Bharathidasan University

Programme: MSc Environmental Science and Sustainable Management

Course Title: Principles of Environmental Science and Sustainable Development

Course Code: 21PGCC01

Unit- I Planet Earth

Class 3

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The Earth System

Connections among the great spheres

This Island Earth

About 4.5 billion years old

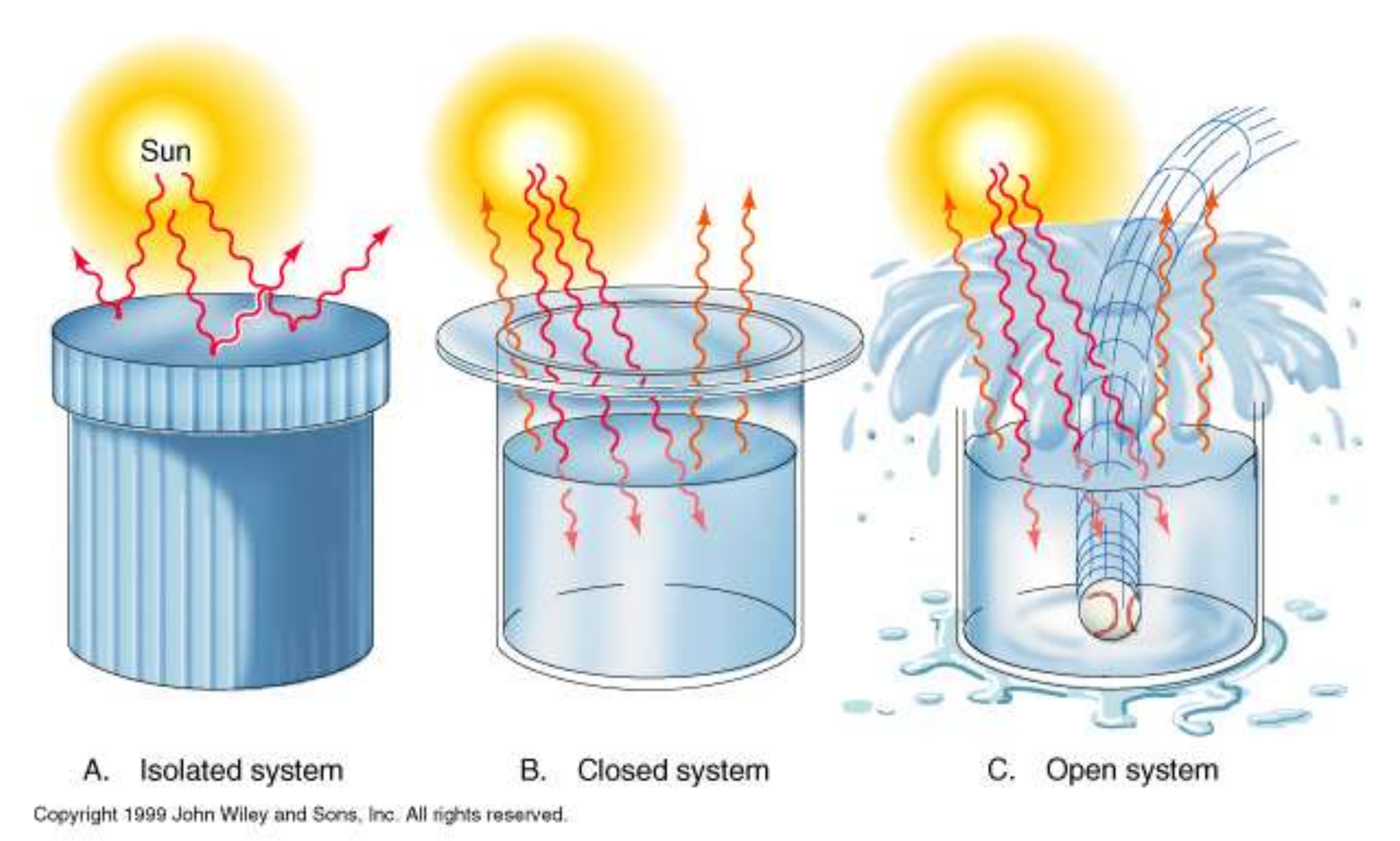
Geologically dynamic internally and externally

Only planet presently known to support life

As far as life is concerned: "Goldilocks of the Solar System" (relative to Sun, not too far, not too close, just right !)

A closed system !

Earth As A Closed System



Closed system: exchange of energy but negligible exchange of mass with surroundings

Earth’s Four Spheres

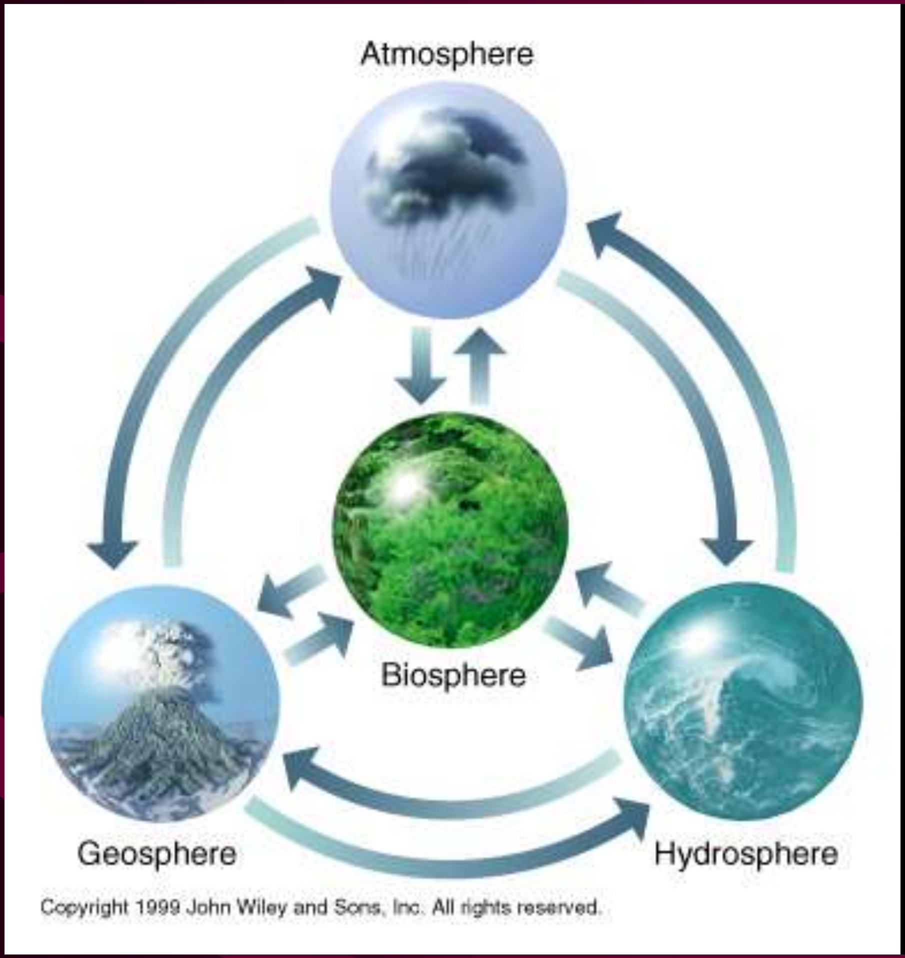
Geosphere: comprises the solid Earth and includes both Earth’s surface and the various layers of the Earth's interior.

Atmosphere: gaseous envelope that surrounds the Earth and constitutes the transition between its surface and the vacuum of space

Hydrosphere: includes all water on Earth (including surface water and groundwater)

Biosphere: the life zone of the Earth and includes all living organisms, and all organic matter that has not yet decomposed.

The Earth's Four Spheres



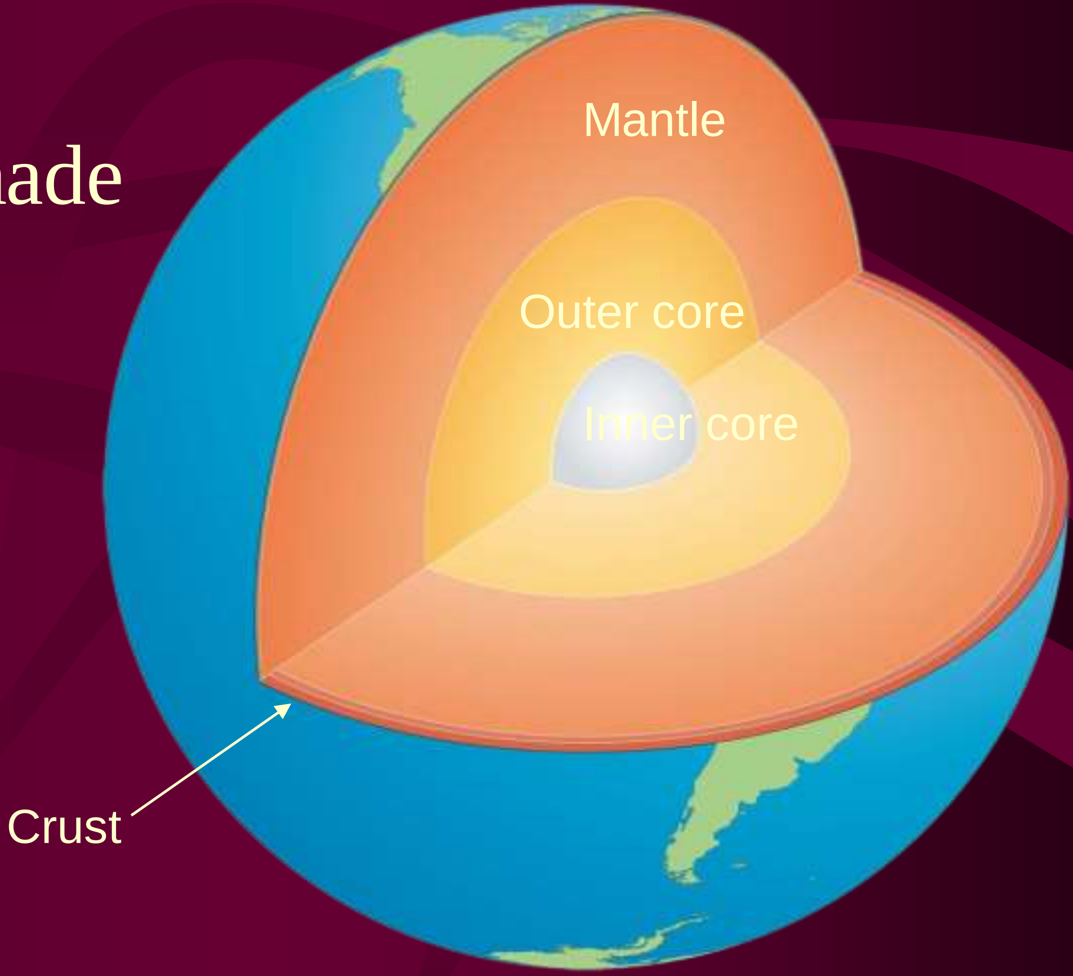
Geosphere (Solid Earth)

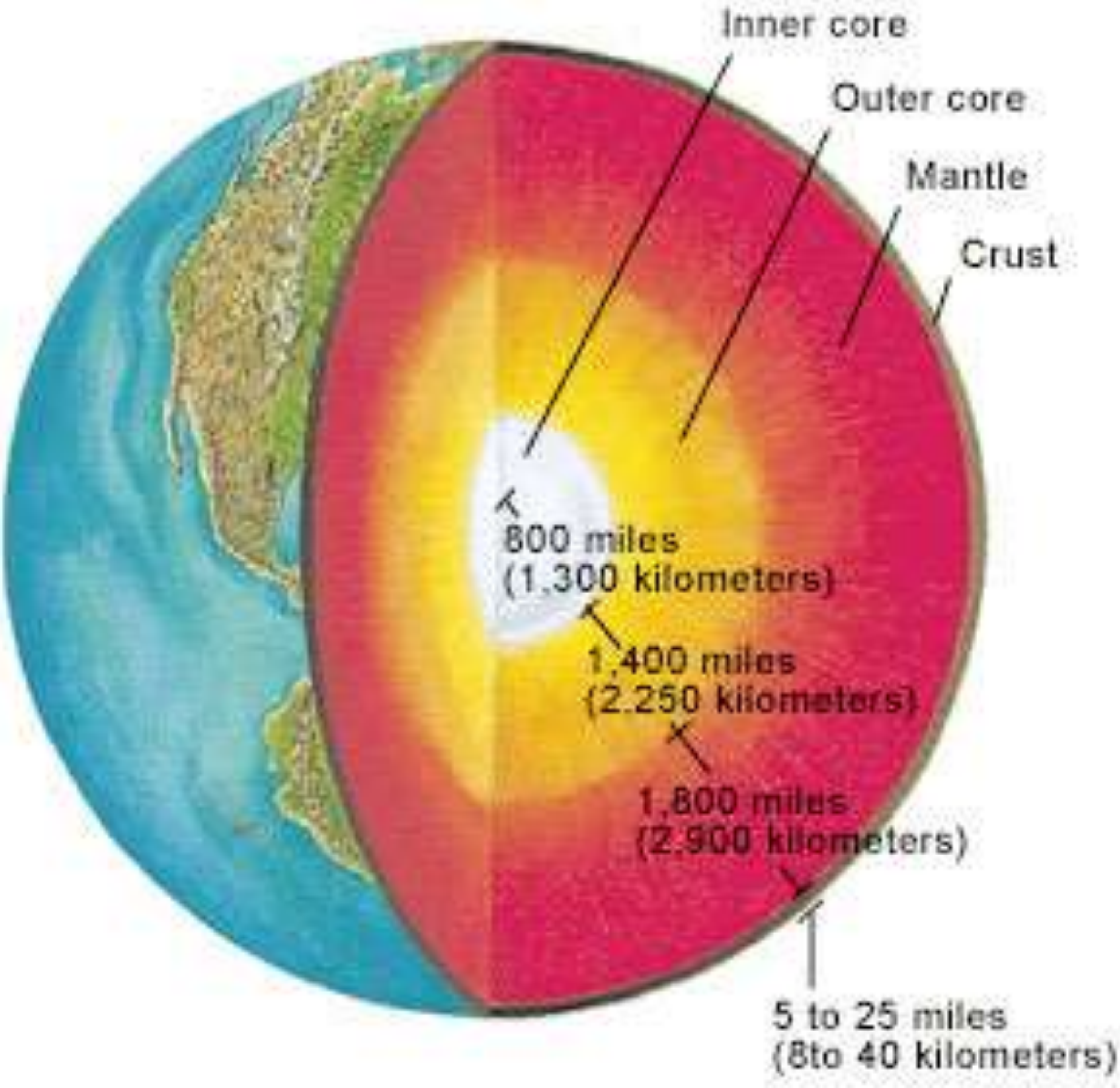
- 94 % percent of the earth is composed of the elements oxygen and silicon (combined as the compound silica [silicon oxide: SiO_2]), iron and magnesium

- interior of the earth is layered both chemically and mechanically.

Structure of the Earth

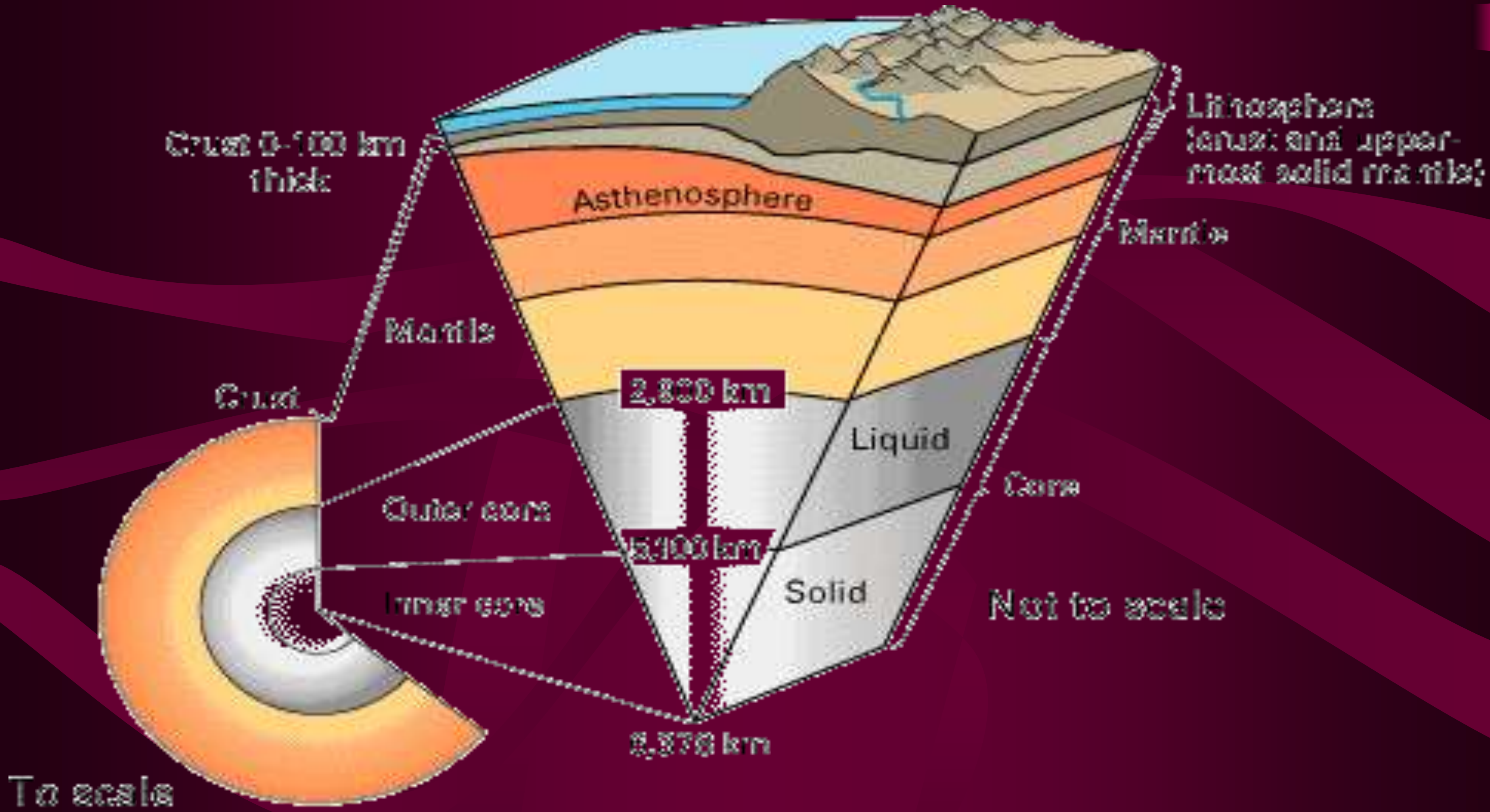
- The Earth is made up of 3 main layers:
  - Core
  - Mantle
  - Crust



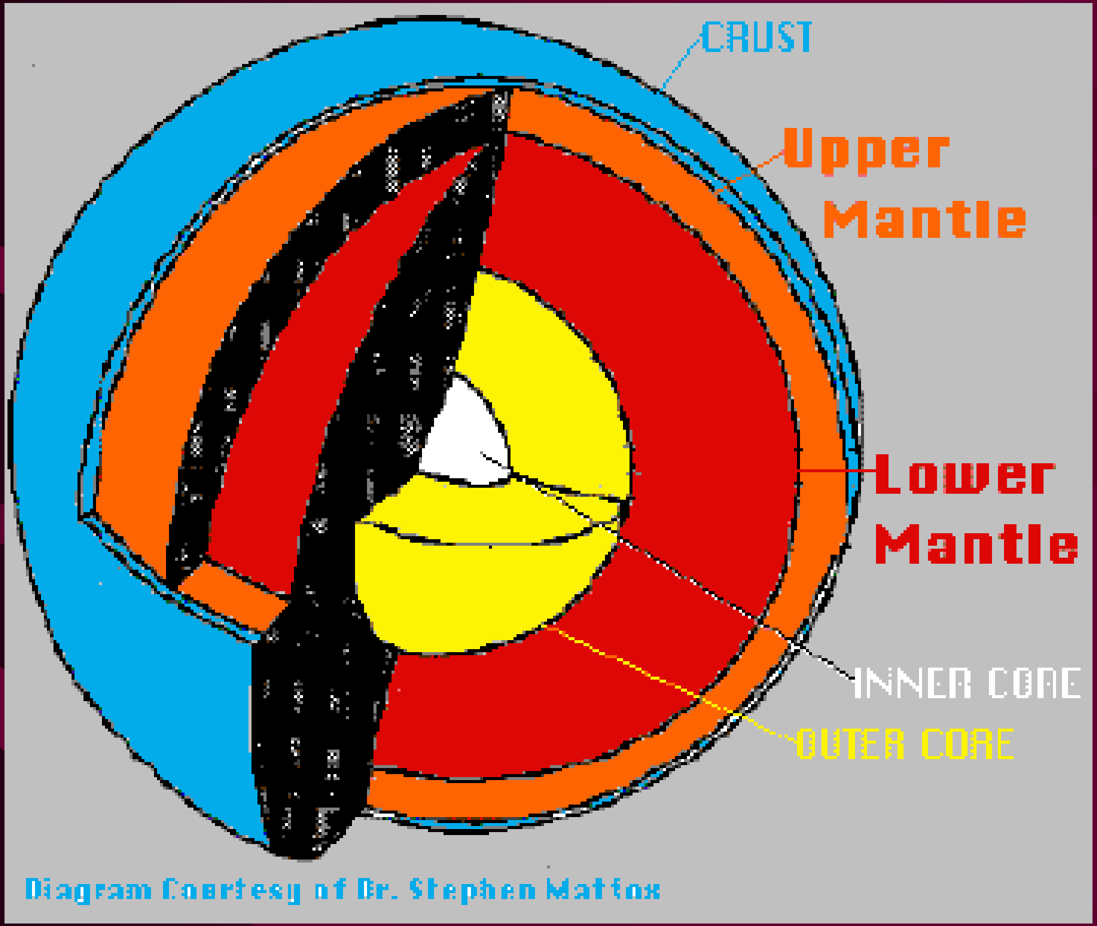

Inner core
Outer core
Mantle
Crust
800 miles
(1,300 kilometers)
1,400 miles
(2,250 kilometers)
1,800 miles
(2,900 kilometers)
5 to 25 miles
(8to 40 kilometers)


Eurasian
plate
Indian
plate
Australian
plate

The Layers of the Earth

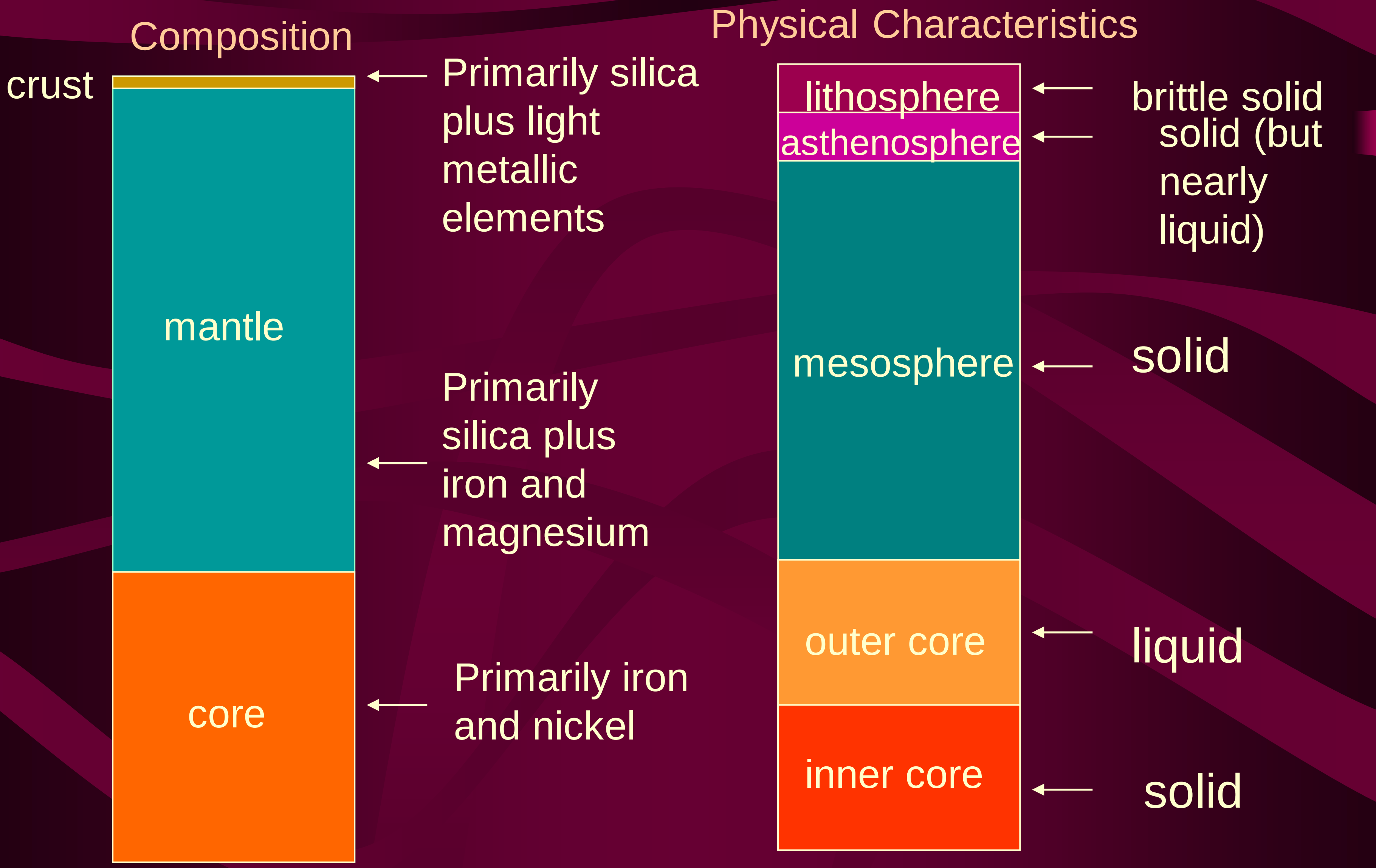


The Three Layers



The Earth is composed of three different layers. The **crust** is the layer that you live on, and it is the most widely studied and understood. The **mantle** is much hotter and has the ability to flow. The core (**outer core and inner core**) are even hotter with pressures so great you would be squeezed into a ball smaller than a marble if you were able to go to the center of the Earth!

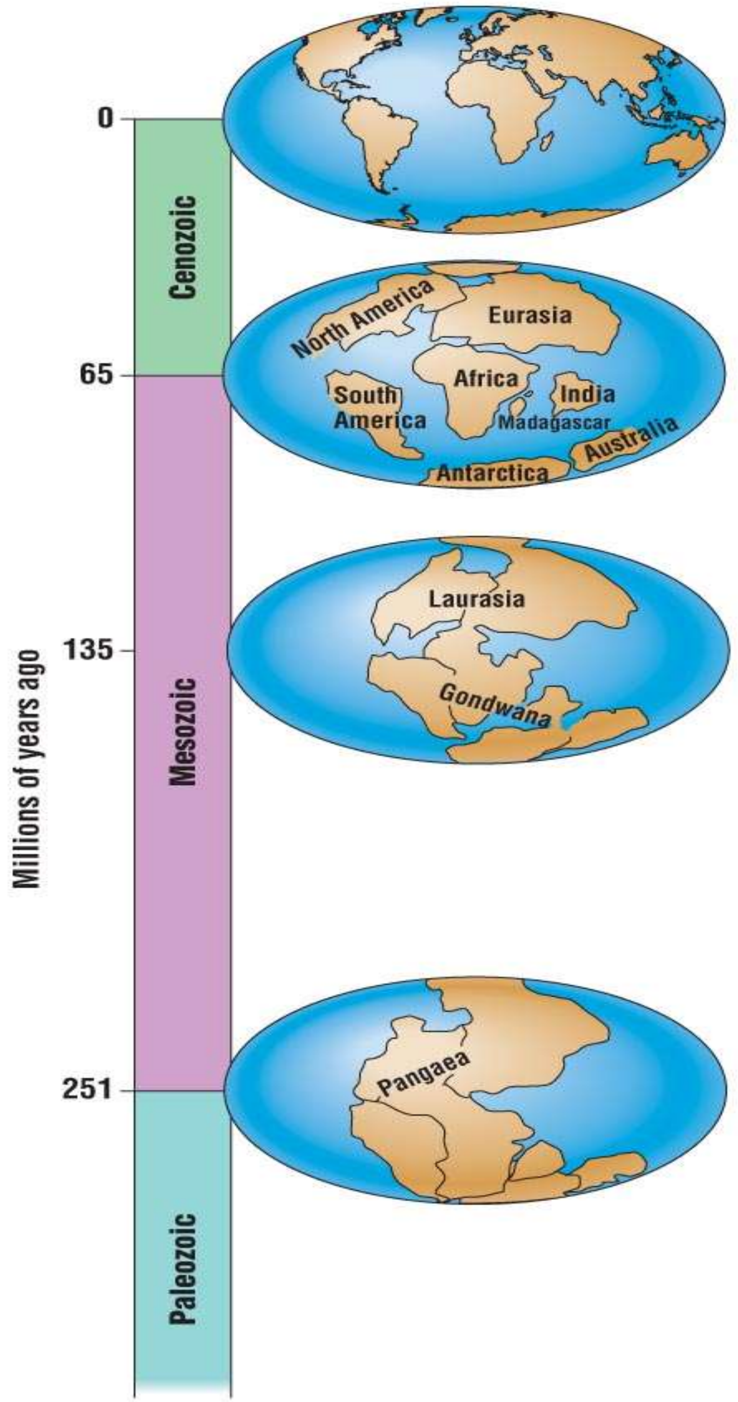
Earth's Layers: Composition and Mechanical Characteristics



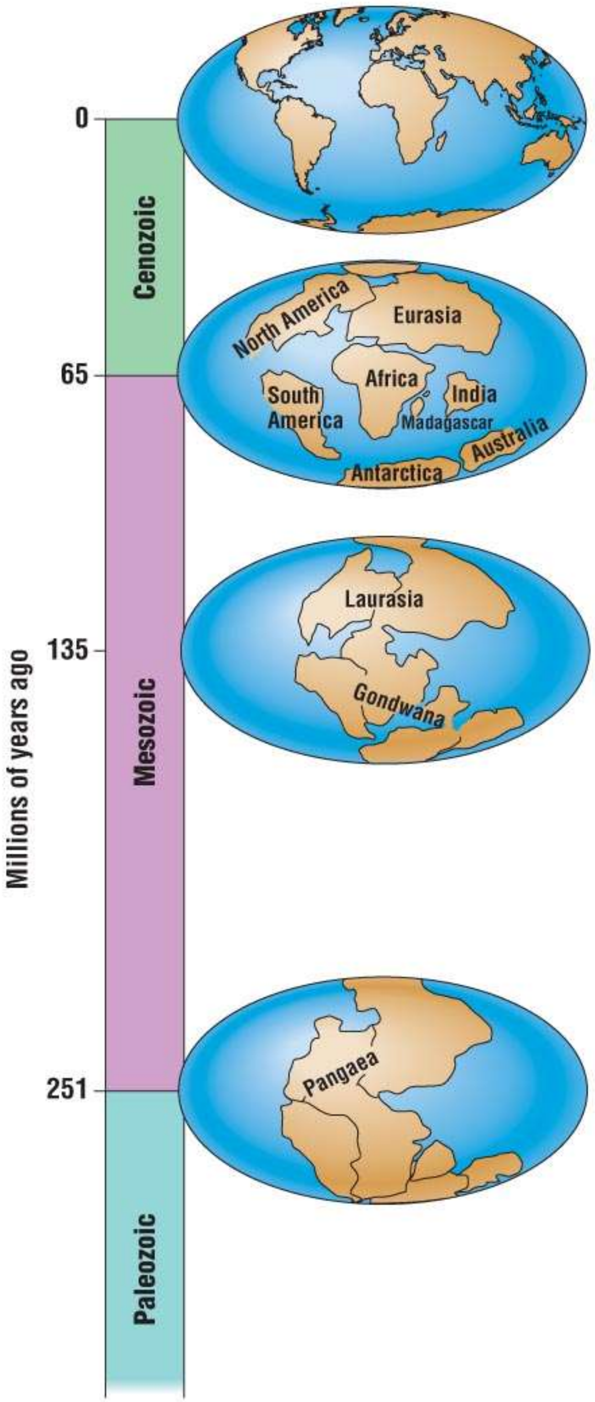
Note: Lithosphere contains both crust and uppermost (brittle) layer of mantle

❖About 250 million years ago

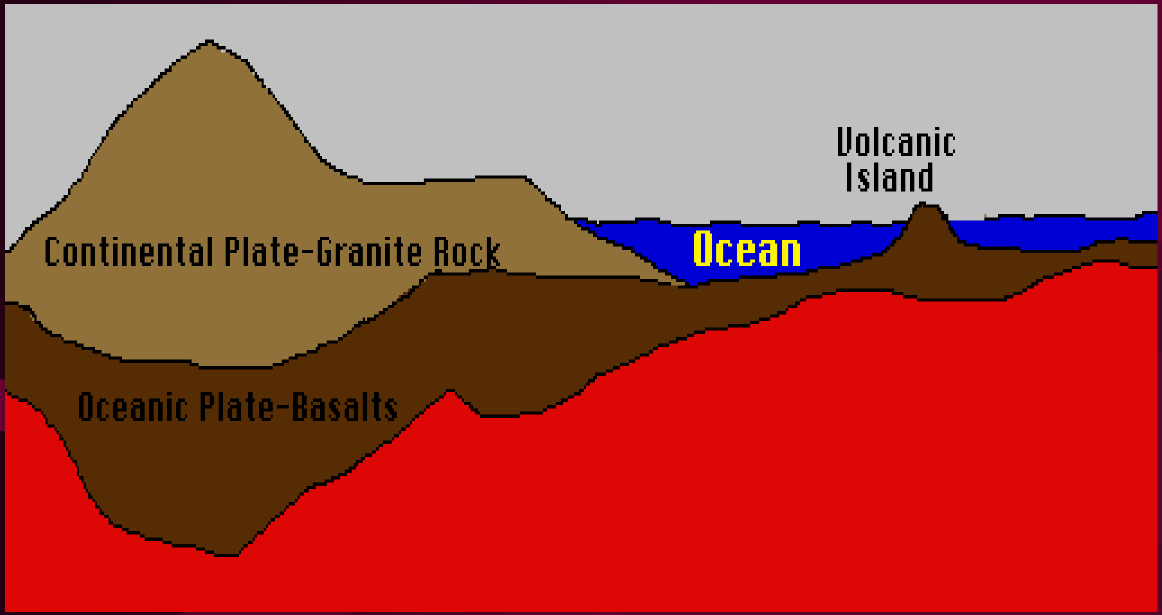
- Plate movements forr the supercontinent Pangaea.
- Many extinctions occurred, allowing survivors to diversify



- About 180 million years ago
  - Pangaea began to break up, causing geographic isolation & new species



The Crust



The Earth's **Crust** is like the skin of an apple. **It is very thin** in comparison to the other three layers.

Outermost layer; thinnest under the ocean, thickest under continents; crust & top of mantle is called the *lithosphere* .

The crust is composed of two rocks. The continental crust is mostly granite. The oceanic crust is basalt. Basalt is much denser than the granite. Because of this the less dense continents ride on the denser oceanic plates.

Lithosphere

- The lithosphere includes the crust and part of the upper mantle. Rock in the lithosphere is solid, like the rock above it. “Litho” means rock. The huge rock plates of the lithosphere carry the world’s continents and oceans.

Earth's Lithosphere

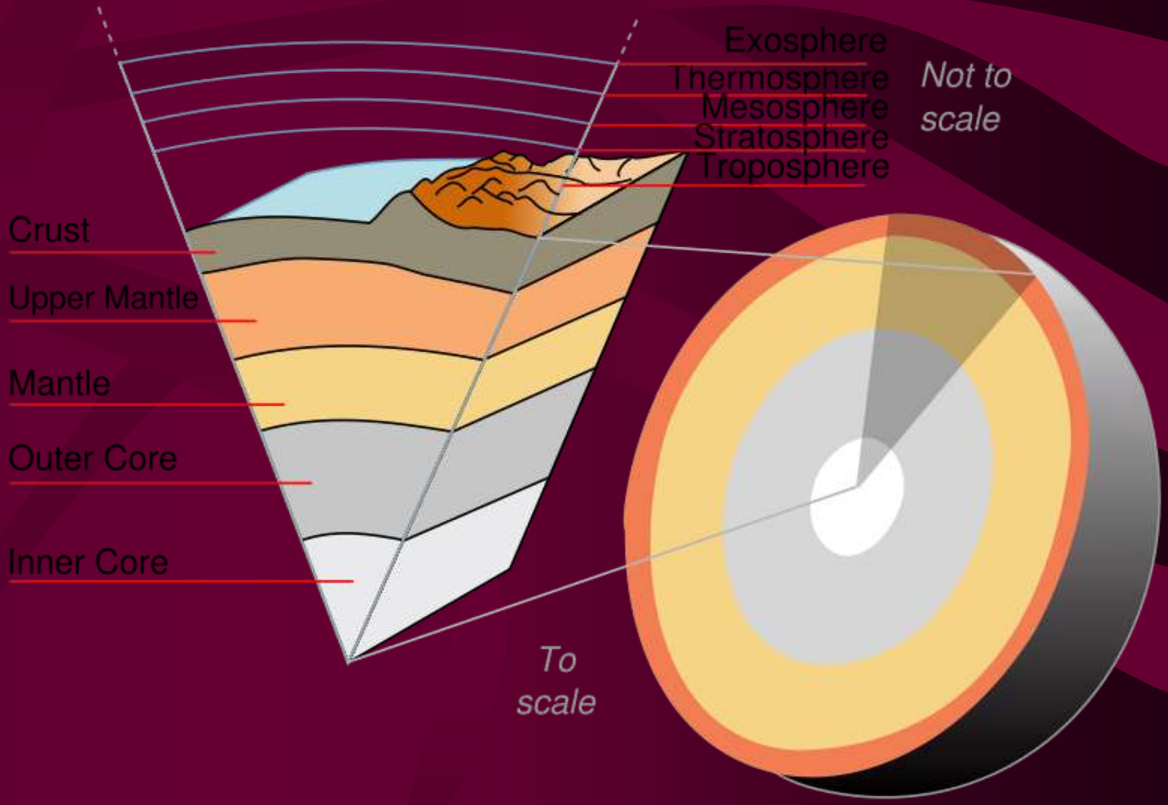
- Crust contains
  - **8 elements** make up 98.5% of weight of Earth's crust (O, Si, Al, Fe, Ca, Na, K, Mg)
  - –Minerals (any naturally occurring inorganic substance found in Earth's crust as a crystalline solid)
  - –Nonrenewable fossil fuels
  - –Potentially renewable soil nutrients (eroded rock, mineral nutrients, decaying organic matter, water, air & living organisms)

Lithosphere

- As these plates move and collide, mountains are built. Earthquakes are triggered. The lithosphere floats on a layer of soft rock that can flow like taffy; the asthenosphere. Astheno means weak. The rock in the asthenosphere flows slowly like putty or taffy.

What lies beneath the tectonic plates?

- Below the lithosphere (which makes up the tectonic plates) is the asthenosphere.

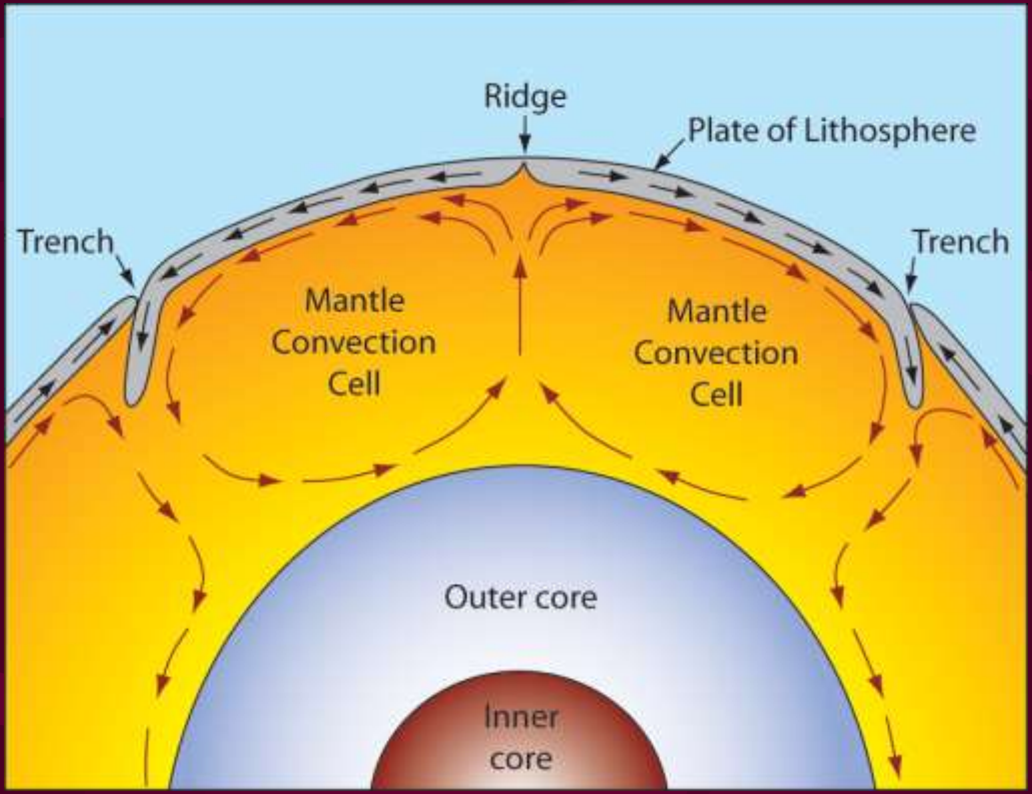


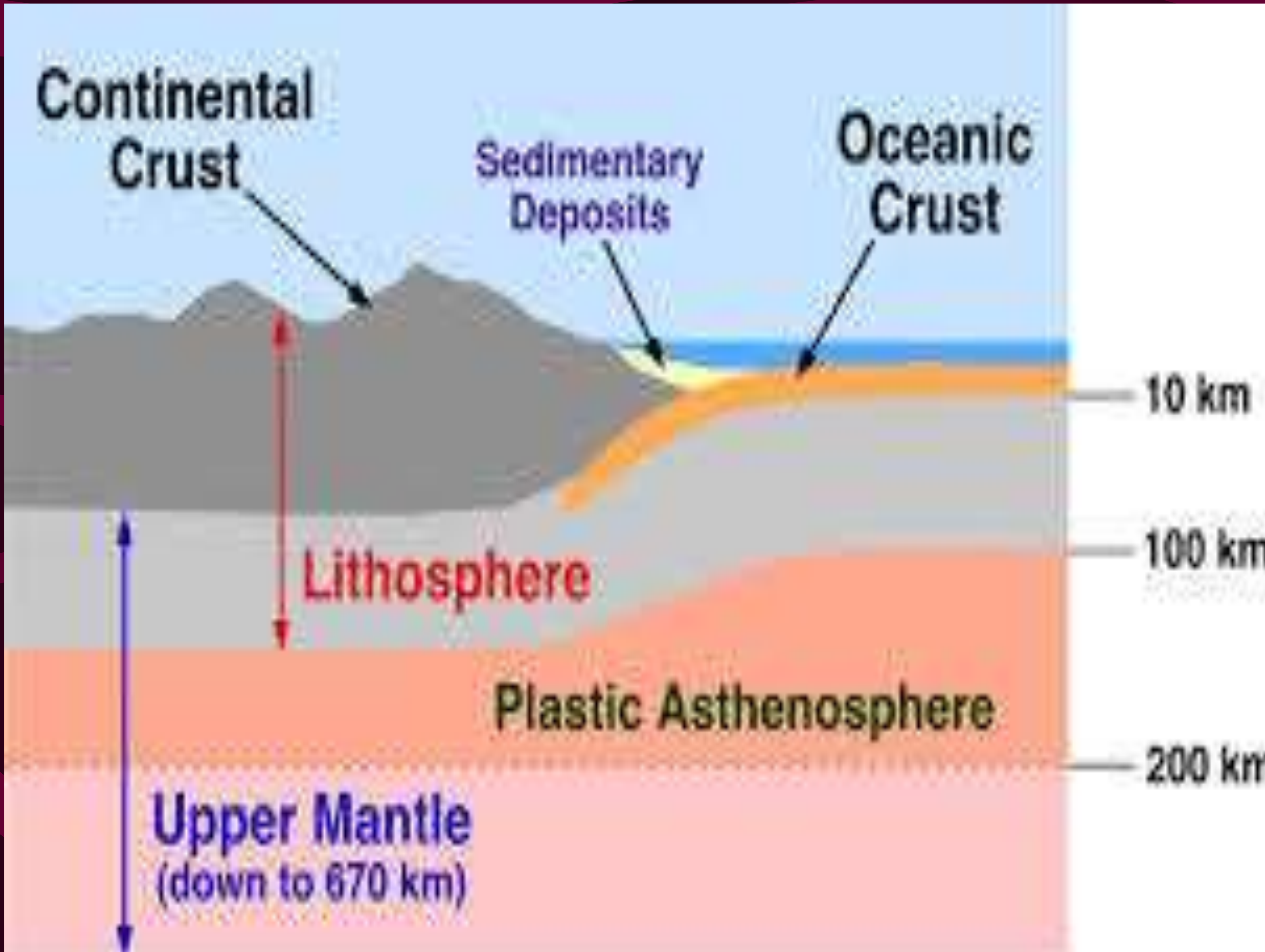
Motion of the Lithospheric Plates

- Plates float on the **upper part** of the ____**mantle**________________.
- ___**Convection**______ currents can cause the asthenosphere to flow slowly carrying with it the plates of the lithosphere.
- **This movement of plates changes the sizes, shapes, and positions of Earth's _continents_____** and ___**oceans**________.

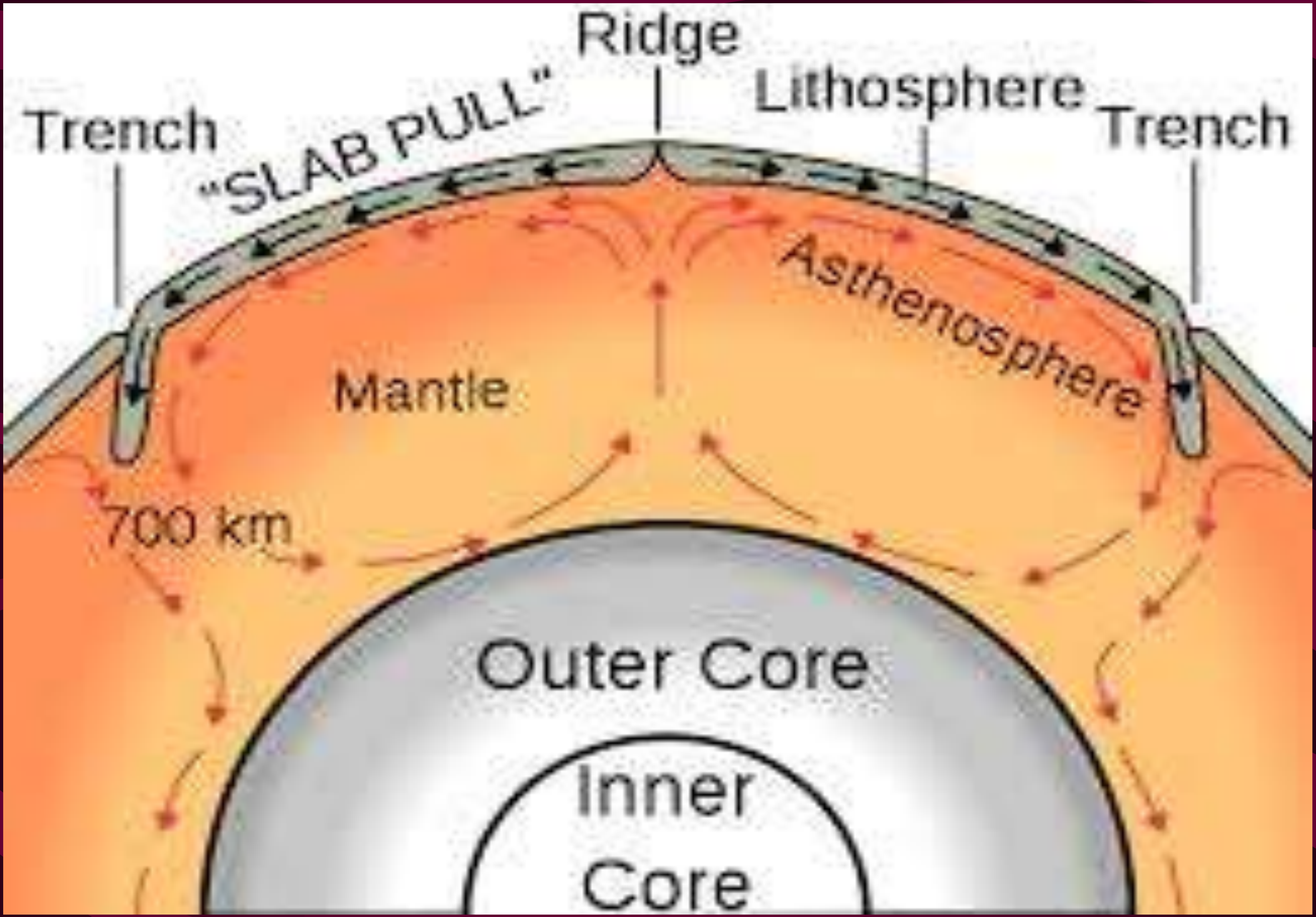
Plate Movement

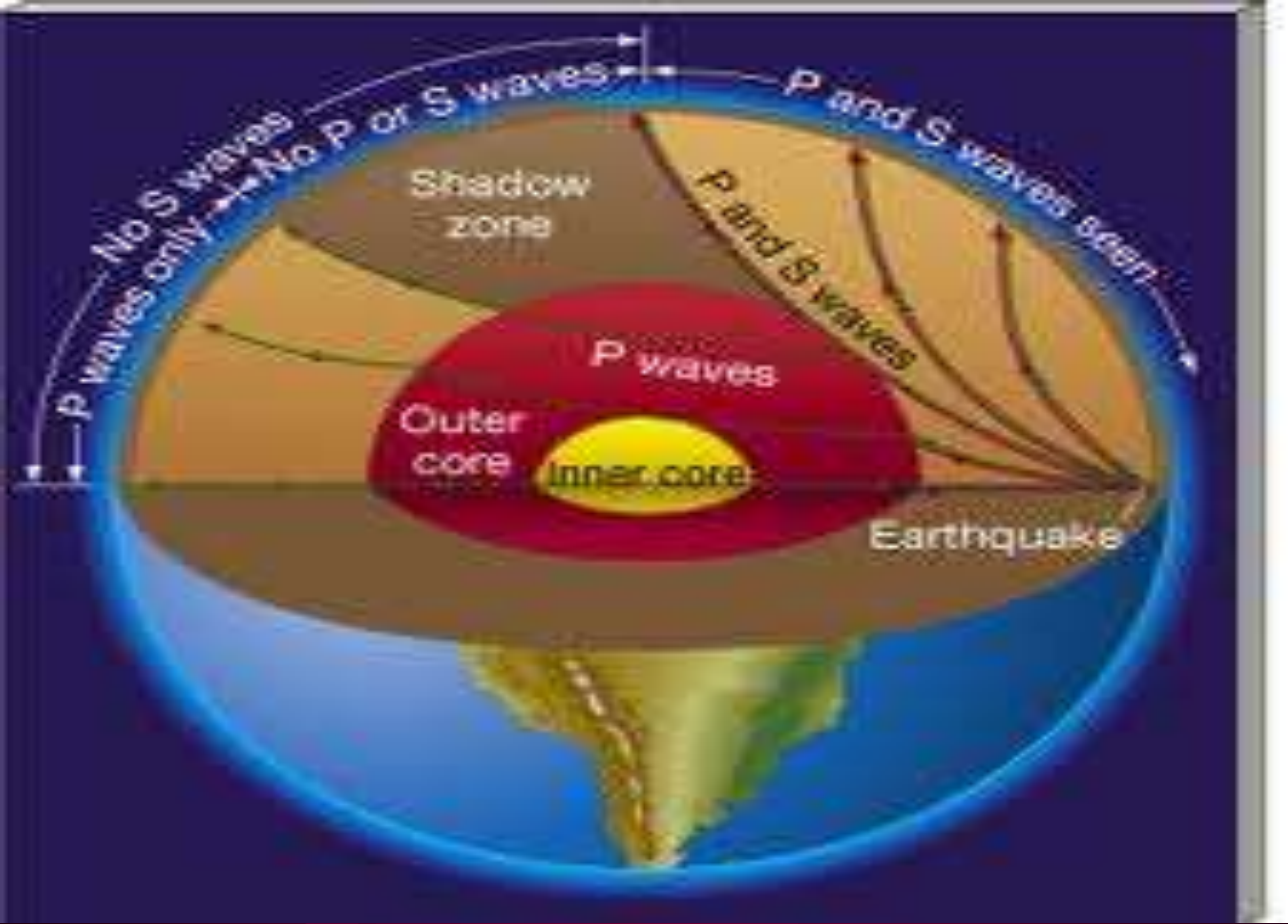
- “Plates” of lithosphere are moved around by the underlying hot mantle convection cells




Continental
Crust
Sedimentary
Deposits
Oceanic
Crust
10 km
100 km
Lithosphere
Plastic Asthenosphere
200 km
Upper Mantle
(down to 670 km)


1
14
11
7
6
Magma source
8
13
Magma source
OCEANIC LITHOSPHERE
9
CONTINENTAL LITHOSPHERE
5
ASTHENOSPHERE
12
2
ASTHENOSPHERE
(semi-solid, slowly flowing upper mantle)
4
ASTHENOSPHERE
100 km
100 km
3
10
LOWER MANTLE

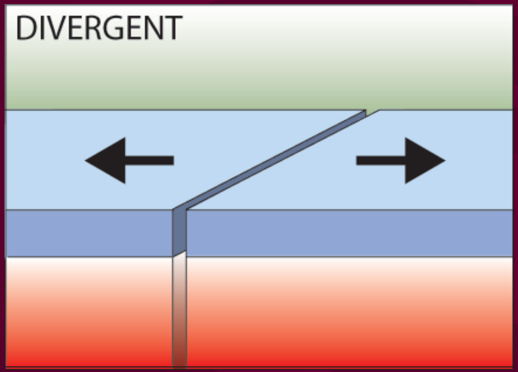

Ridge
"SLAB PULL"
Lithosphere
Trench
Trench
Asthenosphere
Mantle
700 km
Outer Core
Inner
Core

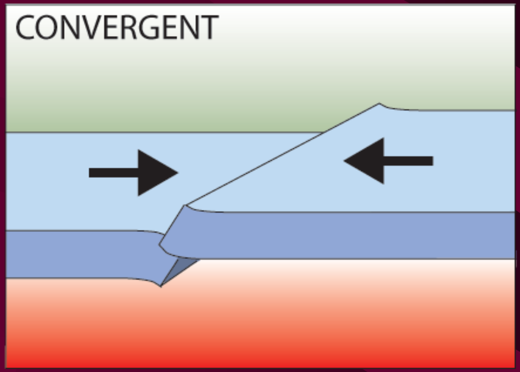

No S waves
No P or S waves
P and S waves seen
P waves only
Shadow zone
P and S waves
P waves
Outer core
Inner core
Earthquake

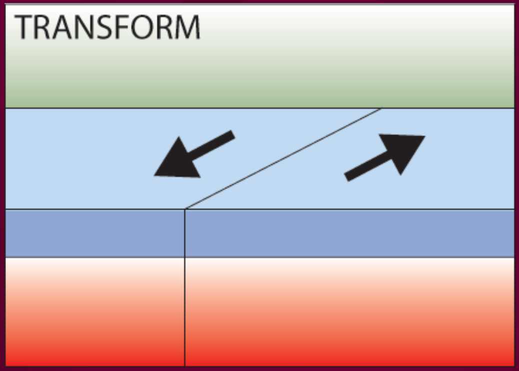
Boundaries

Three types of plate boundary

- Divergent
- Convergent
- Transform







Divergent Boundary

- - where two plates are moving __**apart**______________
- most located along mid-ocean ridge (sea-floor spreading);
- - new crust forms because __**magma**_____ pushes up and hardens between separating plates.

Divergent Boundary

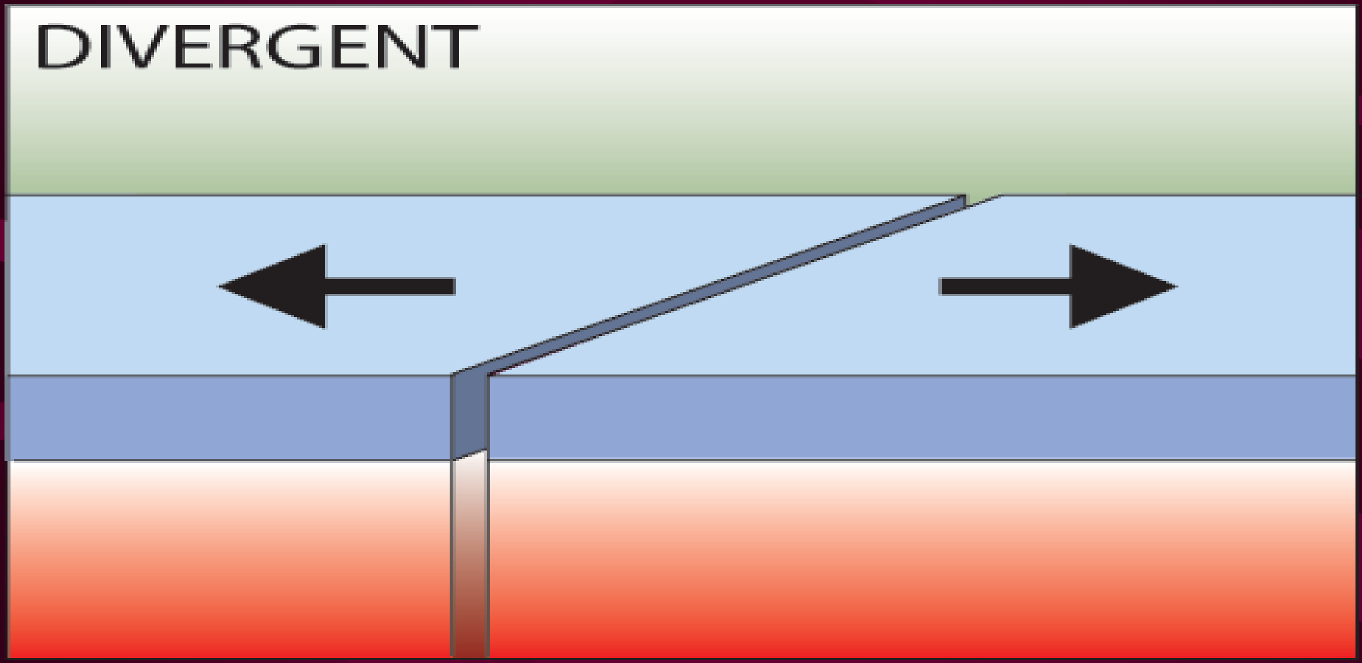
- the presence of mantle convection cells causing the plates to break apart and also as a source for new molten material.

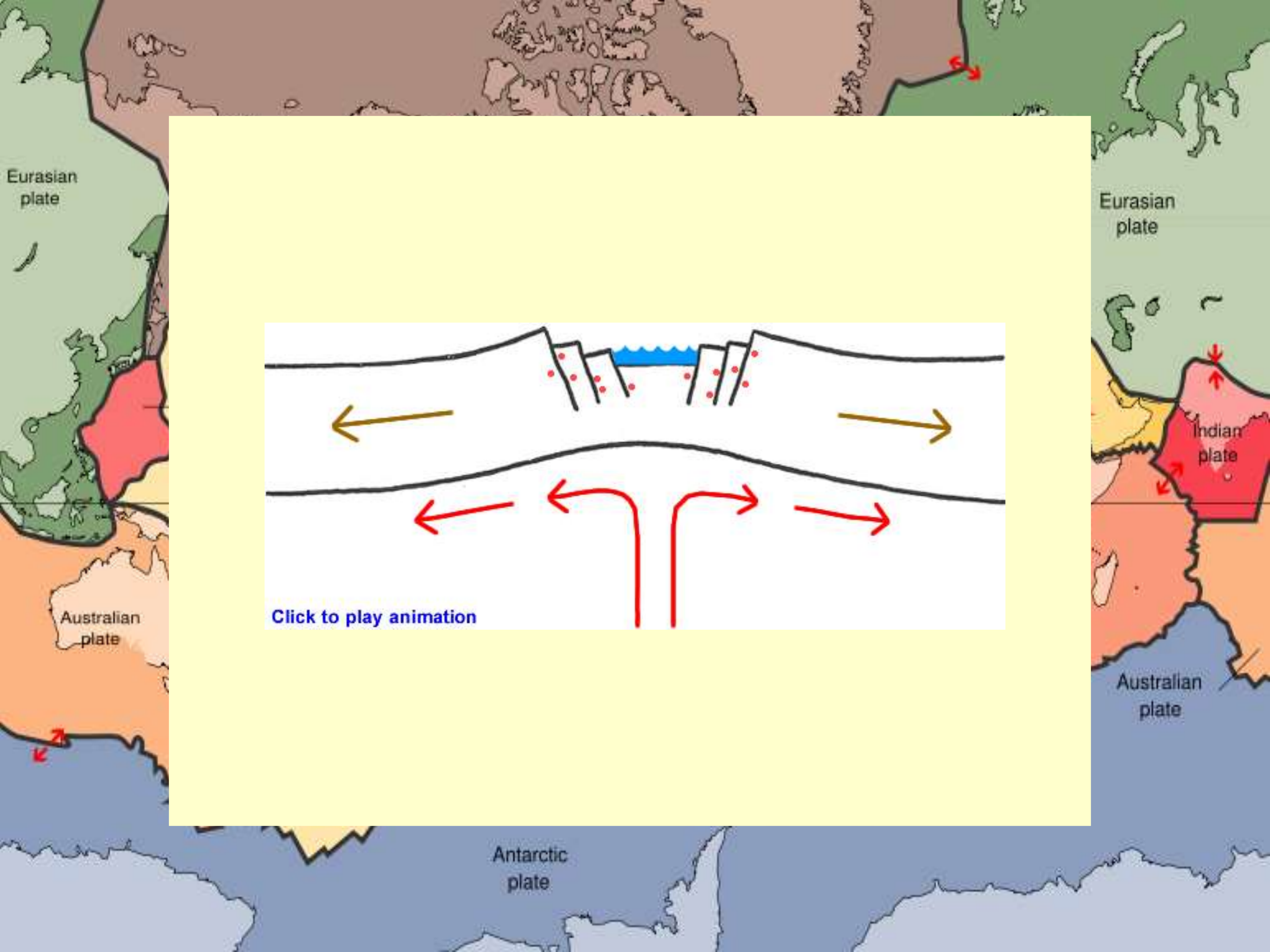
- **Where a divergent boundary forms on a continent it is called a RIFT or CONTINENTAL RIFT, e.g. African Rift Valley.**
- **Where a divergent boundary forms under the ocean it is called an OCEAN RIDGE.**

Divergent Boundary

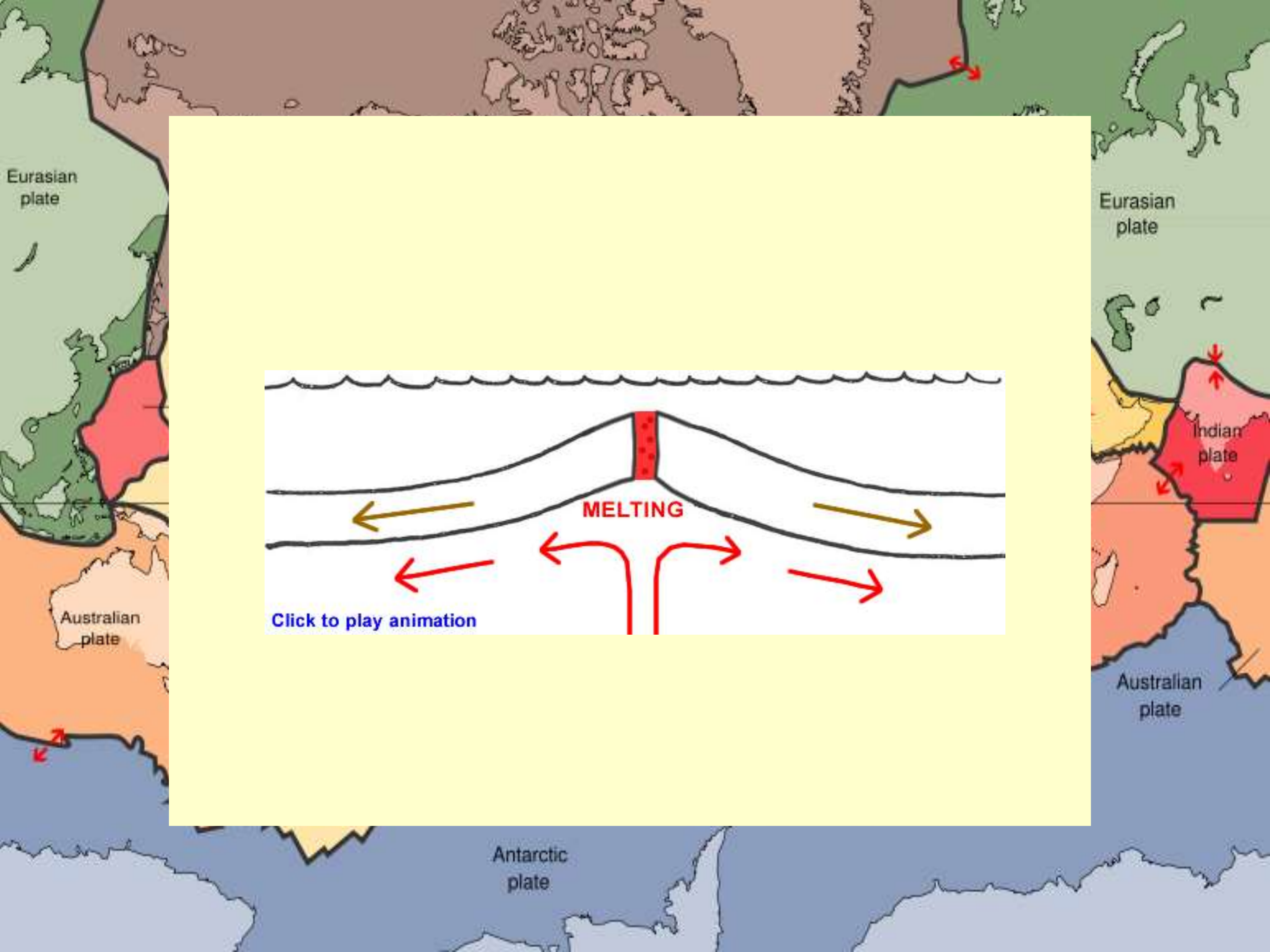
- In plate tectonics, a **divergent boundary** is a linear feature that exists between two tectonic plates that are moving away from each other.
- These areas can form in the middle of continents or on the ocean floor.
- As the plates pull apart, hot molten material can rise up this newly formed pathway to the surface - causing volcanic activity.

Direction of Movement/Sketch

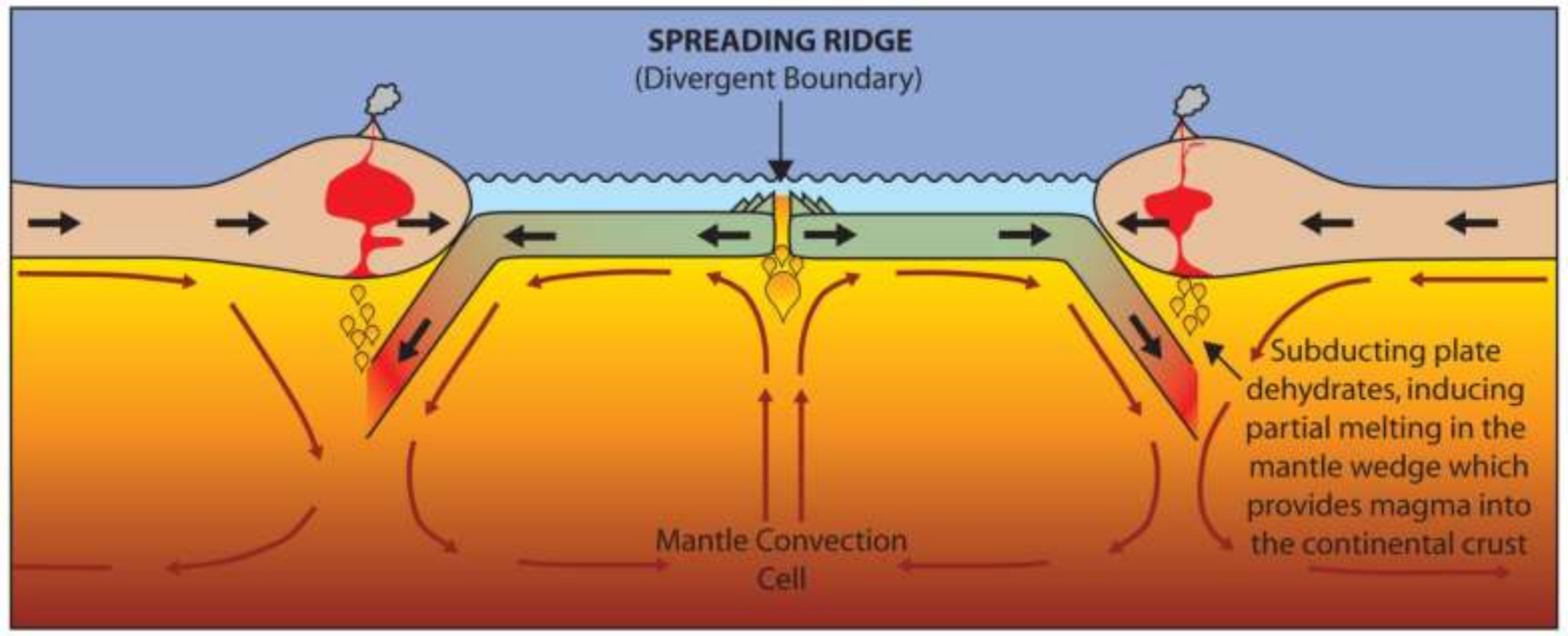




Eurasian plate
Eurasian plate
Indian plate
Australian plate
Australian plate
Antarctic plate
Click to play animation

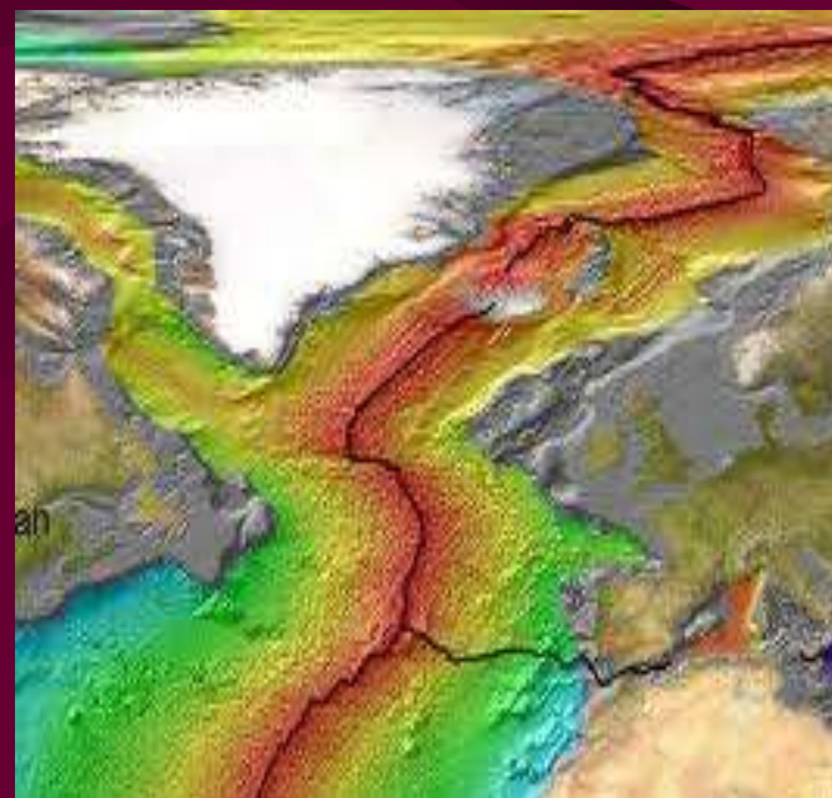

Eurasian plate
Eurasian plate
Indian plate
Australian plate
Australian plate
Antarctic plate
MELTING
Click to play animation

Divergent Boundaries/Sketch



- Spreading ridges
  - As plates move apart new material is erupted to fill the gap

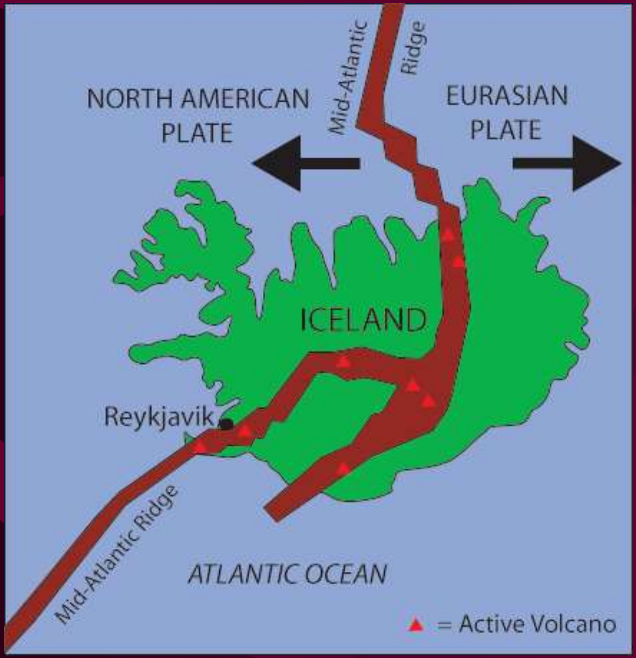
Examples: Divergent Boundaries within the Oceanic Crust: Mid-Atlantic Ridge



Courtesy of www.ngdc.noaa.gov

Iceland: An example of continental rifting

- Iceland has a divergent plate boundary running through its middle



Iceland

- Iceland is located right on top of a divergent boundary. In fact, the island exists because of this feature.
- As the North American plates were pulled apart (see map) volcanic activity occurred along the cracks.
- With many eruptions over time the island grew out of the sea!

Example: Divergent Boundaries within the Continental Crust: East Africa Rift Valley

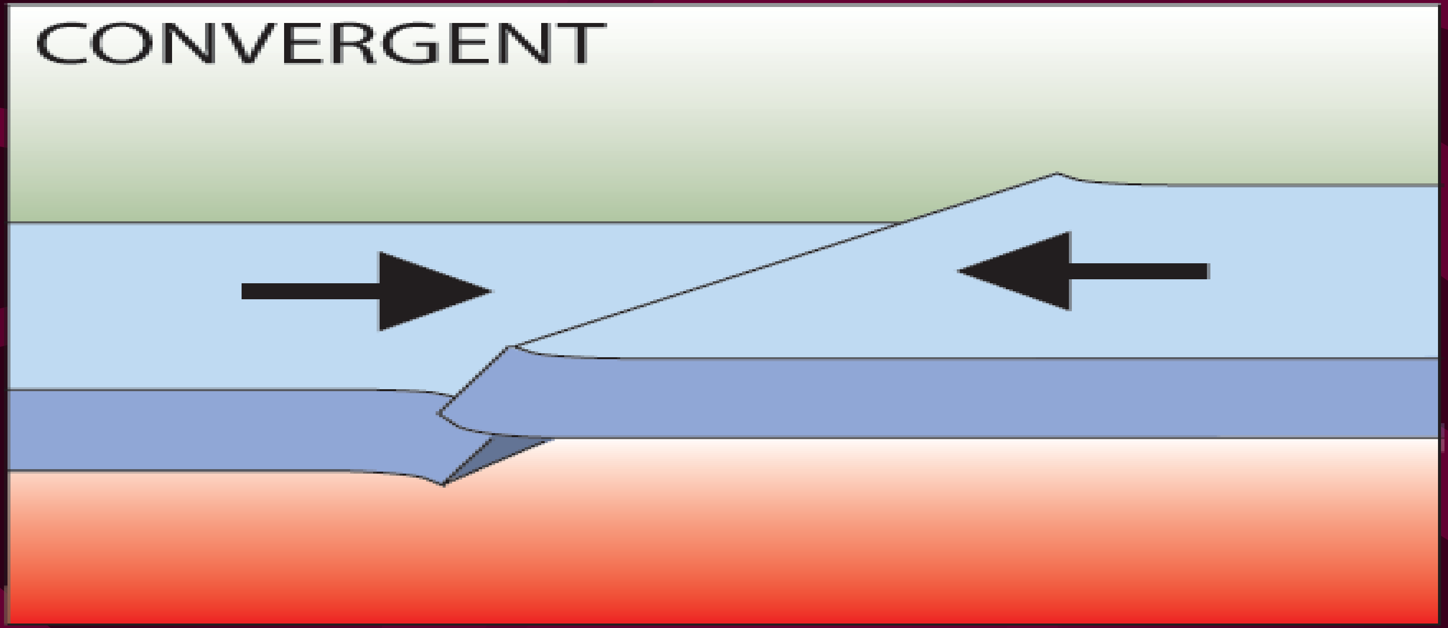
Convergent Boundaries

- There are three styles of convergent plate boundaries
  - Continent-continent collision
  - Continent-oceanic crust collision
  - Ocean-ocean collision

Convergent Boundary

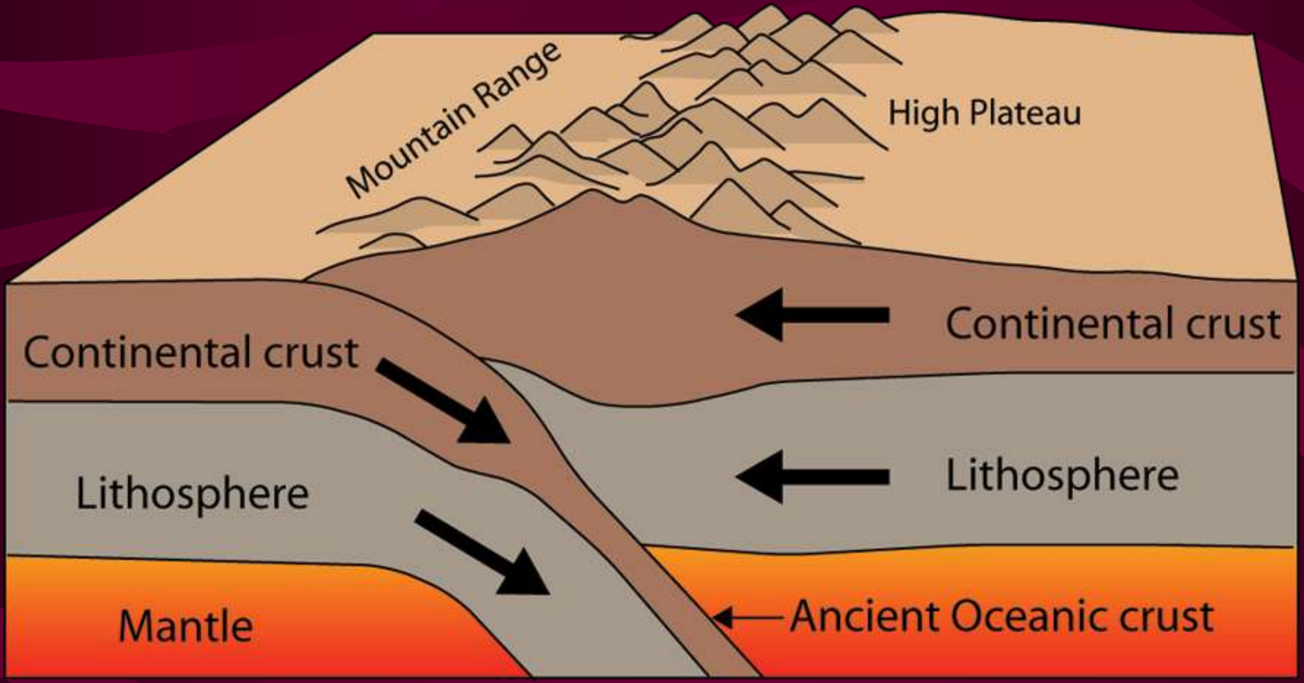
- where two plates come ___**together**______ and __**collide**_____.
- **activity depends upon the types of crust that meet;**
- more dense oceanic plate slides under less dense continental plate or another oceanic plate – **_subduction zone____, some crust is destroyed**;
- two continental plates converge, both plates __**buckle**____________ and ___**push up**_____ into mountain ranges;

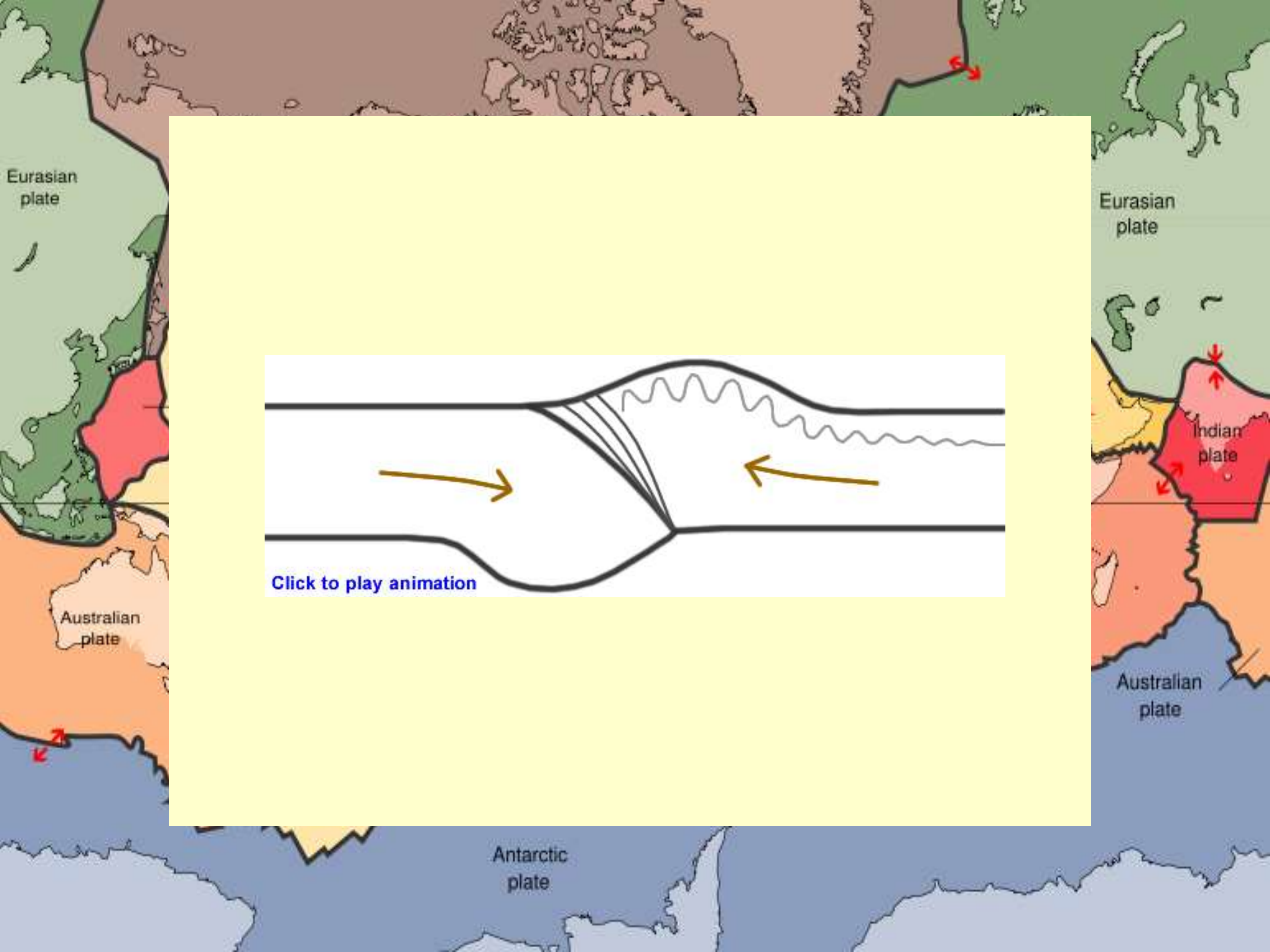
Direction of Movement/Sketch



Continent-Continent Collision

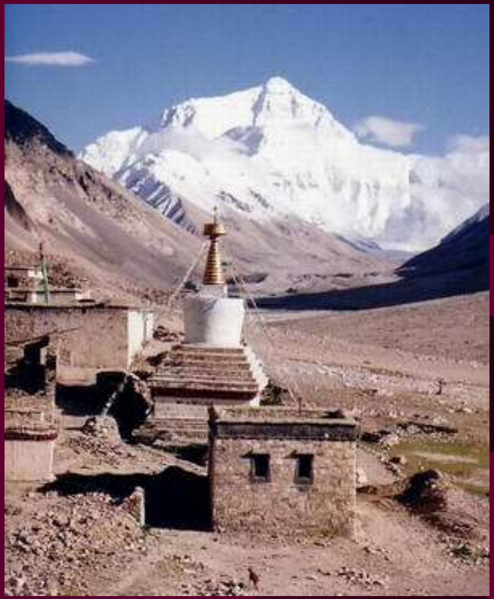
- Forms mountains, e.g. **European Alps, Himalayas**




Eurasian plate
Australian plate
Eurasian plate
Indian plate
Australian plate
Antarctic plate
Click to play animation

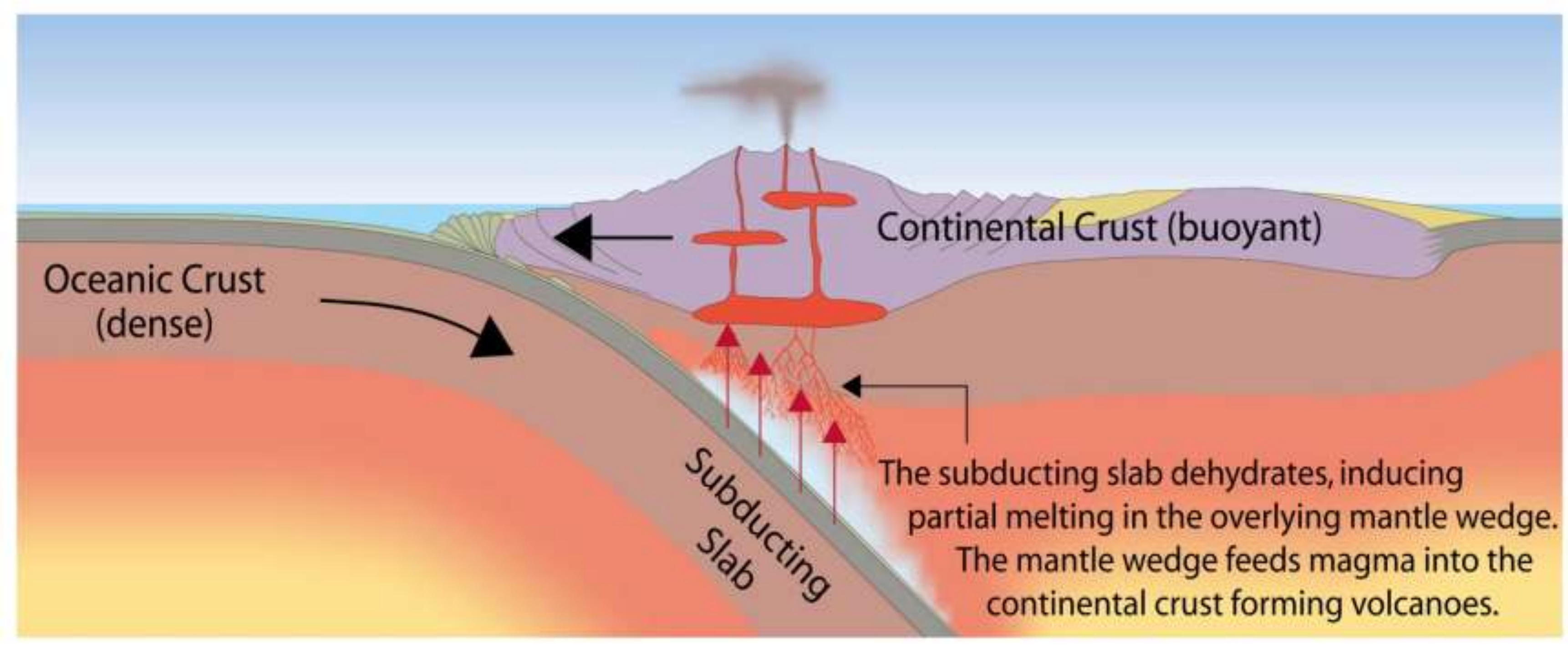
Himalayas

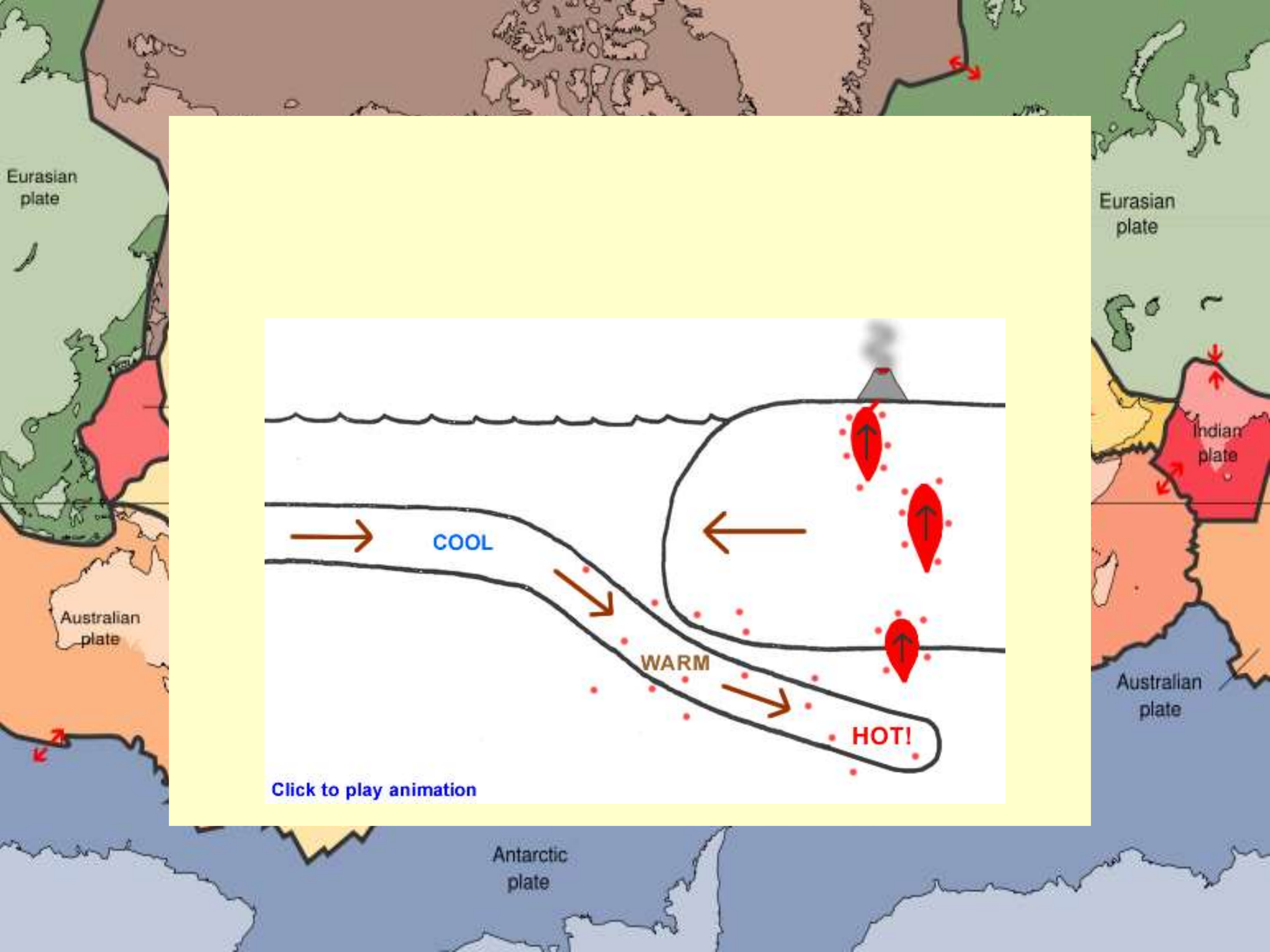
EURASIAN PLATE
INDIA
Today
10 million
years ago
SRI LANKA
38 million
years ago
Equator
55 million
years ago
INDIAN
OCEAN
71 million
years ago
"INDIA"
Land mass
SRI LANKA



Continent-Oceanic Crust Collision

- Called SUBDUCTION

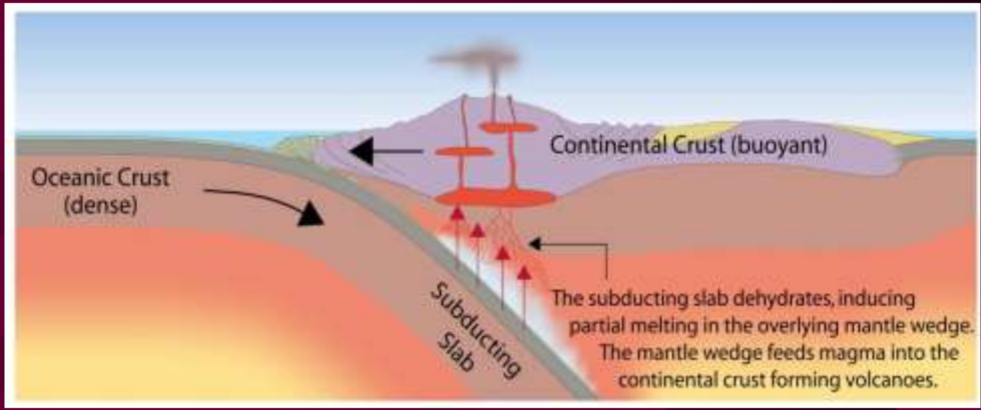



Eurasian plate
Eurasian plate
Indian plate
Australian plate
Australian plate
Antarctic plate
COOL
WARM
HOT!
Click to play animation

Subduction

- **Subduction is a way of recycling the oceanic crust. Eventually the subducting slab sinks down into the mantle to be recycled. It is for this reason that the oceanic crust is much younger than the continental crust which is not recycled.**

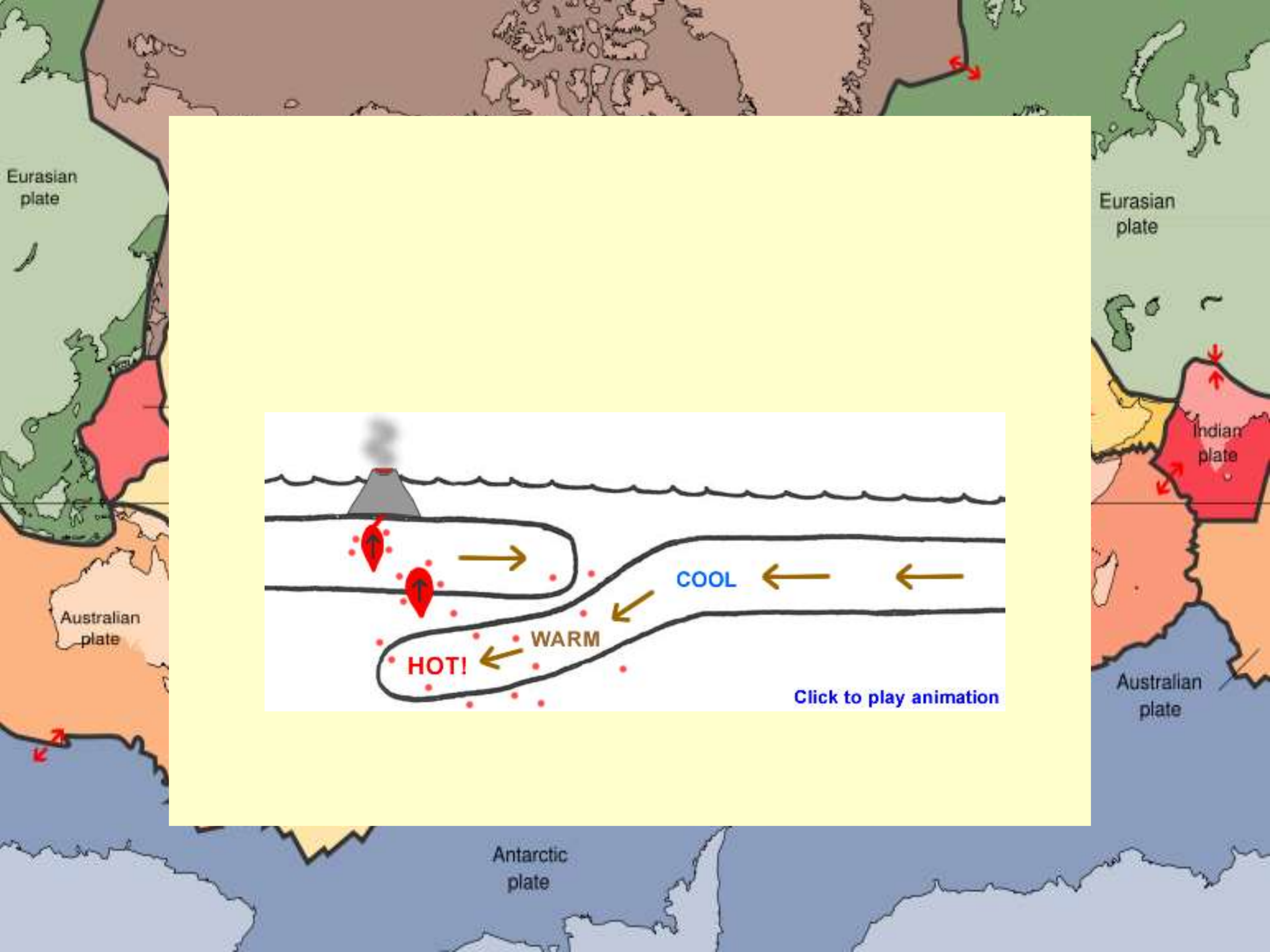
Subduction



- Oceanic lithosphere subducts underneath the continental lithosphere
- Oceanic lithosphere heats and dehydrates as it subsides
- The melt rises forming volcanism
- E.g. **The Andes Mountains, The Cascade Mountains**

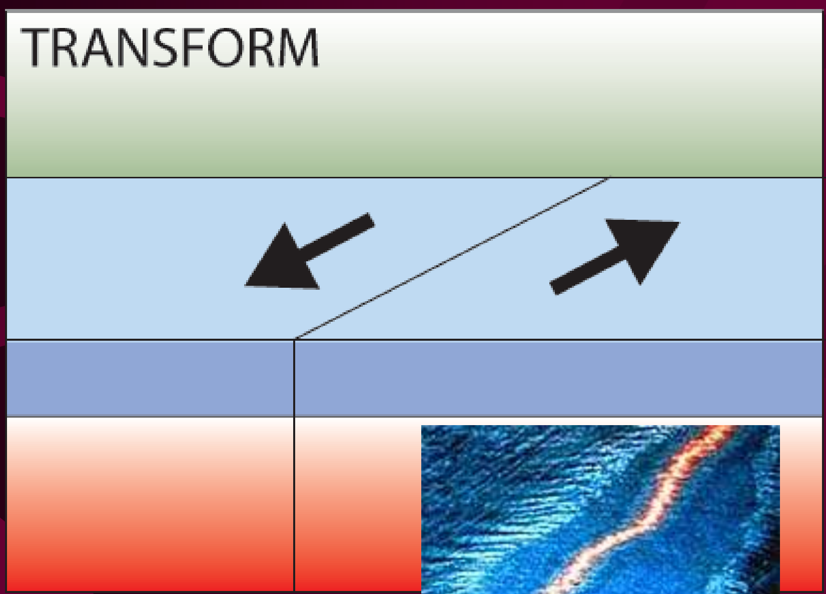
Ocean-Ocean Plate Collision

- When two oceanic plates collide, one runs over the other which causes it to sink into the mantle forming a **subduction zone**.
- The subducting plate is bent downward to form a very deep depression in the ocean floor called a **trench**.
- The worlds deepest parts of the ocean are found along trenches.
  - E.g. The **Mariana Trench** is 11 km deep!


Eurasian plate
Eurasian plate
Indian plate
Australian plate
Australian plate
Antarctic plate
COOL
WARM
HOT!
Click to play animation

Transform Boundaries

- Where plates slide past each other



Above: View of the **San Andreas transform fault**

Transform Boundary

- where two plates __**slide**_______________ __**past**_______________ each other
- **crust is neither created nor destroyed;**
- __**Earthquakes**_________ occur frequently along this type of boundary.

Example

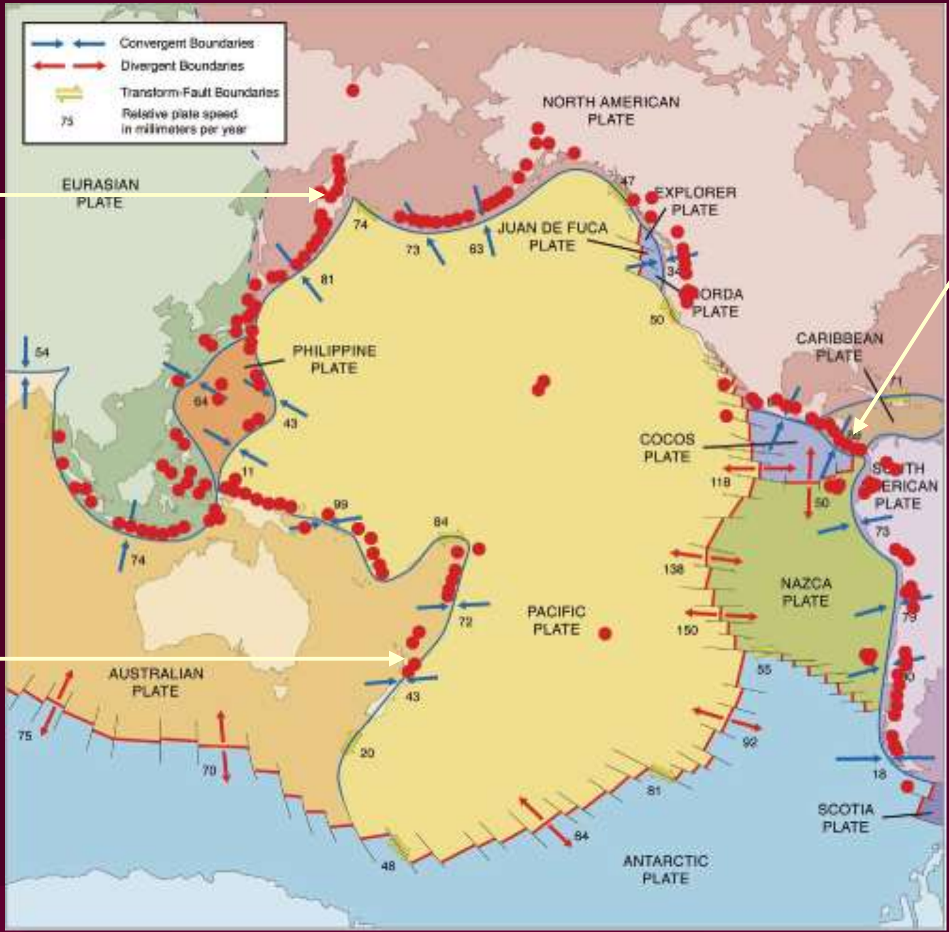
- The **San Andreas fault**, adjacent to which the US city of San Francisco is built is an example of a transform boundary between the Pacific plate and the North American plate.
- **Alpine Fault of New Zealand**

San Andreas Fault Zone

Volcanoes and Plate Tectonics…

…what’s the connection?

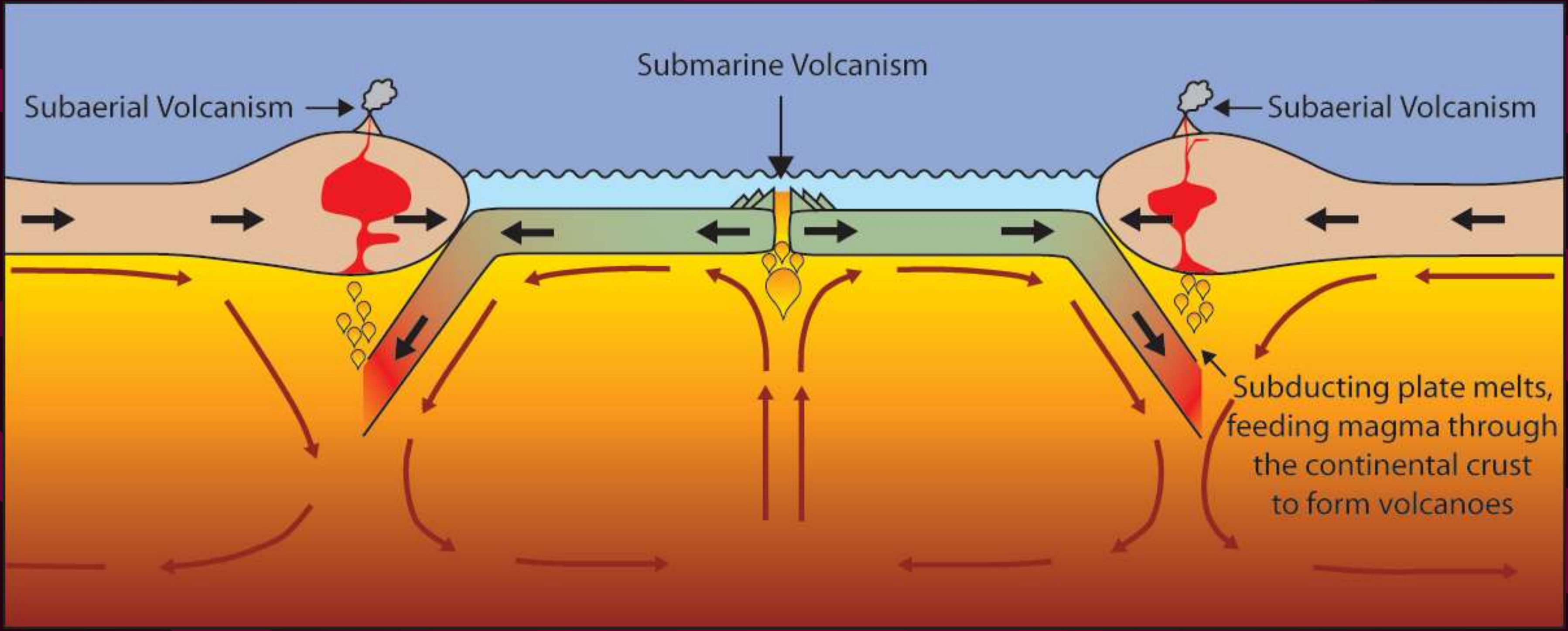
Pacific Ring of Fire



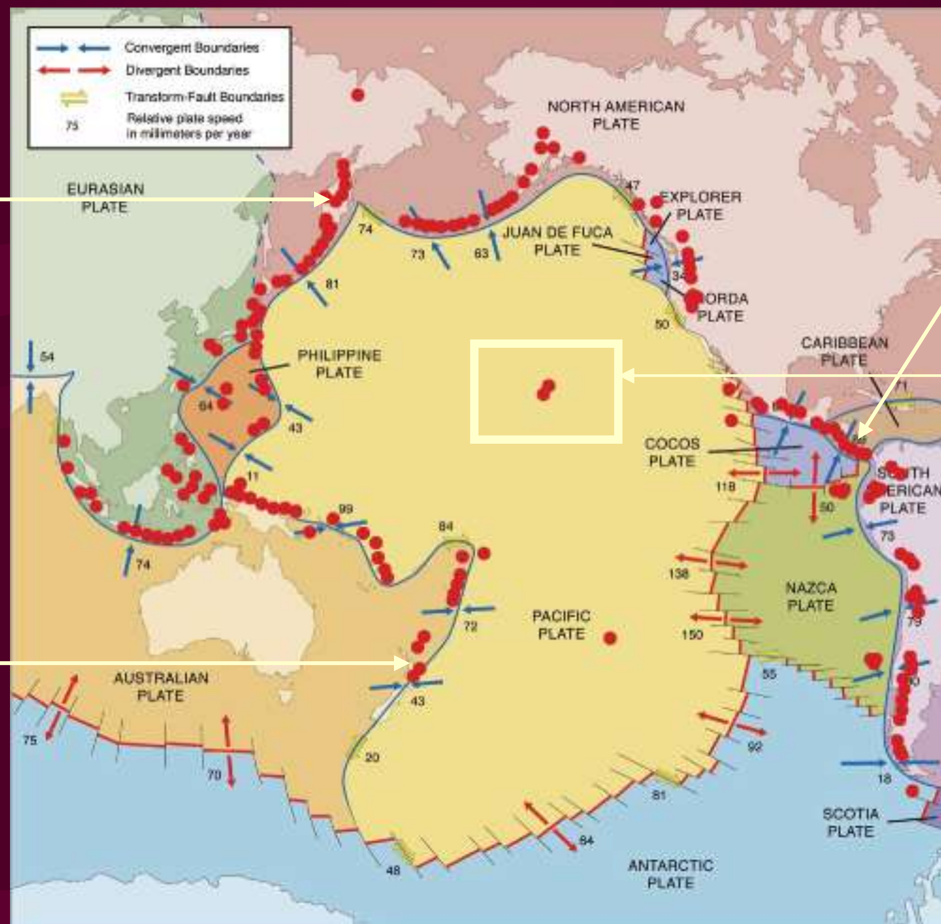
Volcanism is mostly focused at plate margins

Volcanoes are formed by:

- Subduction - Rifting - Hotspots



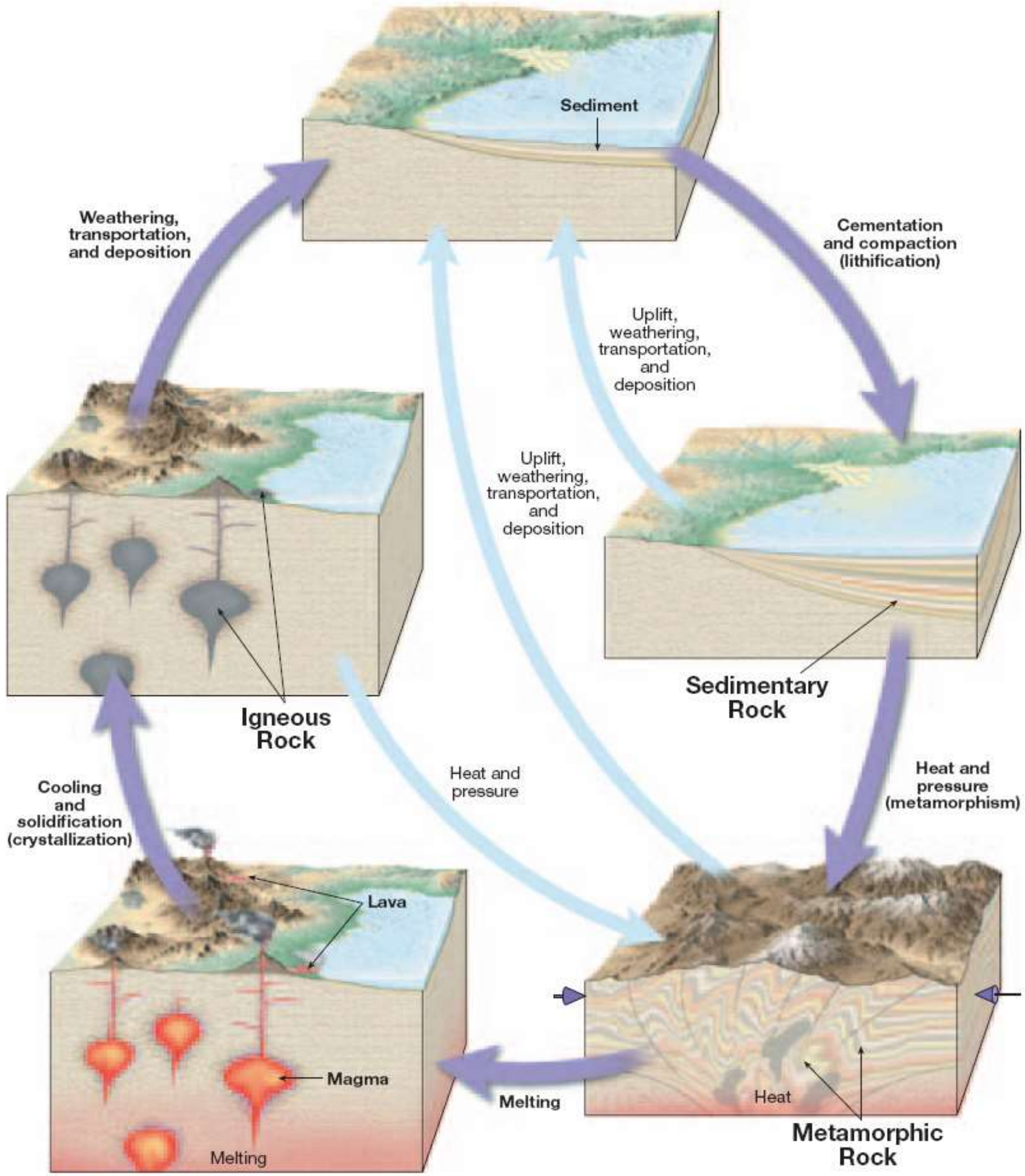
Pacific Ring of Fire



Hotspot volcanoes

(Hawaii)

Rocks



Sediment
Weathering, transportation, and deposition
Cementation and compaction (lithification)
Uplift, weathering, transportation, and deposition
Uplift, weathering, transportation, and deposition
Sedimentary Rock
Igneous Rock
Heat and pressure
Heat and pressure (metamorphism)
Cooling and solidification (crystallization)
Lava
Magma
Melting
Melting
Heat
Metamorphic Rock

Igneous Rocks

- **Magma** – molten material that forms beneath Earth's surface
- When magma cools and hardens beneath the surface or as the result of a volcanic eruption, igneous rock forms
- **Lava** – magma that reaches the surface

Igneous Rocks

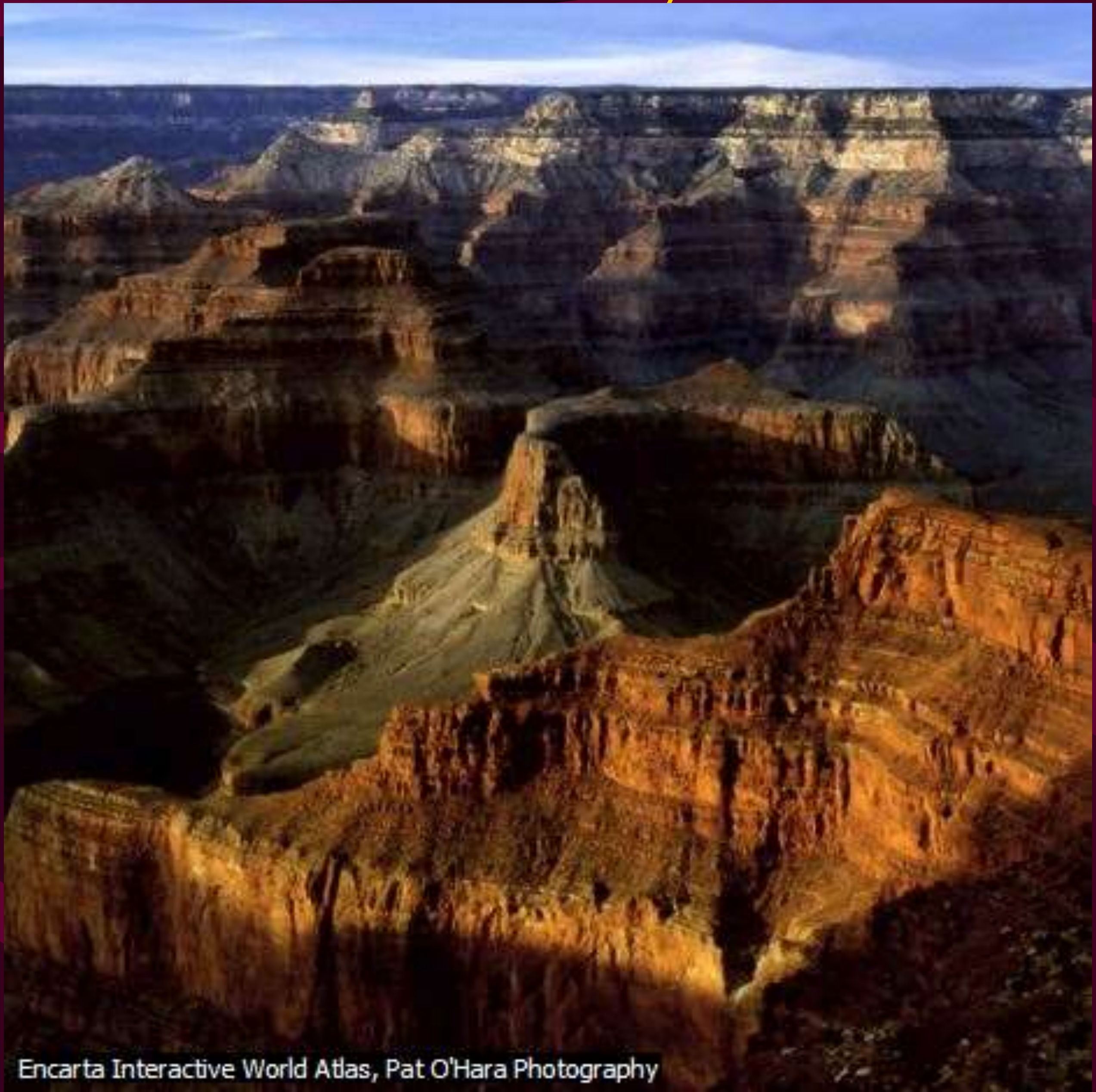
Concept Check

- What is the difference between lava and magma?
- Magma is molten material that forms under the surface, and lava is magma that reaches the surface

Sedimentary Rocks

- **Weathering** – process in which rocks are physically and chemically broken down by water, air, and living things
- **Sediments** – weathered pieces of earth materials
- Eventually, sediments are compacted and cemented to form sedimentary rocks

Sedimentary Rocks



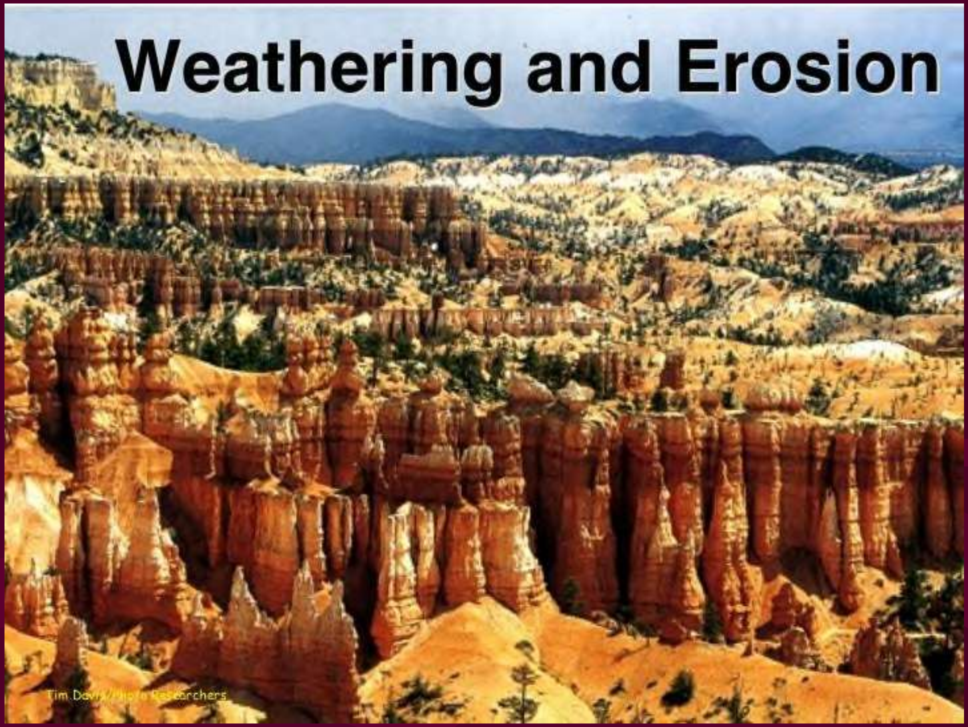
Metamorphic Rocks

- When sedimentary rocks are buried deep enough, they are subjected to changes in pressure and temperature
- Under extreme pressure and temperature conditions, sedimentary rock will change into metamorphic rock
- If subjected to higher pressure and temperature changes, metamorphic rocks may reform into magma

Metamorphic Rocks

Alternate Paths

- The blue arrows on the rock cycle chart show alternate ways that the rock cycle can take if it doesn’t follow the paths previously discussed
- For example, an igneous rock that remains buried could be subjected to strong forces and become a metamorphic rock
- Processes driven by heat from Earth’s interior are responsible for forming both igneous and metamorphic rocks
- Weathering and the movement of weathered materials are external processes powered by the energy of the sun; external processes produce sedimentary rocks



Weathering: the processes which wear rock down and turn it into sediments of various kinds.

Erosion: the removal of weathered material.

Weathering

- Rocks and minerals are not in equilibrium with the environment around them. Weathering is the process by which rocks and minerals become equilibrated with their surroundings.

Types of Weathering

- **Chemical**
  Minerals making up a rock are chemically altered. They either transform to other minerals or dissolve.
- **Physical/Mechanical**
  Rocks are fragmented through generally inorganic mechanisms, while the chemical composition of the rocks' minerals does not change.
- **Biological**
  Living organisms can accelerate either of the previous two mechanisms.

Chemical Weathering

- Rainwater is always slightly acidic (and in some places, very acidic!). Carbon dioxide dissolves in water and becomes carbonic acid, which is the stuff that makes sodas acidic (the concentration of carbon dioxide is much lower in regular water, which is why it doesn't feel or taste acidic). This acid reacts chemically with minerals and either dissolves them or turns them into other minerals.

Chemical Weathering of Tombstone due to acid rain.

http://edutel.musenet.org:8042/gravenet/images/close_lam

Chemical Weathering

- **Dissolution/Leaching**
  Some rocks dissolve completely when exposed to rainwater; two important ones are rock salt and limestone. When these rocks dissolve, the materials which make them up become ions in solution in the water, and are carried away with it.

Cave Formations

http://www.yucatantoday.com/images/destinations/cave

Chemical Weathering

- **Oxidation/Rusting**
  In general, oxidation is when an atom or ion loses one or more electrons. A prime example is when iron rusts -- rusting is when iron ions change from one form to another, and they lose one electron along the way. Iron-bearing minerals also ``rust'' as the iron contained in their structures changes form as above.

Weathering
Oxidation/Rusting

http://www.geographyjim.org/images/weathering/oxidati

Chemical Weathering

- **Hydration**
  Some minerals react with water and acid to take up hydrogen and ``kick out'' other cations; this process is called hydration. Feldspars tend to hydrate and change to clay.

Physical Weathering

- Rocks are naturally fractured at several levels. Mineral grains have boundaries, which can be areas of weakness in the rock. Sedimentary rocks (next time) often are layered and the layers sometimes are not bound together well. More massive rocks can have joints (cracks which have no relative motion across them, only spreading) which will open as the rocks are exposed due to erosion. Physical weathering acts to widen these fractures.

Massive rocks can have joints.

http://www.ecopix.net/contributor/malcolmt.htm

Physical Weathering

- **Frost wedging**
  Frost wedging happens when water filling a crack freezes and expands. The expanding ice presses against the rock and wedges open the crack.

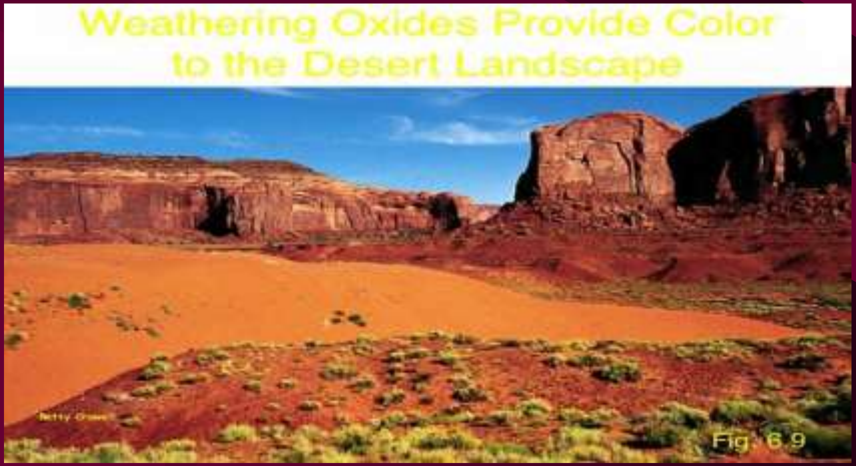
Frost Shattering: Because water expands when it freezes, it can cause rocks to break apart. Water can seep into small cracks in a rock or other substance. When the water freezes, it expands, causing the rock to break apart. This Colorado rock formation continues to show sign of frost action resulting from long and snowy winters

http://www.geographyjim.org/weathering.htm

Physical Weathering

- **Heat/Cold Cycles**
  As rocks are alternately heated and cooled, they expand and contract; minerals expand and contract different amounts, and this differential expansion and contraction may stress rocks and crack them. This is mostly found in deserts; the actual mechanisms by which it happens are still under study.

http://www.aapg.org/explorer/2001/06jun/sphinx.jpg



http://www.gly.fsu.edu/~salters/GLY1000/10Weathering_Erosion/Slide19.jpg

Physical Weathering

- **Unloading**
  Plutonic igneous rocks form at depth in the crust, and may have zones of weakness in them. When these rocks are exposed (through erosion of overlying rock) they expand, and the zones of weakness open up as joints. Granite tends to open and peel away sheets of rock (think of peeling an onion); the domes in Yosemite are formed by this process, which is called exfoliation.

Basket Dome in Yosemite Valley

http://www.caingram.info/Colorado/usa2.htm

Physical Weathering

- **Abrasion**
  Wind, waves, rain, glaciers, and so on abrade rocks' surfaces, wearing them down.

http://www.sfu.ca/~jkoch/older_stuff/glacierglossary.htm

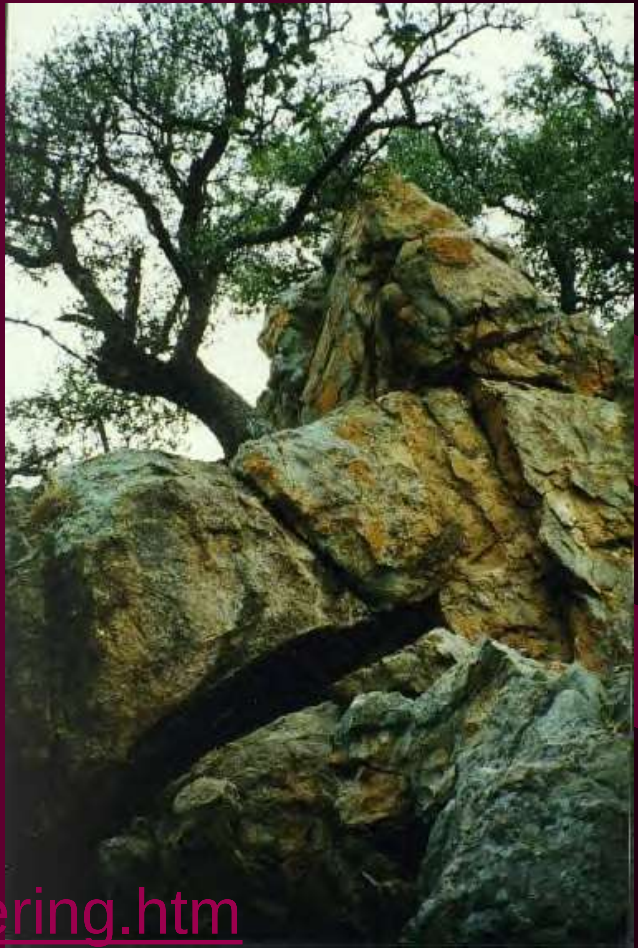
Biological Weathering

- Biological weathering is, of course, weathering done by living things. I suppose it could really be called a special case of either physical or chemical weathering, but it is kind of neat that life on the planet can weather rocks.

http://www.gly.fsu.edu/~salters/GLY1000/10Weathering_Erosion/10Weathering%20and.htm

Biological Weathering

- **Tree roots**
  Tree roots grow into cracks and widen them, which helps physical weathering.



Plants and animals can also cause mechanical weathering. Seeds can find their way into the cracks in rocks where they can sprout and grow. As the plant grows its roots grow down into the crack in the rock and get eventually get larger. The growth of the plant can cause the rock to break apart. This is called root pry.

http://www.geographyjim.org/weathering.htm

Biological Weathering

- **Bacteria**
  Some bacteria and other organisms secrete acidic solutions, which helps chemical weathering.

Plant Acid: Lichens and mosses produce a weak acid that may dissolve rocks and minerals. The rocks break into smaller and smaller pieces. This process, shown at left, is important in soil formation.

http://www.geographyjim.org/weathering.htm

Biological Weathering

- **Chitons/Limpets**
  These mollusks are common. They live in small hollows which they scrape into rocks, and you can find them in tide-pool areas.



http://www.mesa.edu.au/friends/seashores/molluscs.html

Controls on Weathering Rate

- Weathering doesn't proceed at the same rate everywhere. For example, rocks in arid regions may be only very slightly weathered, while similar rocks in the tropics are so weak you can kick them apart. Some general statements can be made about the factors which influence the rate of weathering:

Controls on Weathering Rate

- The more massive the rock, the slower it will weather physically.
- Heavy rainfall and high temperatures promote chemical weathering. Thus desert rocks show less weathering than rocks in tropical rain forests.
- Soil is both a weathering product and an agent of weathering. Since soil holds moisture and organisms, rocks will weather more quickly when in contact with soil than when they are not.
- The longer a rock has been exposed at the surface, the more weathered it will be, all other things being equal.

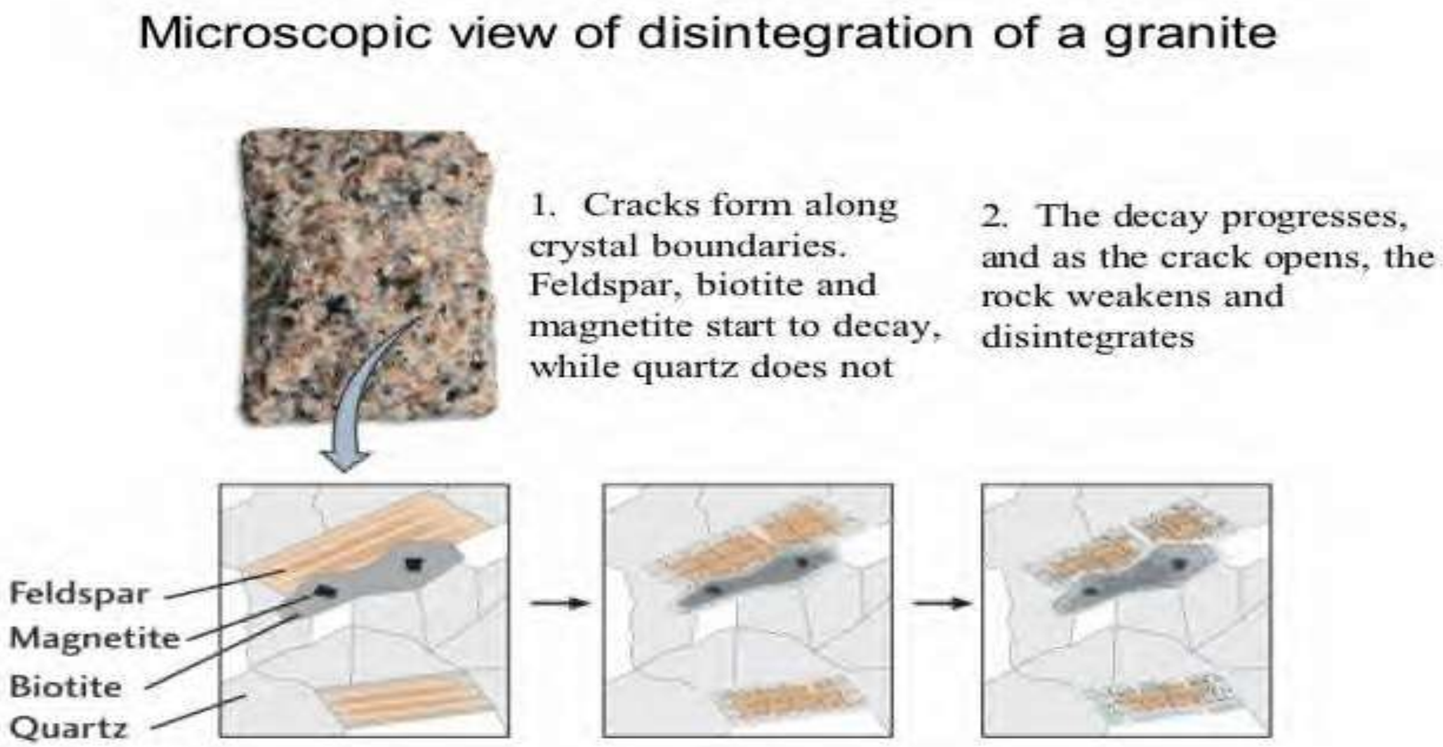
Controls on Weathering Rate

- Chemical weathering rates are controlled by the environment but also by the minerals involved.
- The more soluble a mineral is, the more weathered it will be. Calcite and halite are highly soluble, while quartz is not.

Controls on Weathering Rate

- The more quickly a mineral dissolves (the higher the rate of dissolution), the more weathered it will be. This is related to how hard it is to break bonds in the crystal structure of the mineral. Quartz dissolves very slowly, since it is a tough framework structure. Olivine, on the other hand, dissolves more rapidly, since it is made of isolated silica tetrahedral which are not as tightly bound to one another.

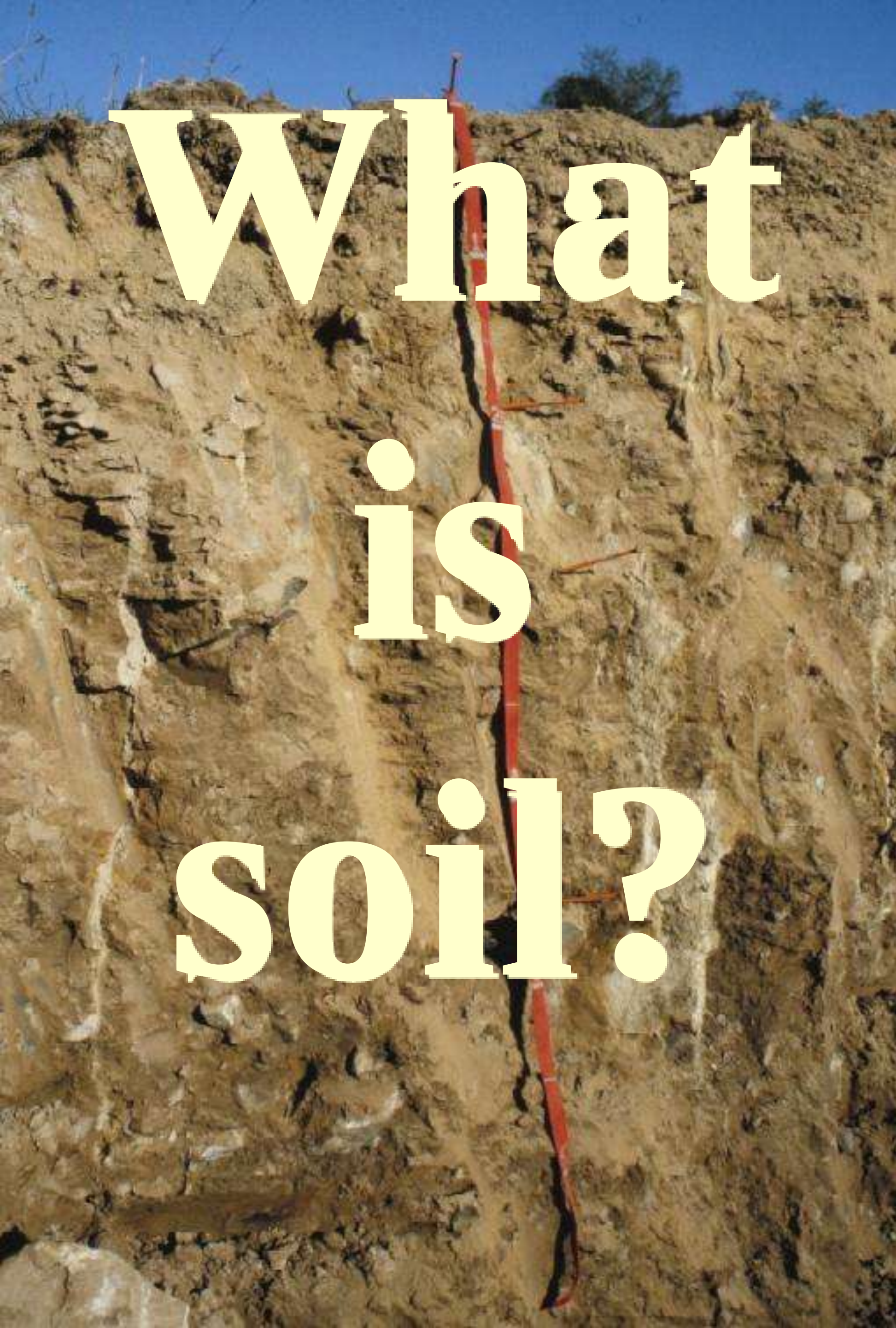
Controls on Weathering Rate



http://www.gly.fsu.edu/~salters/GLY1000/10Weathering_Erosion/10Weathering%20and.htm

Controls on Weathering Rate

- The earlier a mineral crystallizes from melt, the less stable it is at surface conditions. Feldspars will weather more quickly that quartz, despite the fact that they are both framework silicates. This is because feldspars freeze at higher temps than quartz and are thus more unstable at surface conditions.

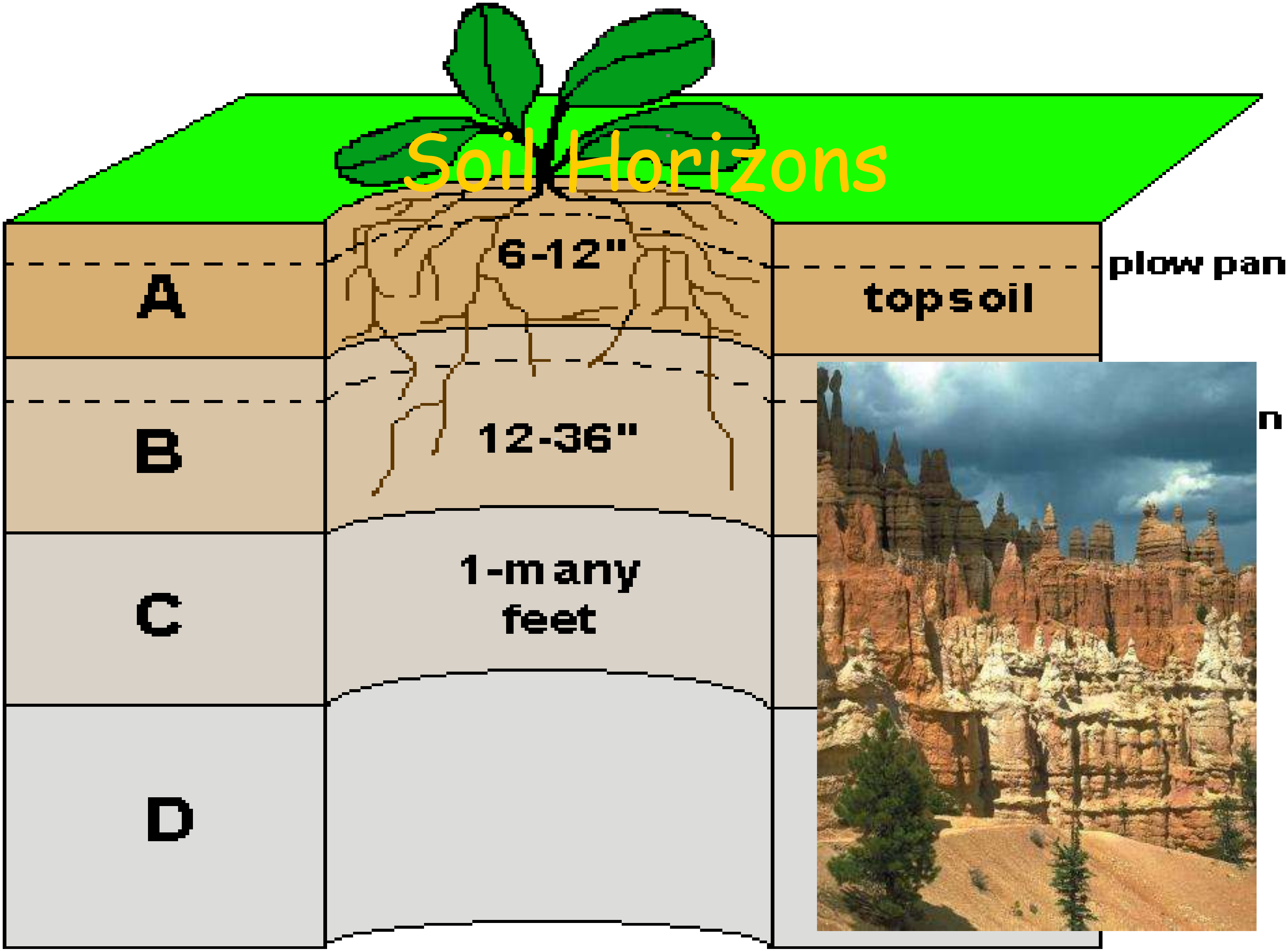

What
is
soil?


Soil is the unconsolidated cover on the surface of the earth.
Soil is made up of
mineral particles,
organic particles,
air, and
water.
Soil is capable of supporting plant growth.

Functions of agricultural soils

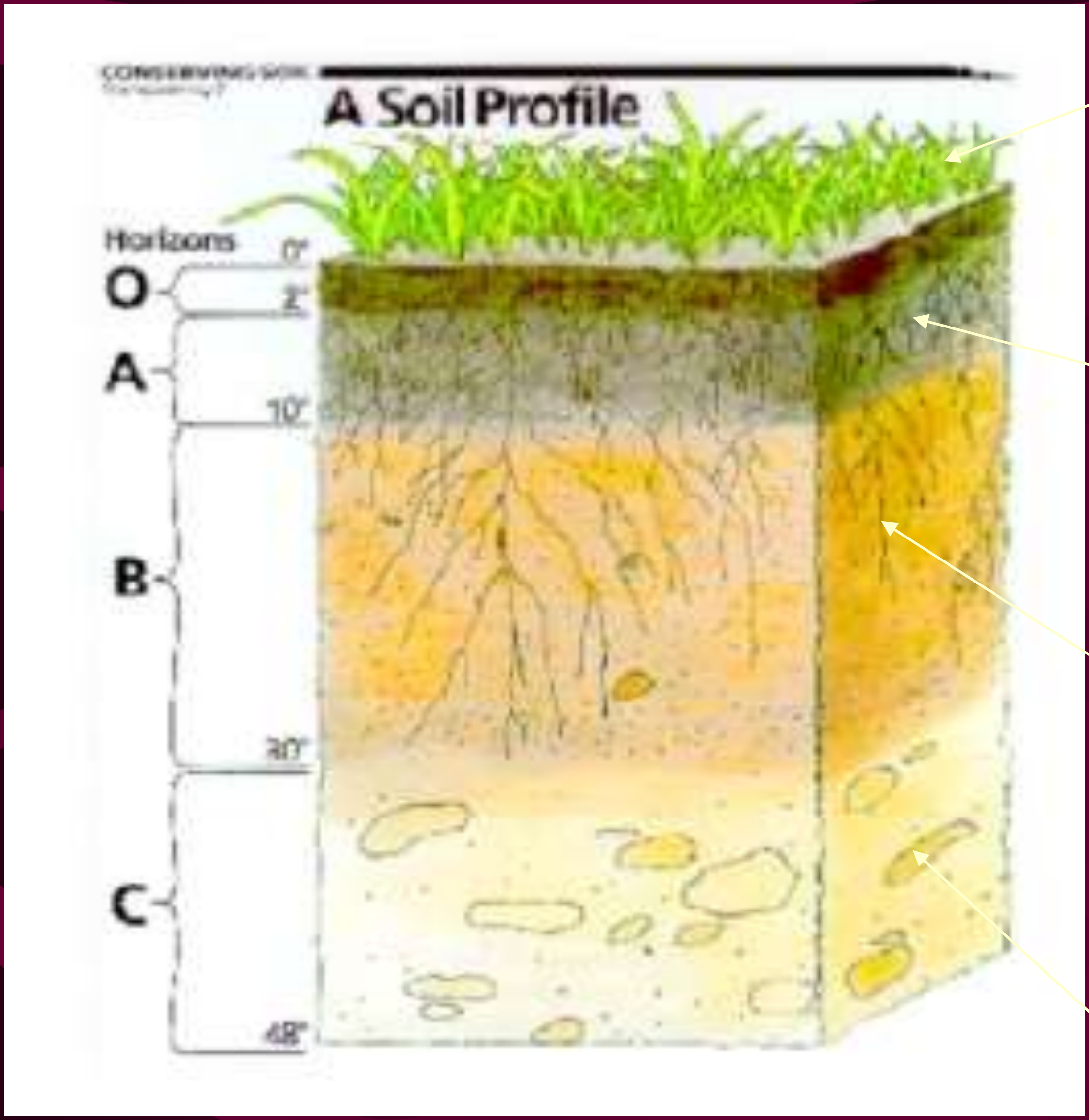
- Anchor plant roots
- Supply water to plant roots
- Provide air for plant roots
- Furnish nutrients for plant growth
- Release water with low levels of nutrients

Soil Horizons



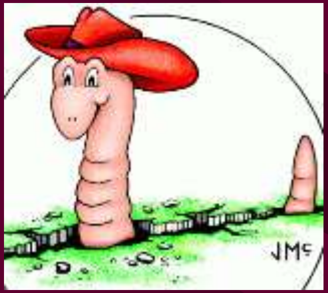
Life in Soil

- Some soil organisms mix the soil and make spaces in it for air and water. Other soil organisms make humus, which makes soil fertile.
- Litter – the loose layer of dead plant leaves and stems on the surface of the soil
- Decomposers – organisms that break down dead organisms and digest them

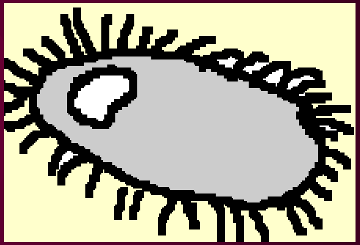


Chipmunks live in dens in the soil and search the litter for seeds and nuts.

Plant roots break up the soil and hold it in place.



Earthworms break up the soil, making it easier for plant roots to spread and for air and water to enter the soil.

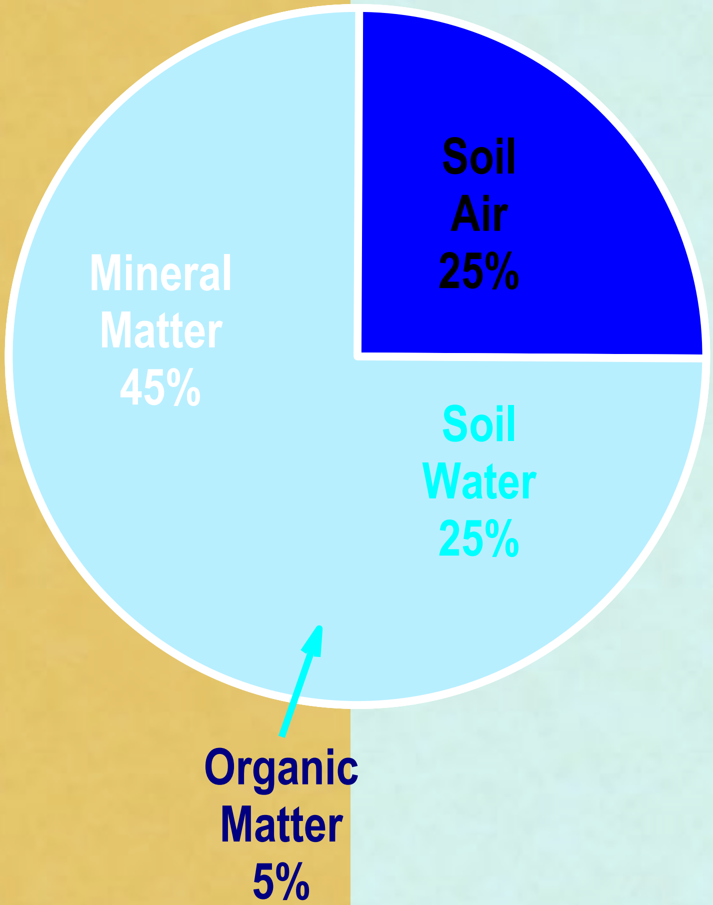


Bacteria are decomposers that break down animal and plant remains and wastes.

Soil Components

The 4 parts of soil

About ½ of the soil volume is solid particles



About ½ of the soil volume is pore space

Components of Soil

- **Mineral Composition of Soils**
  - Minerals - Inorganic (nonliving) substances, definite composition, characteristic physical properties
    - Melting temp, shape, color, hardness
    - **Primary minerals** – formed by the cooling of molten rock
    - **Secondary minerals** – precipitated or recrystallized from solutions that contains elements from dissolutions from other minerals

Components of Soil

- **Rocks** – mixtures of minerals
  - **Igneous** – cooled molten rock
  - **Sedimentary** – sediments deposited in water & consolidated materials
    - Form from one time rock, minerals, soil particles, and soluble substances cemented into hard masses
      - » Sandstones
      - » Shales – consolidated clays & silts
      - » Limestones – clays, silts, and sands cemented in mixtures of calcium carbonates and magnesium carbonates (50% mass is carbonates)
      - » Dolomites – magnesium carbonates
      - » Quartzites – silica-cemented sands

Components of Soil

- **Metamorphic** – igneous or sedimentary rock hardened/altered by heat, pressure, reactions with other chemical solutions
  - may be as hard or harder than other forms, weather to produce similar soils
  - Gneiss – minerals form segregated light/dark bands (granites)
  - Schist – fissile/foliated (flaky/layered), composed of many minerals
  - Slate – hardened shale or siltstone, very hard (pool tables, chalkboard)
  - Quartzite – recrystallized quartzic sandstone, formed by heat & pressure, slow to weather, produces sandy & shallow soils
  - Marble – hardened limestone or dolomite (easily decomposed)

Components of Soil

- Mineral soils
  - Develop from minerals and rocks
  - Mostly quartz, feldspars, dark minerals, lime, gypsum
    - Weather to sands, clays
    - Also provide the majority of soil mineral nutrients

Organic Materials in Soil

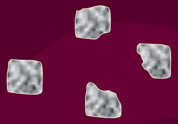
- 98% of all soils are mineral soils
- Organic soils form from plant residues in ponded or cold, wet areas
  - Decomposition is slow
  - Referred to as: peat or muck
  - Anaerobic decomposition is slow
  - Organic soils can be deep if allowed to decompose naturally
    - Florida Everglades, Stockton Delta in CA

Organic Materials in Soil

  - Common materials: grasses, mosses, leaves, cattails, reeds
- All soils contain significant organic matter
- Organic soils are very rich when excavated
- Less sites for organic soils today as many marshes, wetlands, etc. have been drained for development or agriculture

Soil Texture

- The mineral part of soil consists of sand, silt, and clay particles

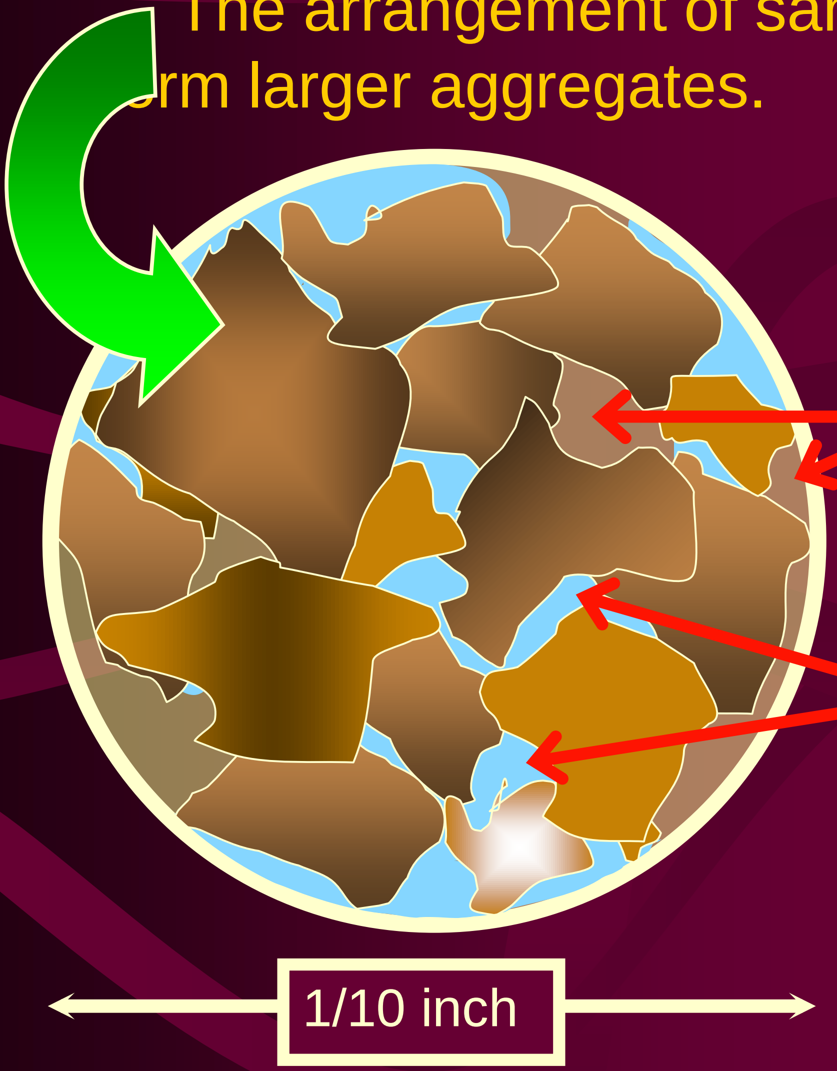


Sand	Silt	Clay
0.1 – 0.002 in	0.002 – 0.0001 in	Less than 0.0001 in
2 – 0.05 mm	0.05 - 0.002 mm	Less than 0.002 mm

- The amounts of each size particle determines the textural property of the soil
  - Coarse textured, loose (more sand, less clay)
  - Fine textured, heavy (more clay, less sand)
  - Loamy (more even mix of sand, silt and clay

Soil Structure

The arrangement of sand, silt, and clay particles to
orm larger aggregates.



- Organic matter is the glue that holds the aggregates together
- Large pores (spaces) between aggregates are filled with air in a moist soil.
- Small pores are filled with water in a moist soil. Even smaller pores inside the aggregates (not shown) are also filled with water.

Supplying Plant Nutrients

Nutrients that plants obtain from the soil

Macronutrients:

(needed in large amounts)

- Nitrogen (N)
- Phosphorus (P)
- Potassium (K)
- Calcium (Ca)
- Magnesium (Mg)
- Sulfur (S)

Micronutrients:

(needed in small amounts)

- Chlorine (Cl)
- Cobalt (Co)
- Copper (Cu)
- Iron (Fe)
- Manganese (Mn)
- Molybdenum (Mo)
- Nickel (Ni)
- Zinc (Zn)

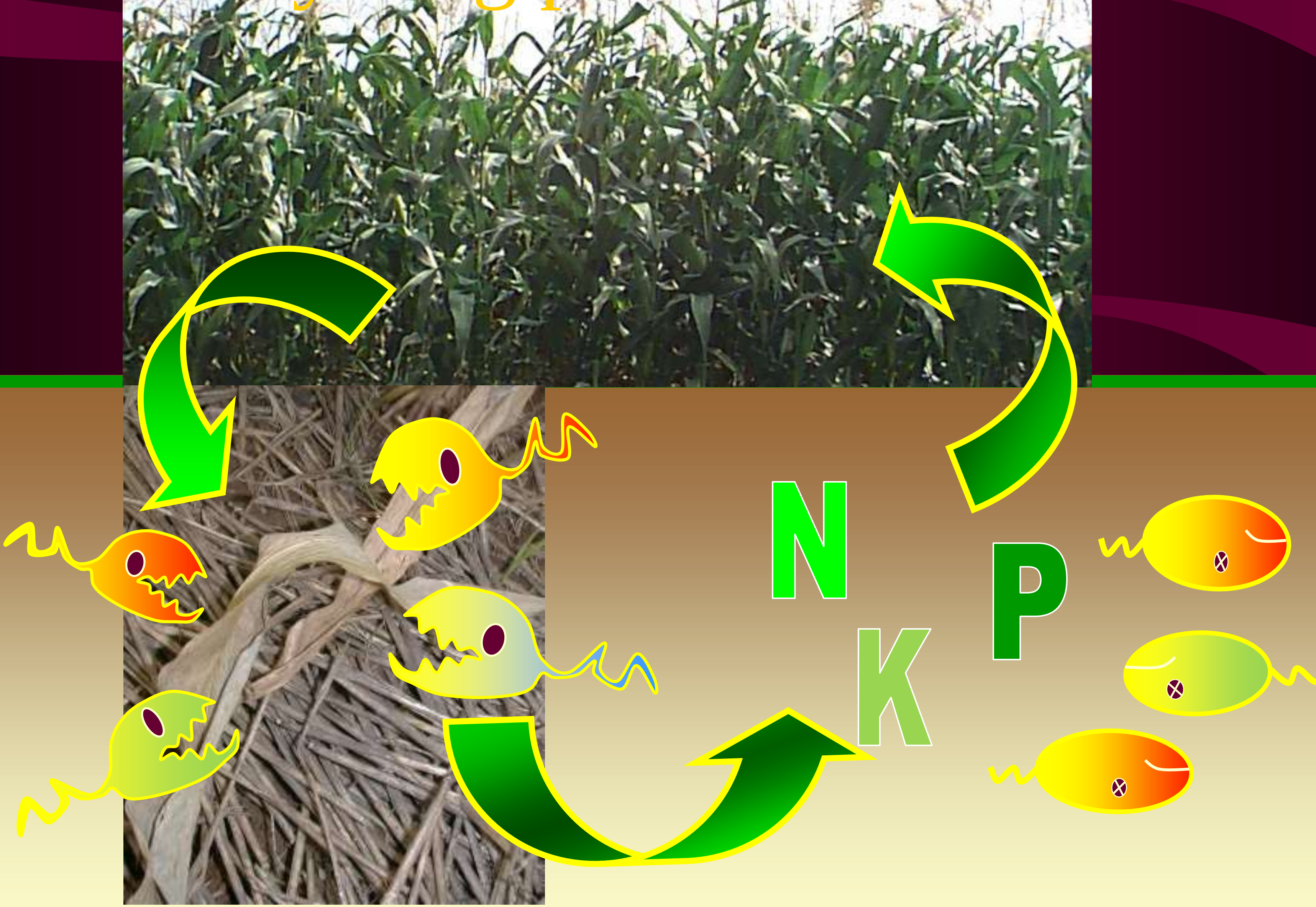
Where do plant nutrients come from?

- Decaying plant litter

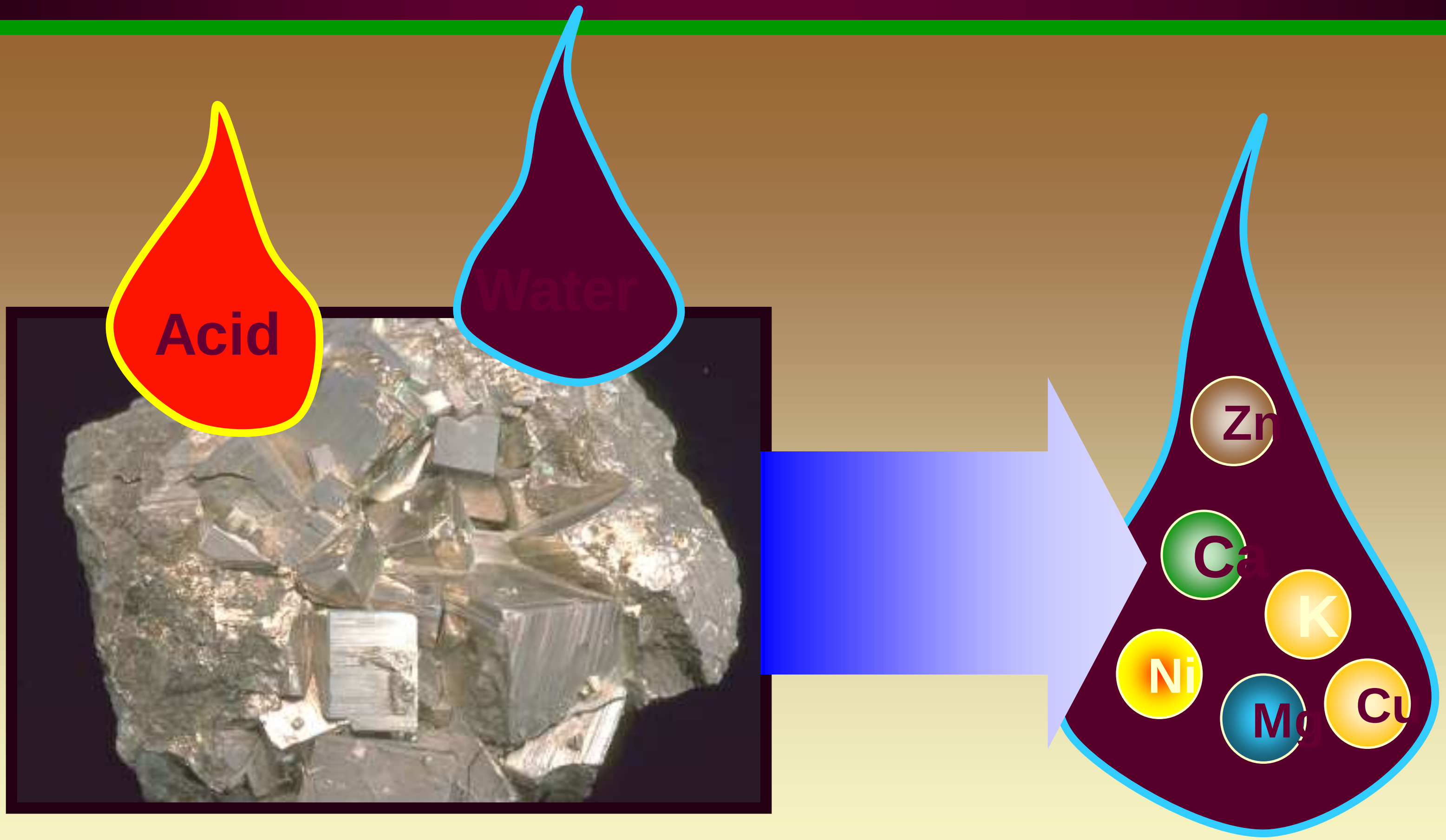
- Breakdown of soil minerals

- Addition by humans
  - Commercial fertilizer
  - Manure
  - Lime
  - Other

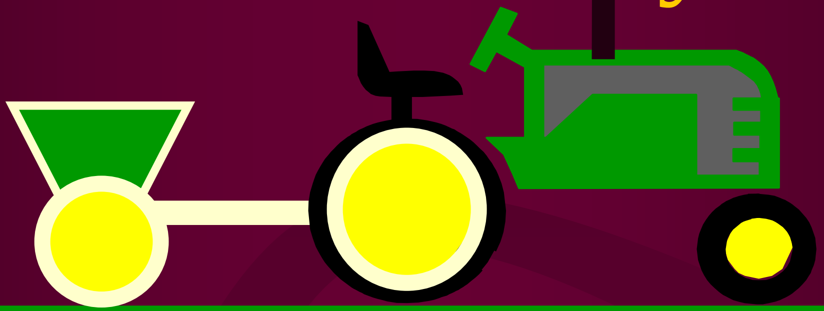
Recycling plant nutrients



Breakdown of soil minerals



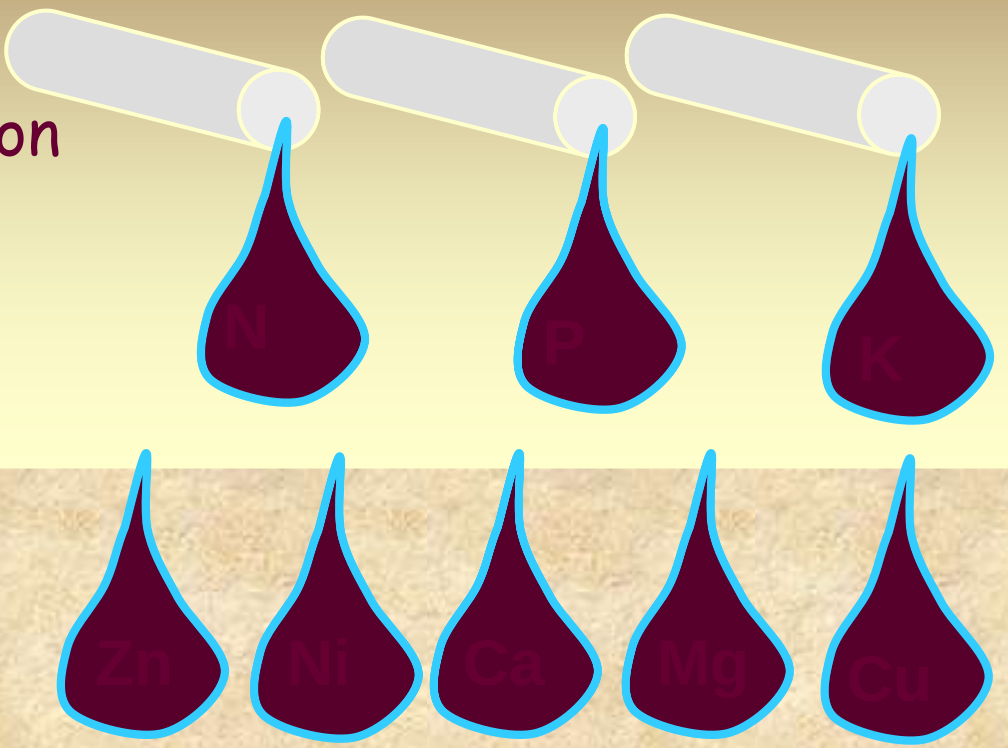
Nutrient additions by humans



- Commercial fertilizers
  - Nutrients are in a form that is available to plants
  - Dissolve quickly and nutrients go into soil water
- Lime
  - Dissolves slowly as it neutralizes soil acidity
  - Releases calcium and magnesium
- Organic nutrient sources
  - Manure, compost, sewage sludge
  - Decay and nutrient release is similar to crop litter

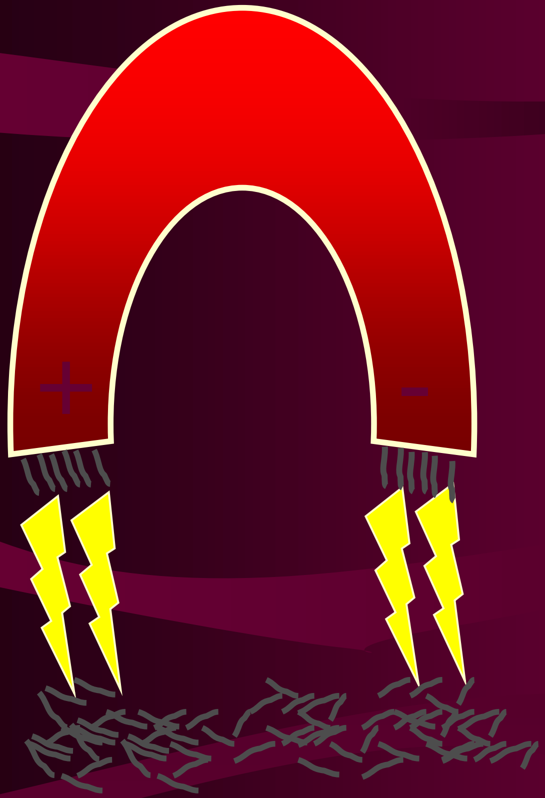
The soil solution

- Soil water is a complex solution that contains
  - Many types of nutrients
  - Other trace elements
  - Complex organic molecules
- Nutrients in the soil solution can be readily taken up by plant roots



- If nutrients remained in solution they could all be quickly lost from the soil.

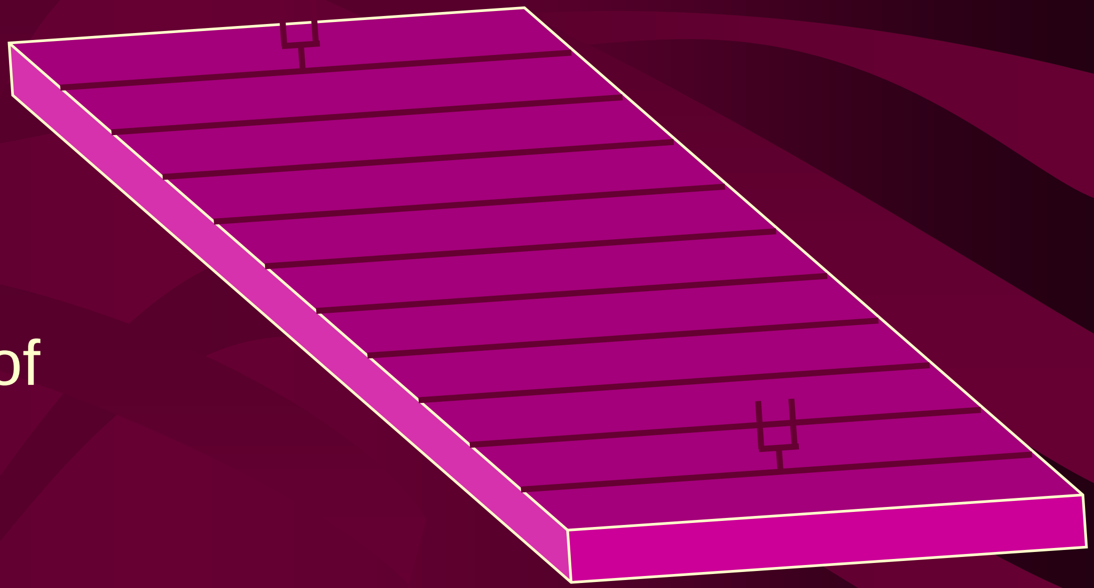
Adsorption



- Adsorption refers to the ability of an object to attract and hold particles on its surface.
- Solid particles in soil have the ability to adsorb
  - Water
  - Nutrients and other chemicals
- The most important adsorbers in soil are
  - Clays
  - Organic matter

Surface area of clay

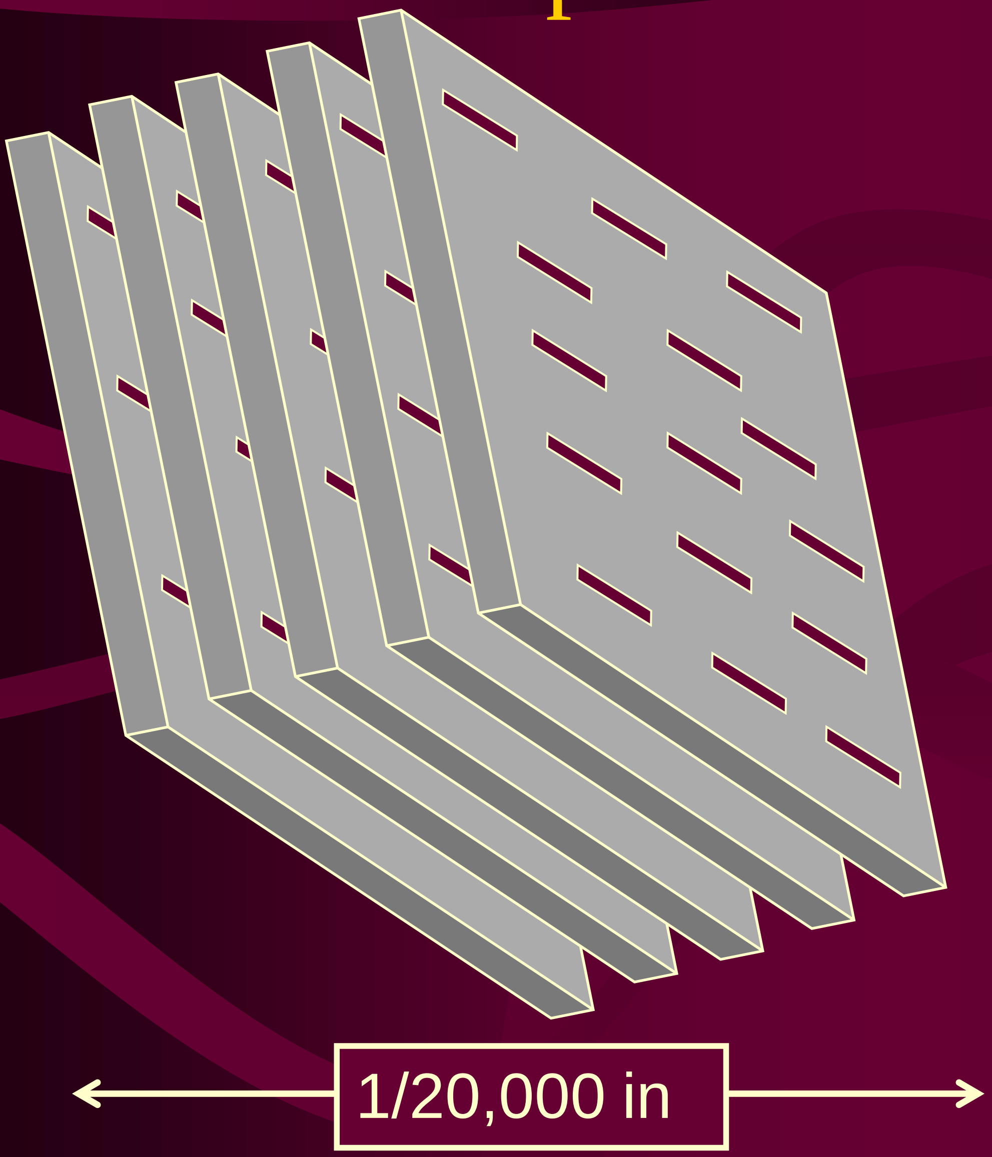
¼ cup of clay has more surface area than a football field



The large surface area of clay allows it to

- Adsorb a lot of water
- Retain nutrients
- Stick to other soil particles

Properties of Soil Clays



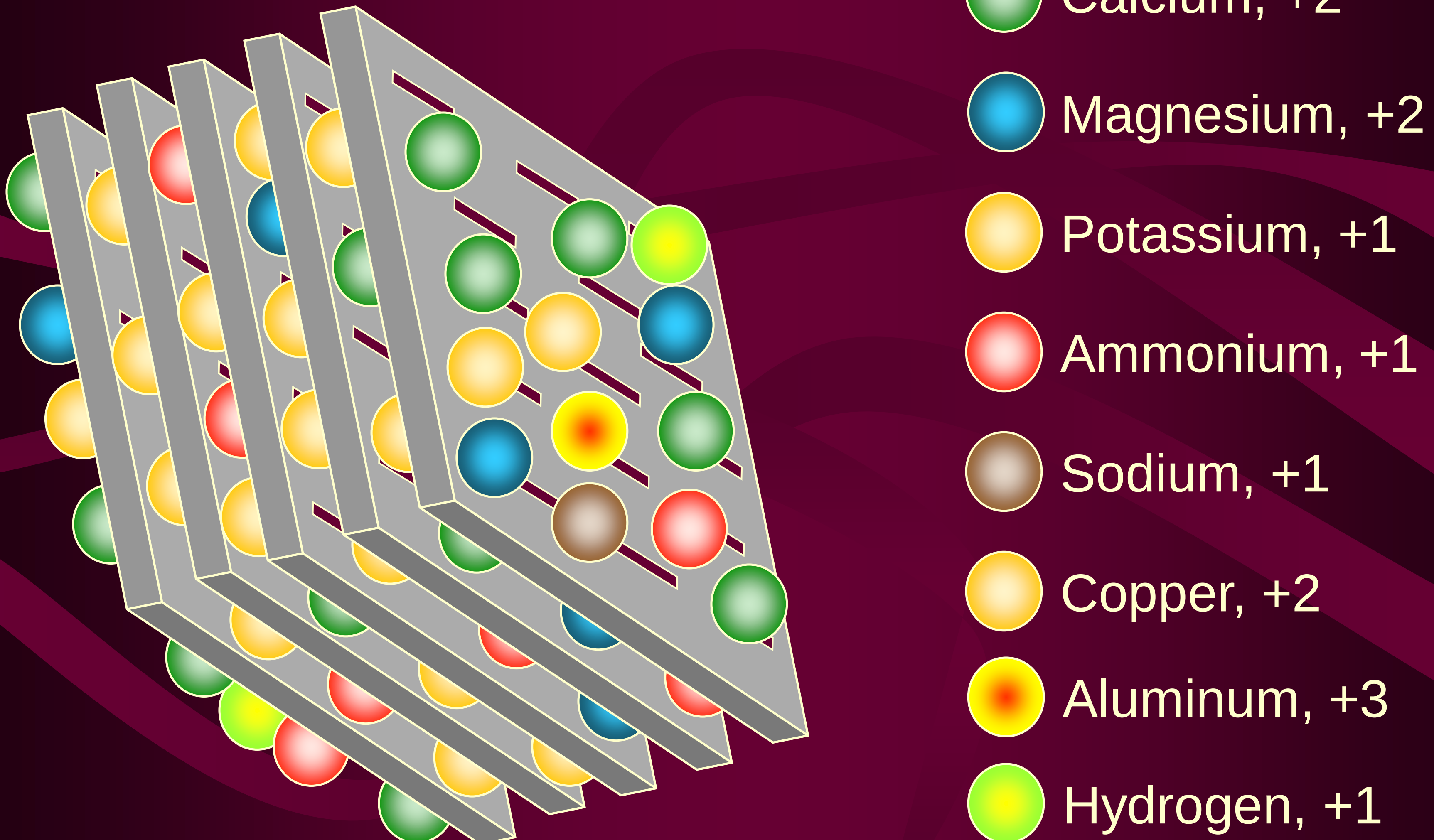
Clay particles are stacked in layers like sheets of paper.

Each clay sheet is slightly separated from those on either side.

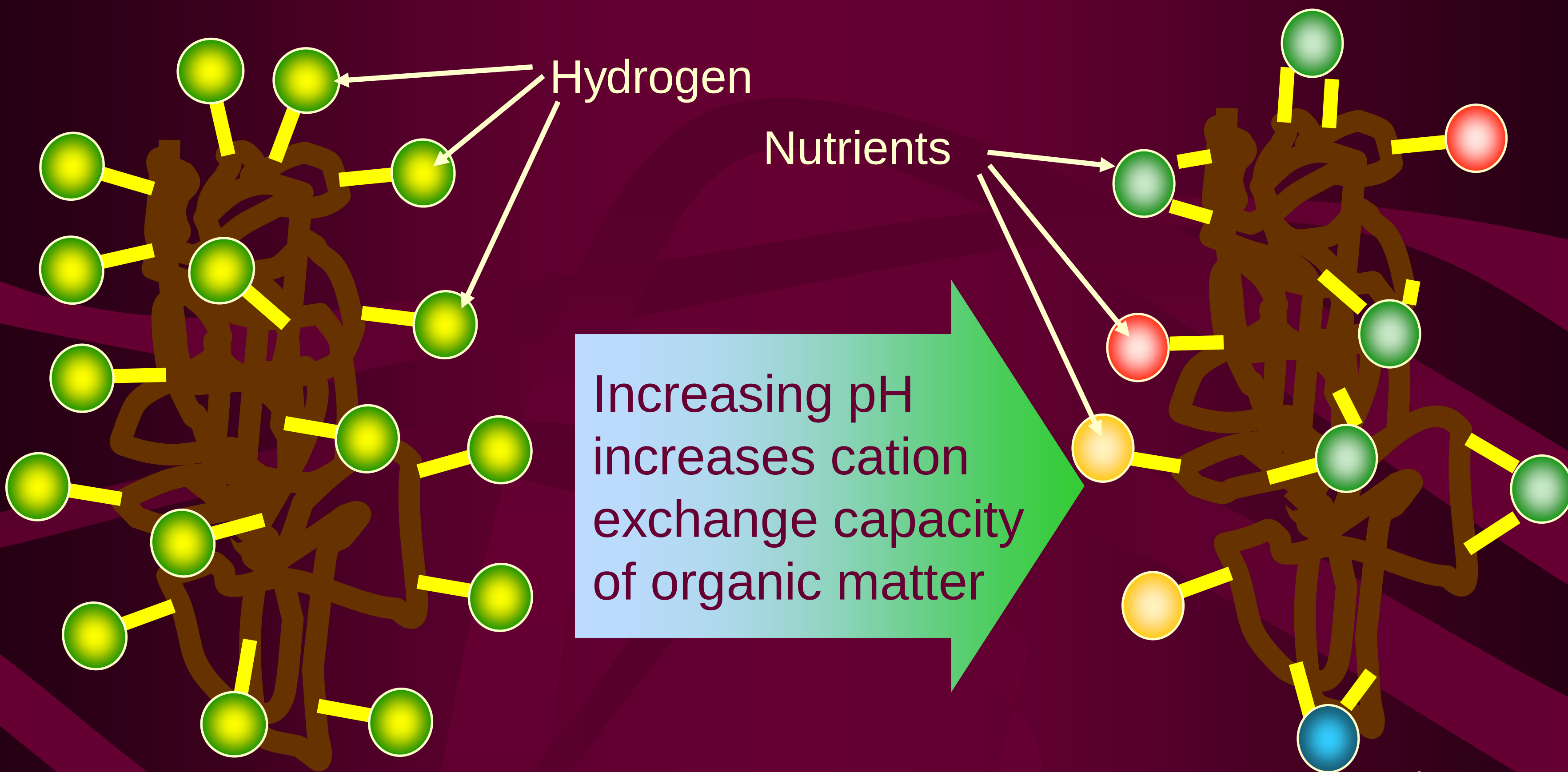
Each sheet has negative charges on it.

Negative charges have to be balanced by positive charges called cations.

Cation Retention on Soil Clays



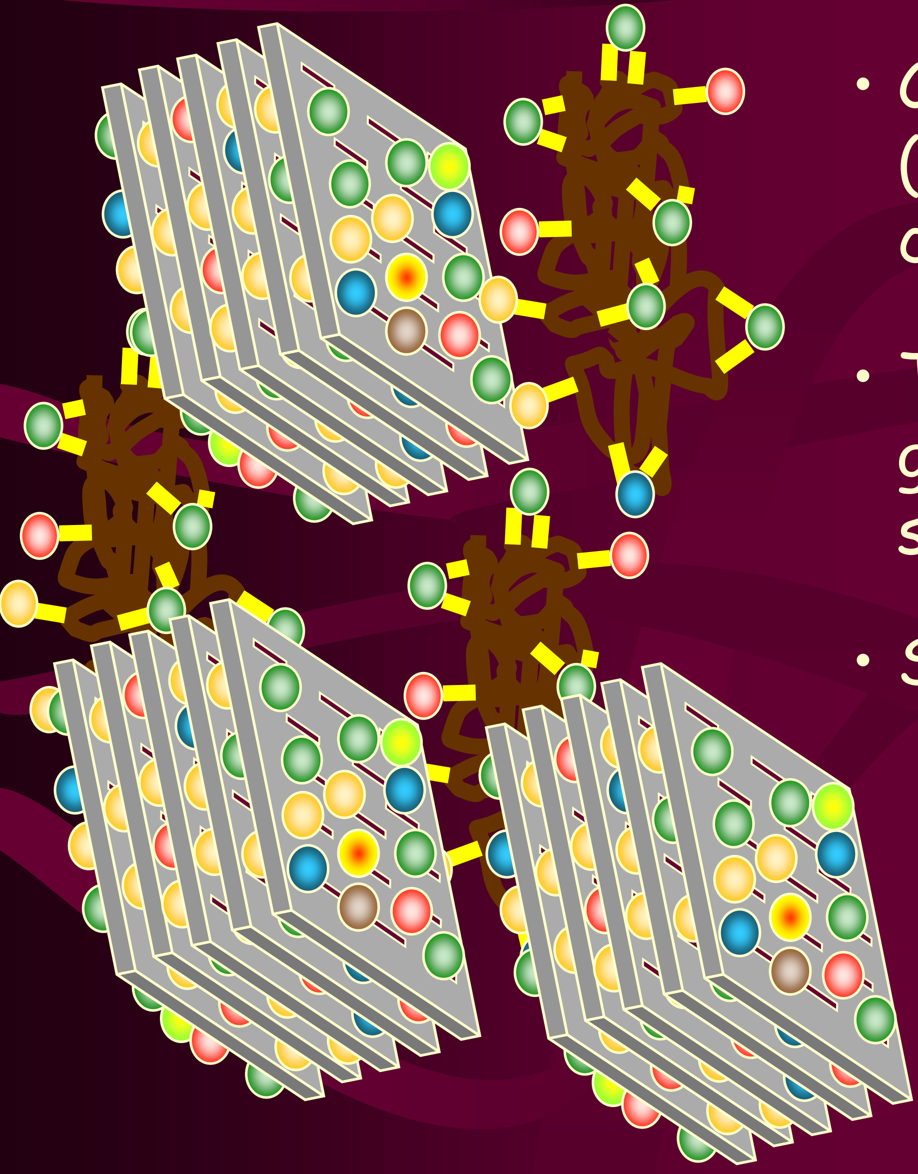
Cation Retention on Organic Matter



Low pH, 4 - 5
(acidic soil)

Neutral pH, 7
(“sweet” soil)

Cation Exchange Capacity



- Cation exchange capacity (CEC) is the total amount of cations that a soil can retain
- The higher the soil CEC the greater ability it has to store plant nutrients
- Soil CEC increases as
  - The amount of clay increases
  - The amount of organic matter increases
  - The soil pH increases

Negatively Charged Nutrients (Anions)

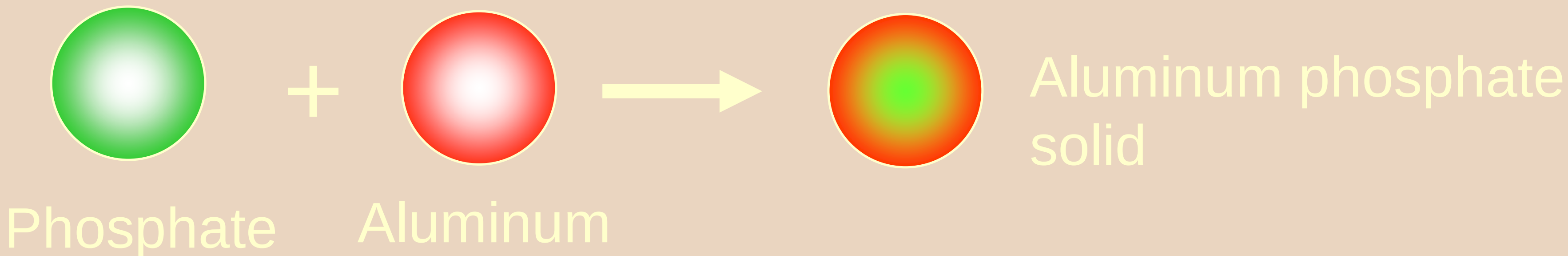
- Some very important plant nutrients are anions.

1-	2-	2-	1-
Nitrate	Phosphate	Sulfate	Chloride

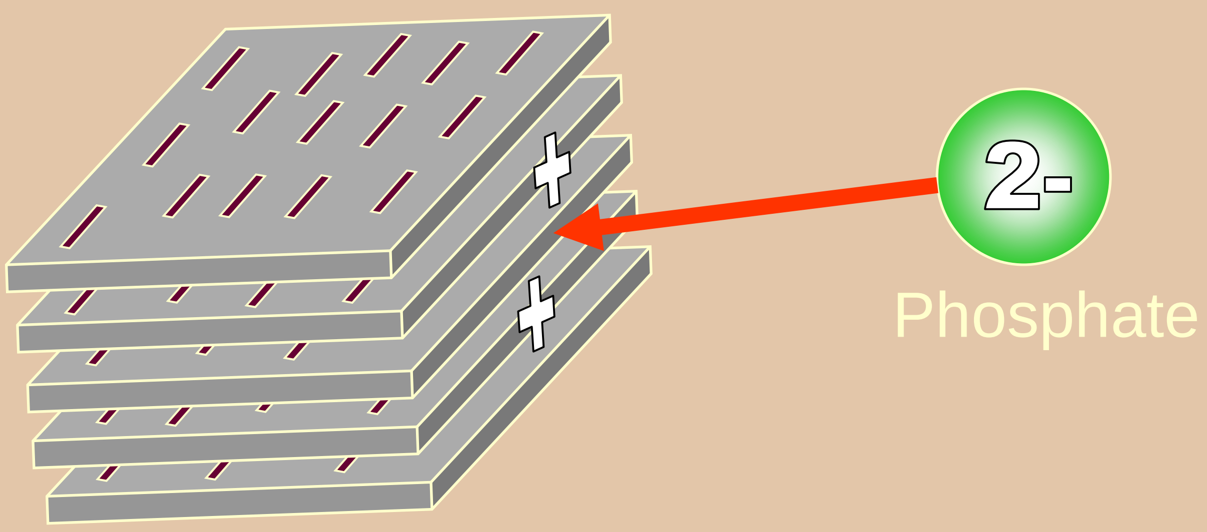
- Soils are able to retain some of these nutrient anions.
- Retention of nutrient anions varies from one anion to another

Phosphate retention in soil

1. Formation of a new solid material

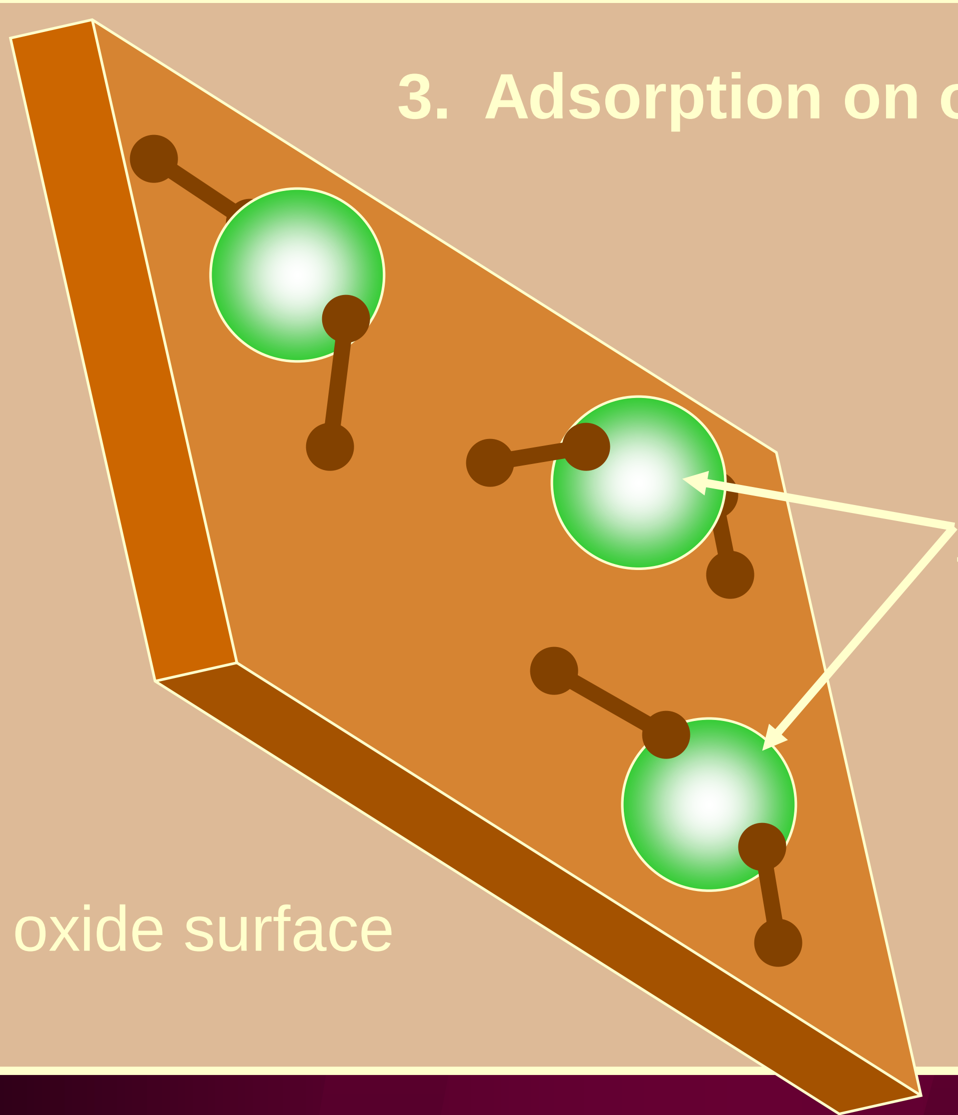


2. Anion exchange



Phosphate retention in soil

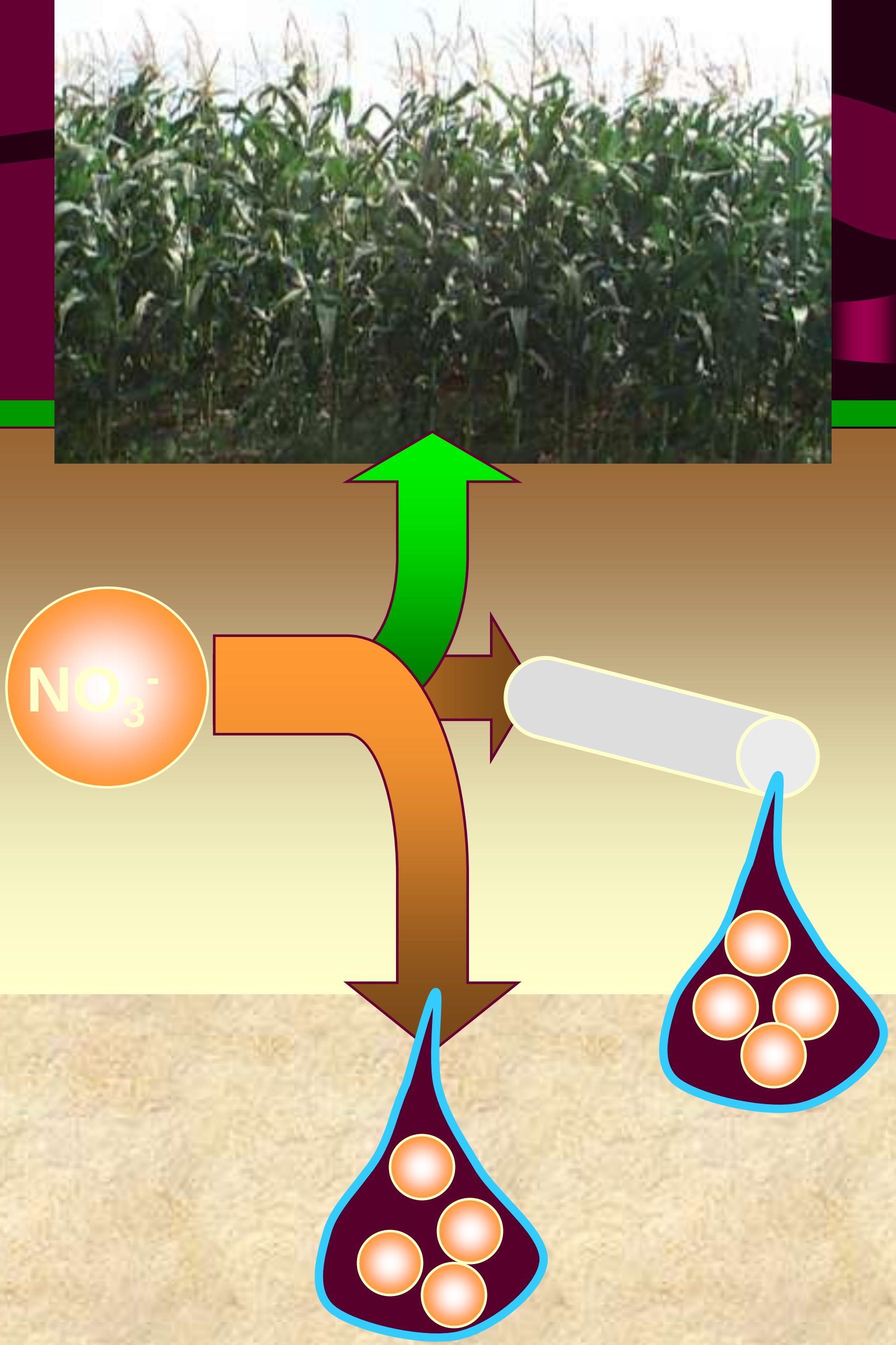
3. Adsorption on oxide surfaces



Phosphate anions - Each held by two chemical bonds to the iron oxide surface

Iron oxide surface

Nitrate (NO_3^-) retention in soils

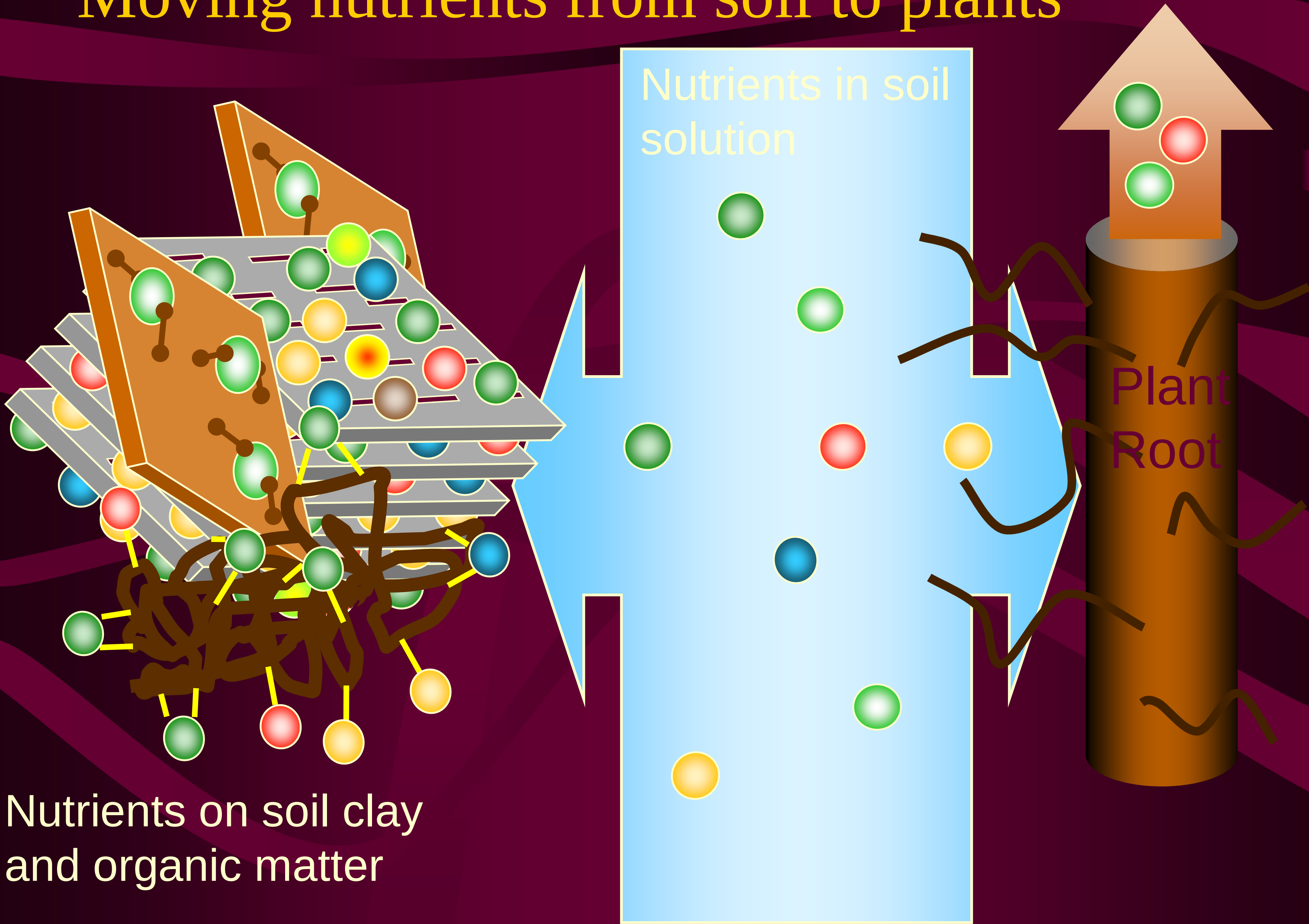


Unlike phosphate, nitrate is <u>very weakly</u> held by soils

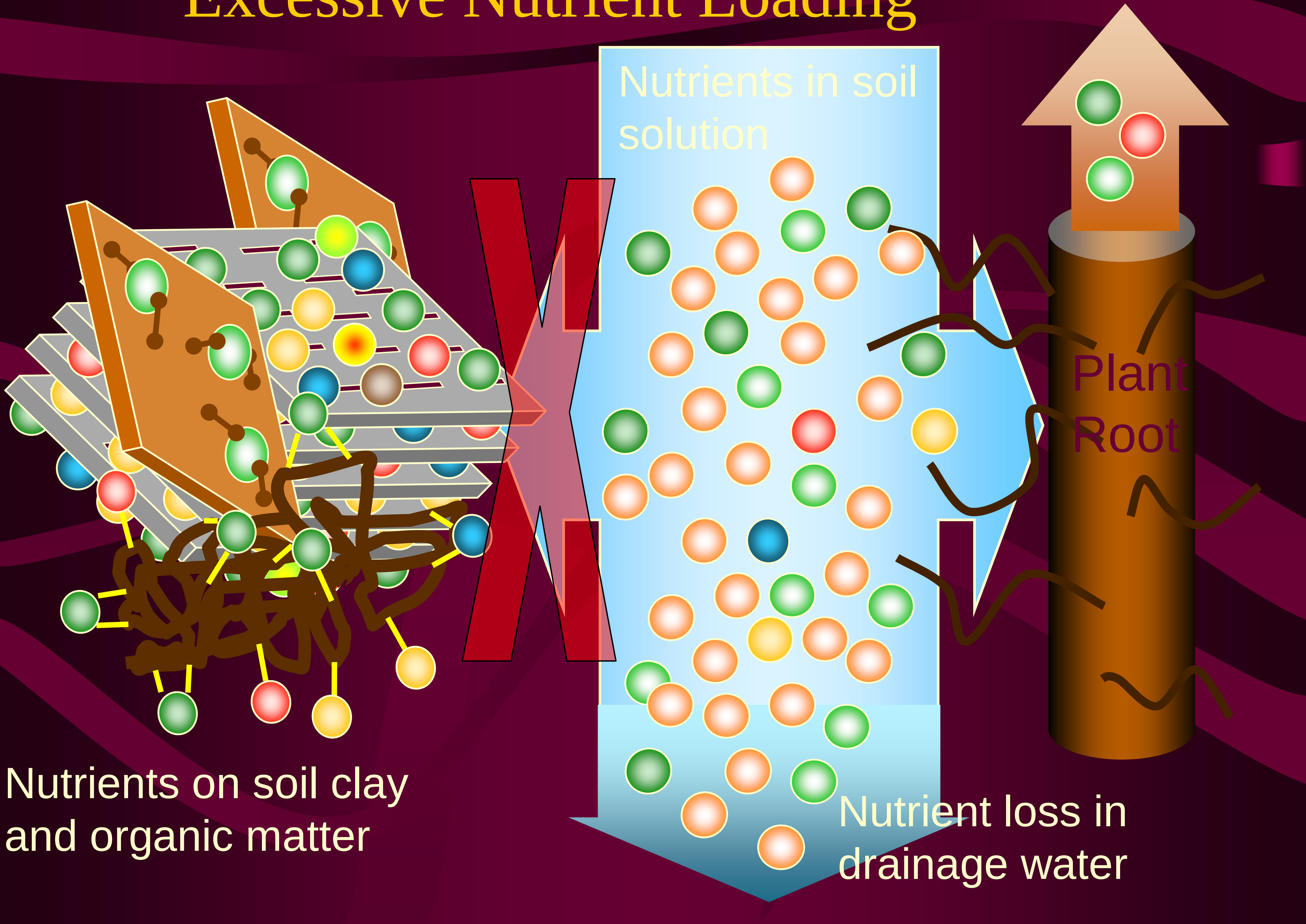
- Nitrate <u>does not</u> react to form new solids
- Nitrate is <u>not held</u> by oxide surfaces

If nitrate is not taken up by plants it is very likely to be lost from the soil

Moving nutrients from soil to plants



Excessive Nutrient Loading



The black box is open

- Soil consists of mineral and organic matter, air and water
- Soils are able to adsorb nutrients and other chemicals
- The most important adsorbers are clay and organic matter
- Adsorbed nutrients are available to plants
- Adsorbed nutrients are not prone to loss in drainage water
- Soil adsorption capacity can be exceeded leading to greater nutrient loss