 (Surface winds and pressure zones)



Collect a copy of the Higher Exam Question Shown here

Identify the KEY WORDS in the questions. Understand exactly what it is asking you to do!

Use the Answer Frame on the next slide to help you structure your response.

GOOD LUCK!

1) **Describe** and **explain** each of the atmospheric cells

* Start with Hadley
* Then describe and explain Polar
* Then describe and explain Ferrel

2) **Explain** how the cells create **different pressure zones** and **identify** the pressure at each latitude.

3) **Introduce the surface winds** by explaining that they blow from High to Low Pressure. State their **names** and describe the **directions** they blow to help transfer energy.

4) **Describe** and **explain** how Rossby Waves can also assist in the transfer of energy

*Answer Frame

A Model Answer

Three atmospheric cells transfer energy across the globe. The first cell, the Hadley cell, results from direct heating of air at the Equator. This warm air rises creating low pressure. The air eventually cools and sinks over the Tropics, making these high pressure zones. (1) Some air is then returned to the Equator as the Trade Winds. At the poles cold air sinks, creating high pressure areas. As this air moves across the earth's surface it is warmed, rises at the sub-tropics and is then returned to the poles. This movement of air is known as the Polar Cell (1). The Ferrel cell sits between the other two cells. It takes in the warm air from the tropics and transfers it to the higher latitudes, reducing deficit at the poles and the surplus at the Tropics. (1)

These cells create a pattern of surface winds which transfer energy. Winds blow from high to low pressure, with Trade winds transferring energy from the Tropics to the Equator, and the Westerlies, transferring energy pole wards from the tropics (1). Rossby waves in the westerly wind belts also assist in energy transfer, as by looping southwards cold air is transferred to lower latitudes and by looping northwards warm air is transferred to higher latitudes.(1)