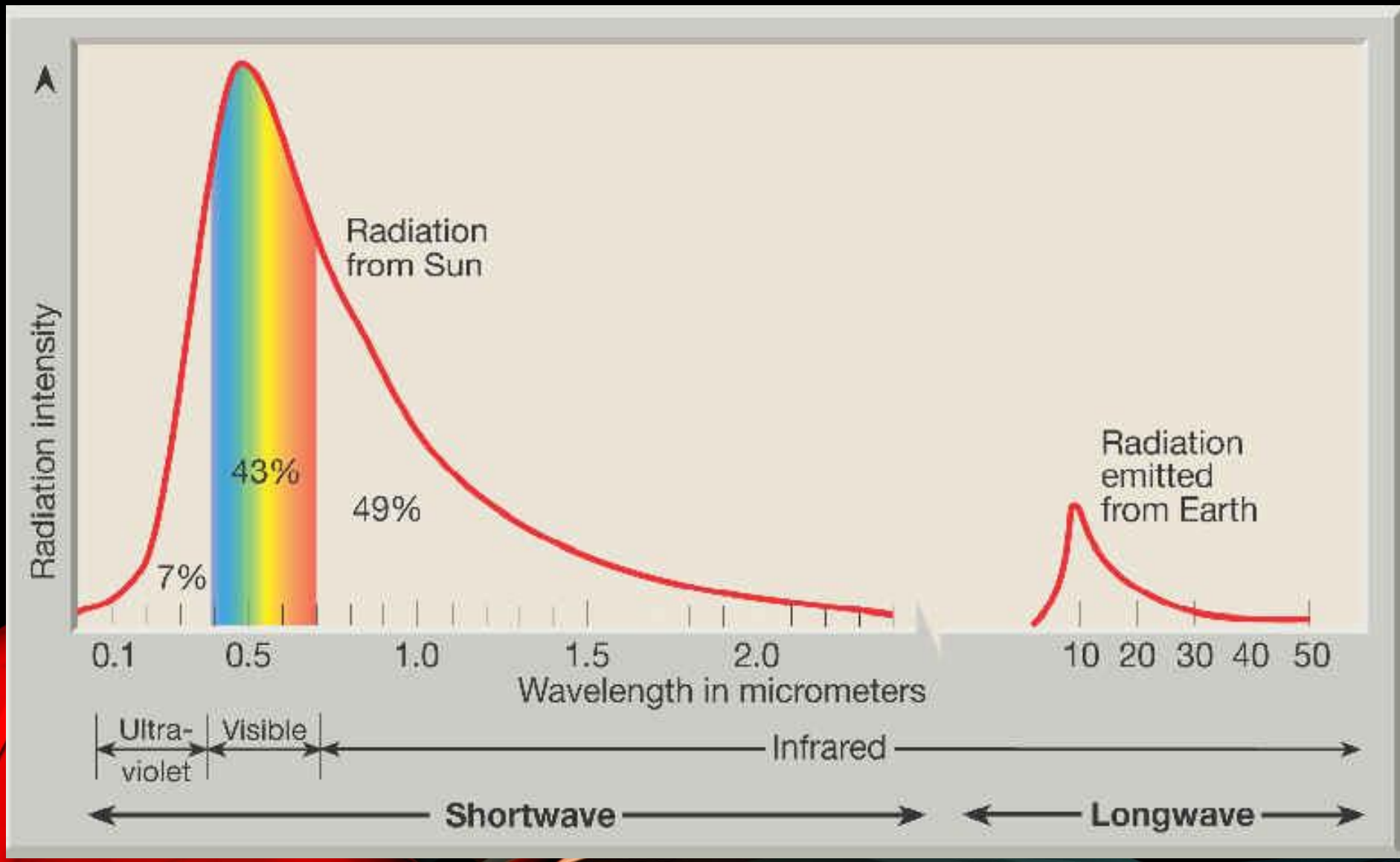
Understanding weather and the weather forecast

Week 20

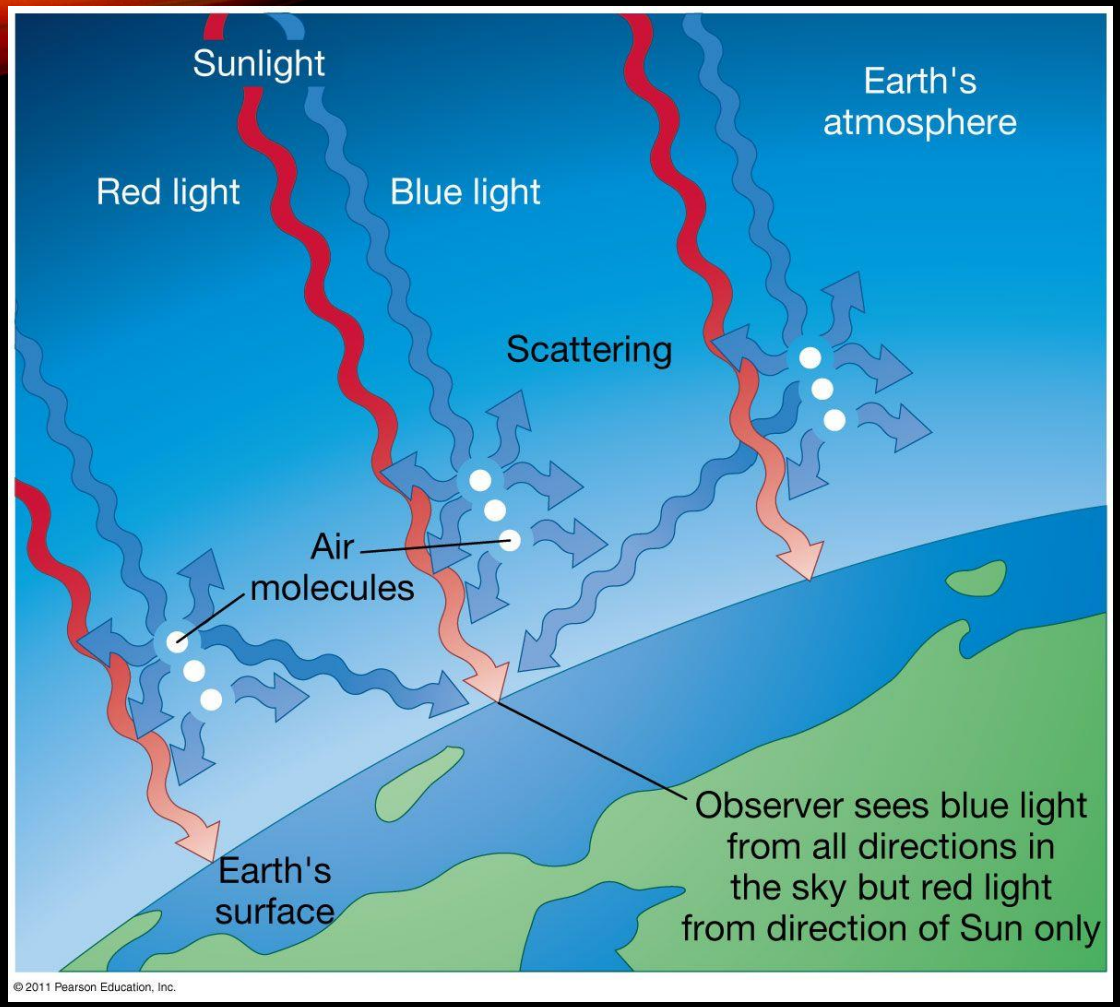
Sky and Rain

Terry Hart

The solar spectrum inward from the sun and the energy outwards from the Earth



Why is the sky blue? Rayleigh scattering



Not quite Rayleigh Scattering but useful a demonstration : https://www.youtube.com/watch?v=5B-qrEdQv1U

Clouds and Rainfall

Any process that cools air can lead to **saturation** and **condensation** of atmospheric water vapour into liquid water droplets. However, there are two important characteristics of water that affect the formation of cloud and rainfall.

1. Even if air is saturated, condensation may not take place without condensation nuclei such as:

- Dust, soot or black carbon from fires, factories or vehicles
- sea salt from ocean wave spray
- sulphates from volcanic activity
- dimethyl sulphide produced from phytoplankton in the ocean
- oxidation of sulphur dioxide and organic compounds.

Harvard video cloud formation Video: how raindrops are formed – Nate Byrne

This is the principle behind:

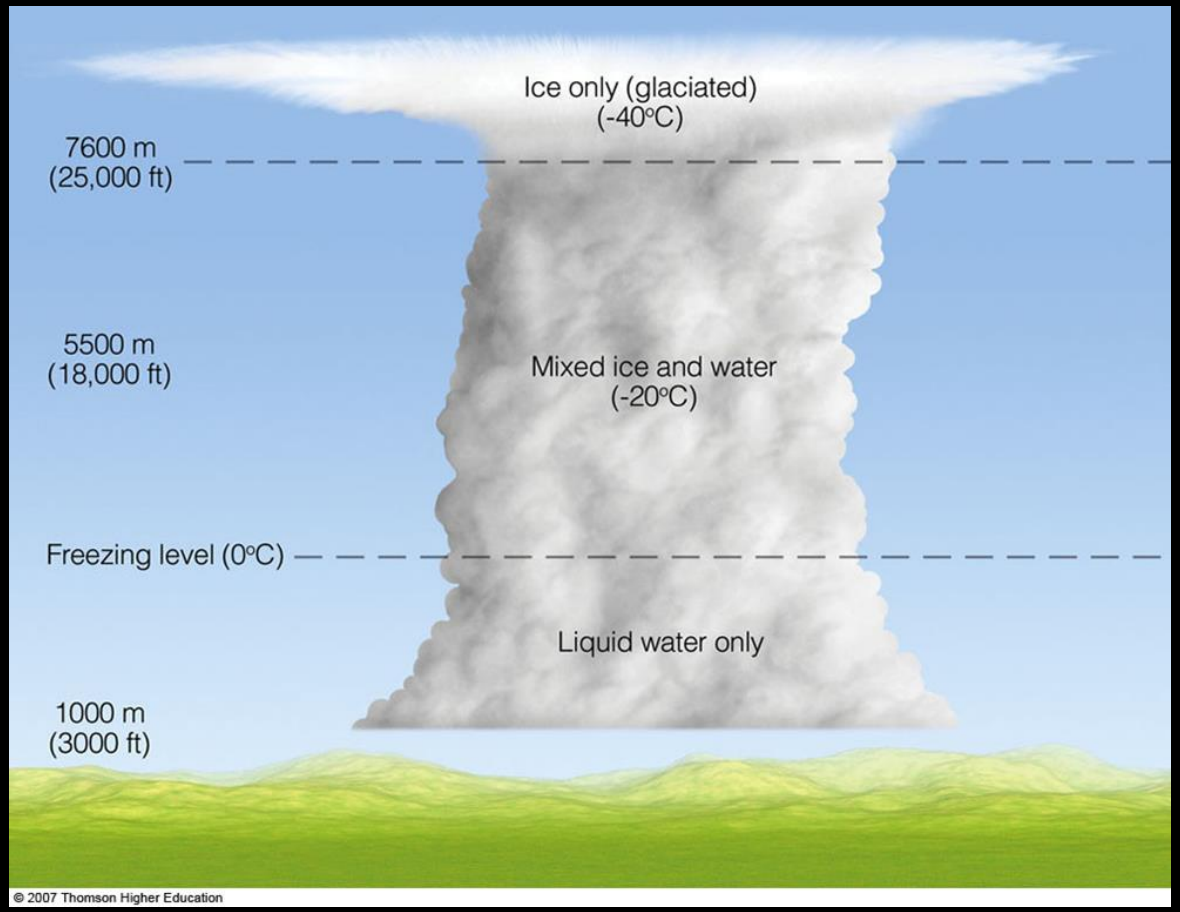
- Cloud chamber used to detect ionising radiation in nuclear physics or cosmic ray studies
- Cloud seeding

Clouds and Rainfall

2. Ice crystals can be cloud condensation nuclei but, even below 0°C water drops may not freeze until the temperature falls to -40 ° C

At temperatures between 0°C and -40 ° C there is a mixture of supercooled water drops and ice crystals.

A layer of supercooled water (especially warmer than -15 ° C) can be a hazard for aircraft. The supercooled water will freeze when it hits the airframe leading to icing on the wing



What holds clouds up?

An early explanation was that clouds were lighter-than-air bubbles.

Actually, they are tiny water drops or ice crystals, typically 20 microns (0.02 mm) in size.

The falling speed is about 0.5 metres per minute (meaning it would take 10 hours to fall 300 metres). So even a small updraft in a cloud will keep the droplet suspended. (Video: How do clouds float?)

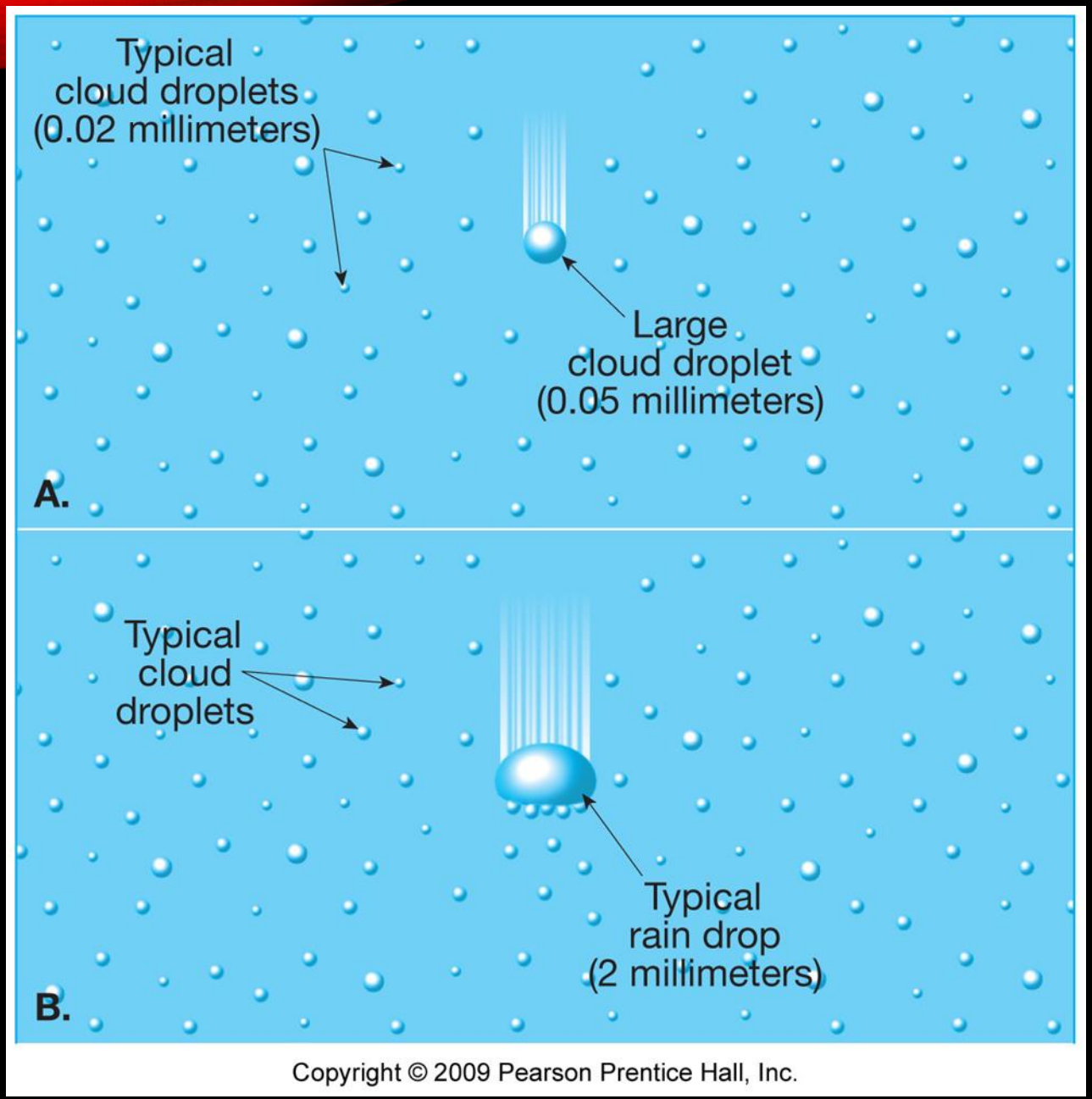
What makes raindrops form and fall?

How do we get drops that are 2-4 mm in size and fall at speeds of more than 6 metres per second (e.g. taking about 3 minutes to fall from 1200 metres to the ground)?

- Collision-coalescence (warm clouds)
- Wegener–Bergeron–Findeisen process (clouds with some ice) (commonly simply the Bergeron process)

Both processes can occur, sometimes within the same cloud.

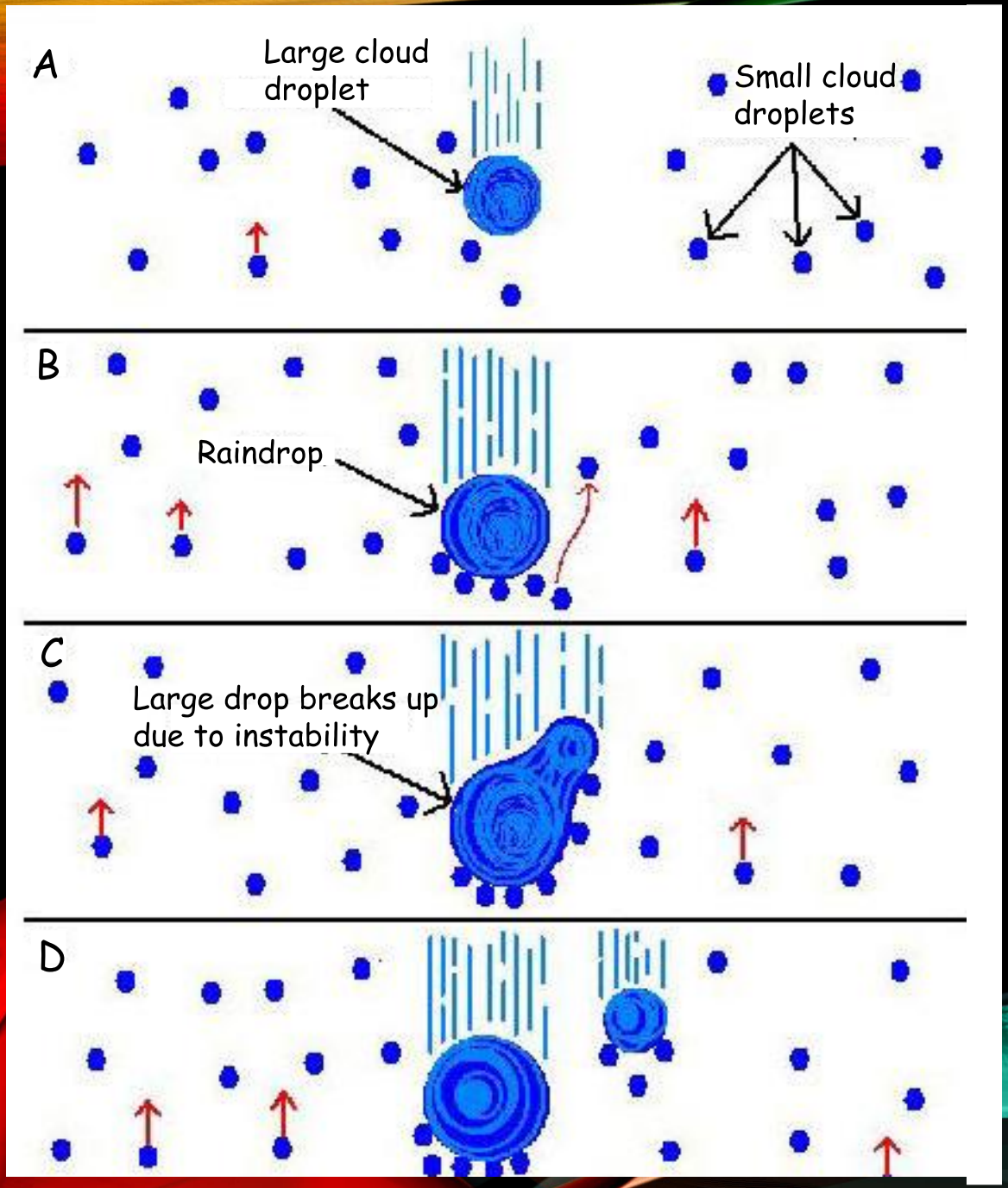
Collision-coalescence process



Larger drops fall through the smaller ones

Drops grow by collisions with smaller drops as they fall.

Larger drops (more than 4 mm) can then break up and continue to fall, collide and coalesce.



Collision-coalescence process

Acknowledgements to Peter Jackson

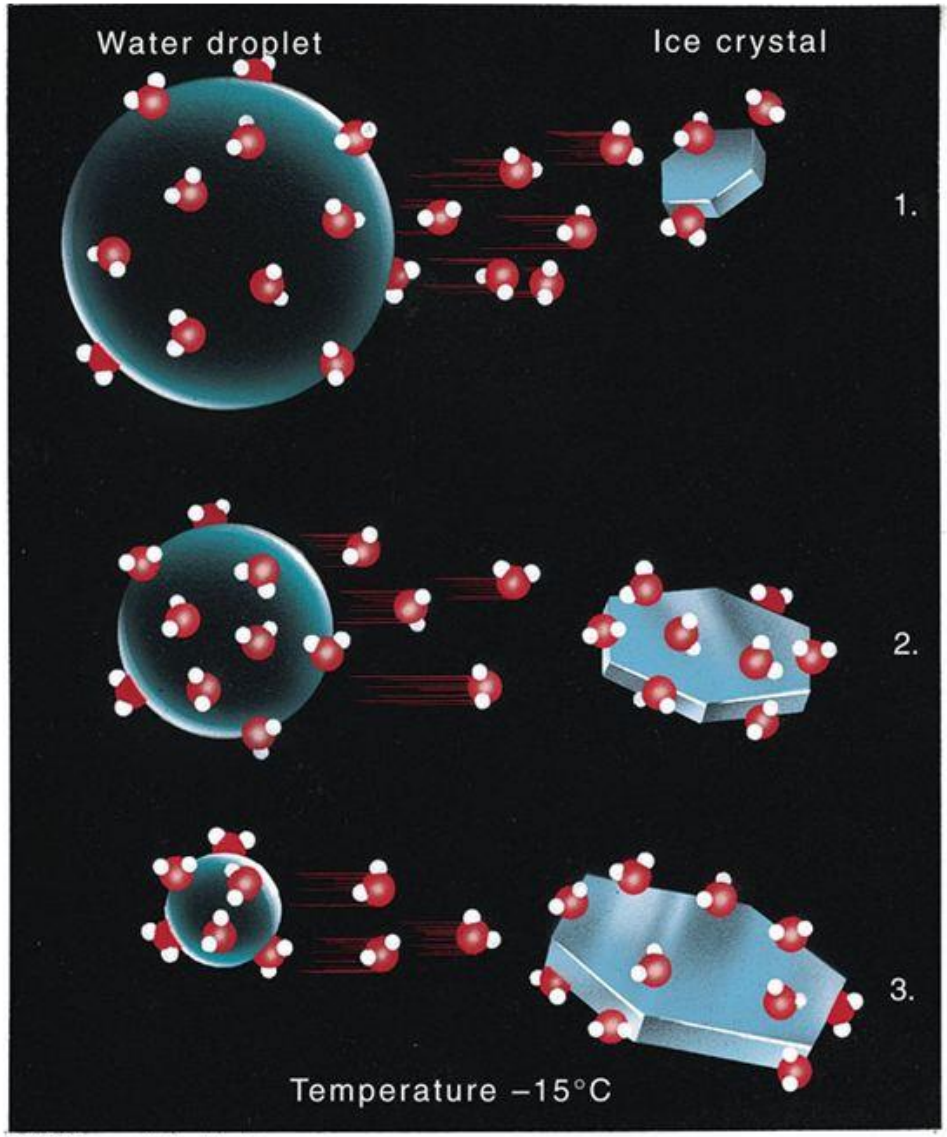
Bergeron Process

Evaporation is larger near droplet, condensation is larger around ice nuclei.

Water diffuses from drop to ice.

Removing water vapor increases evaporation around droplet.

Ice crystals grow at the expense of water droplets.

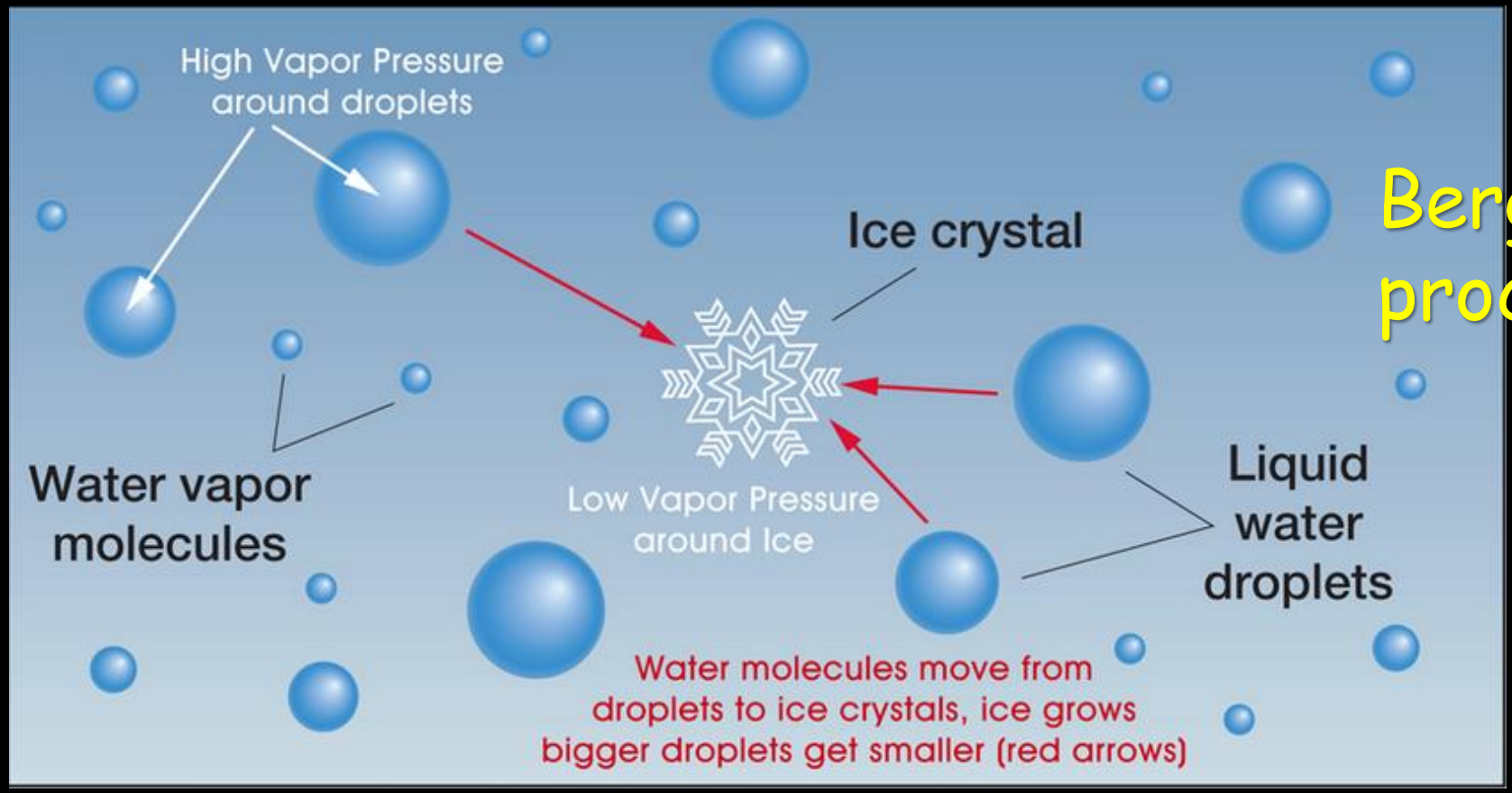


Video demonstration: https://youtu.be/gCNif1XFZk4

- The air around ice cannot hold as much water vapour as liquid water can, so the air around ice becomes saturated before the air around liquid water drops

- High vapour pressure around water droplets ➔ net movement of water molecules to the region around ice crystals

- ice crystal grows at expense of water droplets



Bergeron process

Ice growth through water vapour condensing on ice crystals.

- first proposed by **Alfred Wegener** in 1911 while studying hoarfrost formation.

- In the winter of 1922, **Tor Bergeron** made a curious observation while walking through the woods. He noticed that on days when the temperature was below freezing, the cloud (stratus) deck that typically covered the hillside stopped at the top of the canopy instead of extending to the ground as it did on days when the temperature was above freezing. Being familiar with Wegener's earlier work, Bergeron theorized that ice crystals on the tree branches were scavenging vapor from the supercooled stratus cloud, preventing it from reaching the ground.

- In 1938 German meteorologist Walter Findeisen extended and refined Bergeron's work through both theoretical and experimental work.

The Bergeron Process is more efficient than the collision-coalescence process.

It is especially important in middle and high latitudes, but occurs in the tropics in tall cumulonimbus clouds where the temperature is cold enough for enough ice crystals to form.

Notes:
Alfred Wegener, a meteorologist, first proposed the idea of continental drift.

Tor Bergeron, from Sweden, was an important figure in the promotion of the Norwegian Cyclone Model and the concept of fronts.

Walter Findeisen became Director of the German Weather Service in Prague in 1940 but disappeared after the Russians took over.

What happens after the ice crystals form?

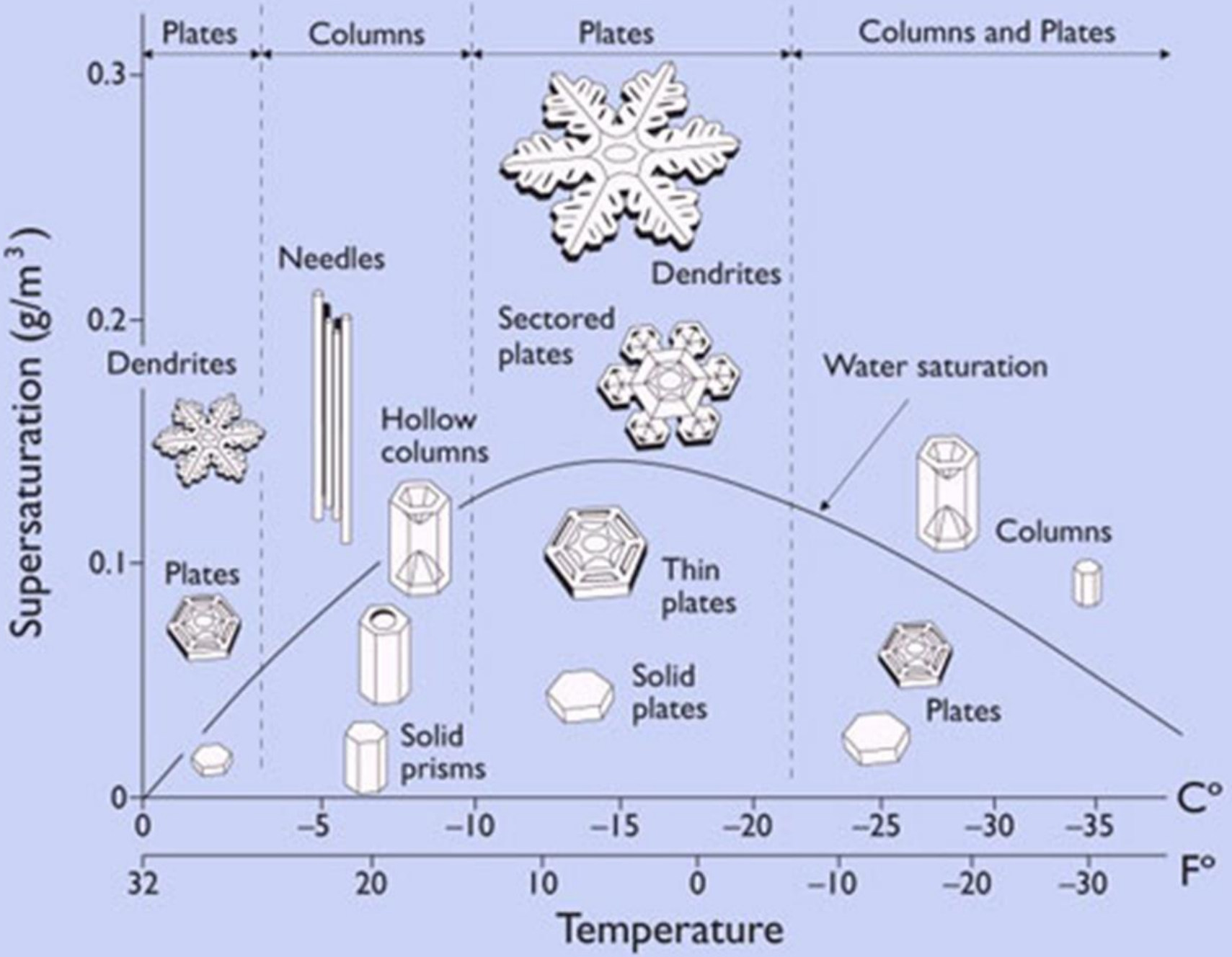
The ice crystals grow large enough to fall, and collide with other ice crystals or grow larger through collision coalescence, aggregation, or accretion leading to the many forms of snow crystals.

Aggregation - when ice crystals are slick or sticky at temperatures of −5 °C and above, because of a coating of water surrounding the crystal.

Accretion - When an ice crystal collides with supercooled water it is called accretion (or riming). The Droplets freeze upon impact and can form graupel.

If the graupel formed is reintroduced into the cloud by updrafts, it may continue to grow larger and more dense, eventually forming hail.

As the crystals grow and fall, the air temperature may be above freezing so that the crystals melt and fall as rain.


Plates
Columns
Plates
Columns and Plates
0.3
0.2
0.1
0
Supersaturation (g/m³)
Dendrites
Needles
Dendrites
Sectored plates
Water saturation
Hollow columns
Plates
Thin plates
Columns
Solid plates
Solid prisms
Plates
C°
0
–5
–10
–15
–20
–25
–30
–35
F°
32
20
10
0
–10
–20
–30
Temperature