AQA Geography A-level

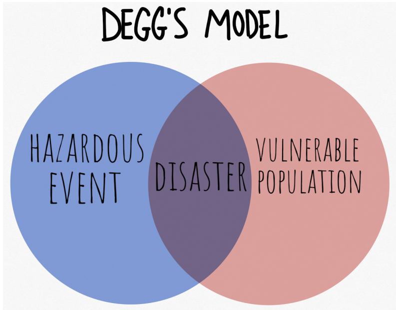
3.1.5: Hazards

Detailed Notes

The Concept of Hazard

A **hazard** is a potential threat to **human life** and **property** caused by an event. Hazards can be human caused or occur naturally (natural hazards). An event will only become a **hazard** when it is a threat to **people**. E.g. if a hurricane hit an uninhabited desert island it would not be classed as a hazard.

Hazards should not be confused with **natural disasters**. A disaster will only occur when a **vulnerable population** (one that will be significantly disrupted and damaged) is exposed to a hazard. Degg's model is a good representation of this concept. If the population is not vulnerable, the hazard will not have a significant effect, thus the event will not be **disastrous**.



There are three major types of geographical hazard:

Geophysical

hazards caused by **land processes**, majorly tectonic plates (e.g. volcanoes)

Atmospheric

hazards caused by **atmospheric processes** and the conditions created because of these, such as weather systems (e.g. wildfires)

Hydrological

hazards caused by **water bodies** and **movement** (e.g. floods)

Hazards can also be classed as a mixture of these geographical processes. For example, a tropical storm could be classed as an hydrological-atmospheric hazard as both of these processes contribute to the hazard. Hazards that are both atmospheric and hydrological are sometimes classed as **hydrometeorological hazards**.

Hazard Perception

People have different **viewpoints** of how **dangerous** hazards are and what **risk** they pose. These perceptions are dependent on **lifestyle factors** which include **economic** and **cultural** elements. Note that these are the economic and cultural factors of **individual people** rather than an entire population's views.

Wealth - The financial situation of a person will affect how they **perceive** hazards. Wealthier people may perceive a hazard to be **smaller** as they are less **vulnerable** (e.g. they have the ability to evacuate with transport access, build stronger houses etc.) However, wealthier people may also view a risk as **greater** as there is more risk of **property damage** and **financial loss** than someone less wealthy. This is, of course, dependent on the person.

Experience - Someone who has **experienced more hazards** may be more likely to understand the **full effects** of a hazard. There are also studies suggesting that people who have experienced hazards are likely to have an **optimistic** and **unrealistic** outlook on future hazards, almost like a

'lightning never strikes the same place twice' mentality. R. Kates describes this in his journal: **Natural Hazard in Human Ecological Perspective: Hypotheses and Models, 1971.**

Education - A person who is more educated about hazards may understand their full **effects** on people and how **devastating** they can be and have been in the past. Those who are less educated may not understand the full extent of a hazard and may not evacuate etc.

Religion and beliefs - Some may view hazards as put there by **God** for a reason, or being part of the **natural cycle of life** etc. so may not perceive them to be negative. In contrast, those who believe strongly in **environmental conservation** may perceive hazards to be a huge risk to the natural environment, especially hazards that are becoming more frequent due to global warming.

Mobility - Those who have **limited access** to escape a hazard may perceive hazards to be greater threats than they are. Whether they are in a **secluded location**, or if they are impaired with a **disability** or **illness**, those who cannot easily leave an area quickly may feel more at risk.

Human Responses to Hazards

Hazards can be responded to in a **passive** way (making no effort to lessen a hazard) or in an **active** way. **Fatalism** is a passive response to a hazard.

- **Fatalism:** The viewpoint that hazards are **uncontrollable** natural events, and any losses should be **accepted** as there is nothing that can be done to stop them.

Active responses to hazards are any strategy used to overall contribute to a lower hazard risk.

- **Prediction:** Using **scientific research** and **past events** in order to know when a hazard will take place, so that **warnings** may be **delivered** and **impacts** of the hazard can be **reduced**. In some cases, hazards may also be **prevented** when predicted early enough (e.g. predicting wildfires from climatic red flags).
- **Adaptation:** Attempting to **live with hazards** by adjusting **lifestyle choices** so that vulnerability to the hazard is lessened (e.g. earthquake proof houses).
- **Mitigation:** Strategies carried out to **lessen the severity of a hazard** (e.g. sandbags to offset impact of flooding).
- **Management:** **Coordinated strategies** to reduce a hazard's effects. This includes prediction, adaptation, mitigation.
- **Risk sharing:** A form of **community preparedness**, whereby the community **shares the risk** posed by a natural hazard and **invests collectively** to mitigate the impacts of **future hazards**.

New Zealand is an example of where risk sharing has worked. As a **multi-hazard** environment, New Zealand is under threat from earthquakes, tsunamis, volcanoes, and weather-related hazards. The cost of these hazards are huge; the Canterbury Earthquake (2010) alone cost the country 20% of it's national GDP. There are now attempts to share the risk by insurance investment, so strategies can be put in place **before** the disasters rather than investing more in a clean up.

Read the Insurance Council of New Zealand's paper here:
https://www.icnz.org.nz/fileadmin/Assets/PDFs/icnz-protecting-nz-from-natural-hazards-2014.pdf

Aspects of Hazards and How They Affect Human Responses

Every hazardous event varies in terms of its location, frequency, and strength. These **aspects** of a natural event create different types of hazards, and influence how people respond to these hazards.

Incidence: **Frequency** of a hazard. This is not affected by the strength of a hazard, it is just how often a hazard occurs.

Low incidence hazards may be **harder to predict** and have less **management** strategies put in place, meaning the hazard could be more catastrophic when it does eventually occur. Also, low incidence hazards are usually (but not always) more **intense** than high incidence hazards. For example, there are only **36 recorded earthquakes** since 1500 that were a magnitude of **8.5 or higher**, but **millions of earthquakes** that are too weak to be recorded are thought to happen **every year**.

Distribution: where hazards **occur** geographically.

Areas of high hazard distribution are likely to have a lot of management strategies, and those living there will be **adapted** to the hazardous landscape because it dominates the area more so than in places with low hazard distribution.

Intensity: the **power** of a hazard i.e. how strong it is and how damaging the effects are

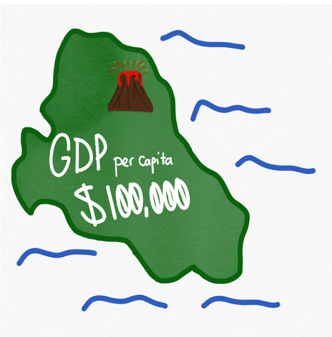
Magnitude: the size of the hazard, usually this is how a hazard's **intensity is measured**

High magnitude, **high intensity** hazards will have **worse effects**, meaning they will require more **management**, e.g. more mitigation strategies will be needed to lessen the effects and ensure a relatively normal life can be carried out after the hazard.

Magnitude and intensity are **not** interchangeable terms and it is important that this is recognised. The magnitude is usually **definable** and can be a **number** - this **does not change**. Intensity, however, is the effects on the **person**, and can change dependent on the **distance** from the hazard or the **management strategies** combating high magnitude risks.

An effective way to remember this is through a **television broadcast** analogy. The **magnitude** is the **signal being sent out** and the frequency of the television transmission; the **intensity** is how well it is being **received by the person**. Even if the quality (intensity) on your end is poor and grainy, the broadcast (magnitude) is always going to be on the same frequency.

Level of development: economic development will affect how a place can **respond** to a hazard, so a hazard of the same magnitude may have very different **effects** in two places of contrasting levels of development.



Even if the hazard is identical, an area with a **lower level of development** is less likely to have **effective mitigation strategies** as these are costly. Therefore, the effects of a hazardous event is likely to be much more catastrophic in a less economically developed area.

However, there are many high income countries that are not as **prepared** for natural hazards as they should be, meaning they lack the **management strategies** for an event. This is especially true in **multi-hazard environments** where resources are spread thinly over a variety of hazards.

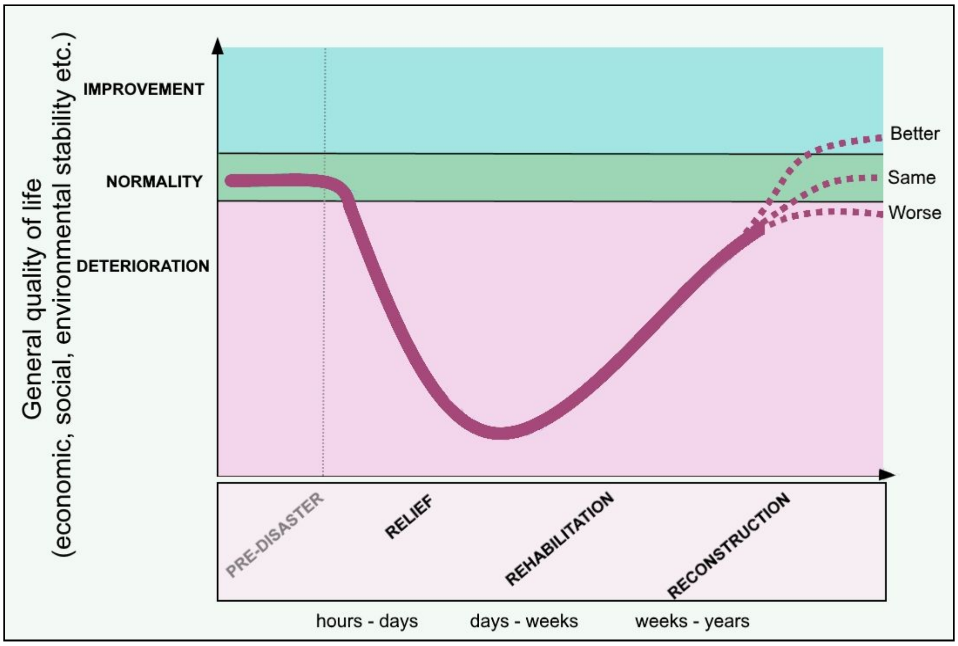
In **Canada** where **wildfires** have been increasing over the last few years (as a result of climate change), less **money** and **resources** have been available for **earthquake** and **tsunami preparation**. Even detailed evacuation routes and tsunami sirens are not available in popular tourist beaches such as Vancouver Island or Pacific Rim National Park. **Text message systems** are available to act as a warning system to suggest people to evacuate, but many people switch their phones off at night, reducing the effectiveness. This [article] explains the inadequate preparation strategies in British Columbia.
Overall, level of development may not have the biggest part to play in a hazard, and it is more to do with how these countries use their development for mitigation.

The Park Model

The Park Model is a **graphical representation** of human responses to hazards. The model shows the steps carried out in the **recovery** after a hazard, giving a rough indication of **time frame**.

- The **steepness** of the curve shows how **quickly** an area **deteriorates** and **recovers**.
- The **depth** of the curve shows the **scale** of the **disaster** (i.e. lower the curve, lower the quality of life).

***The Park Model* of Human Response to Hazards**



Stage 1 - Relief (hours-days)

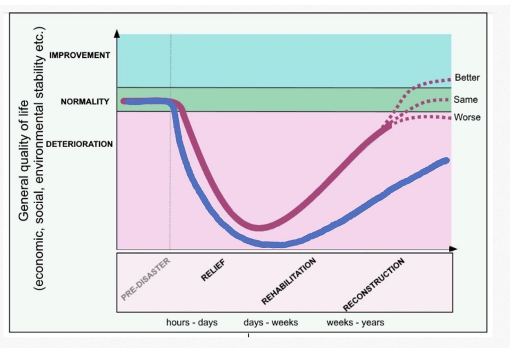
- **Immediate** local **response** - medical aid, search and rescue
- Immediate appeal for **foreign aid** - the beginnings of global response

Stage 2 - Rehabilitation (days-weeks)

- **Services** begin to be restored
- **Temporary shelters** and **hospitals** set up
- **Food and water** distributed
- **Coordinated foreign aid** - peacekeeping forces etc.

Stage 3 - Reconstruction (weeks-years)

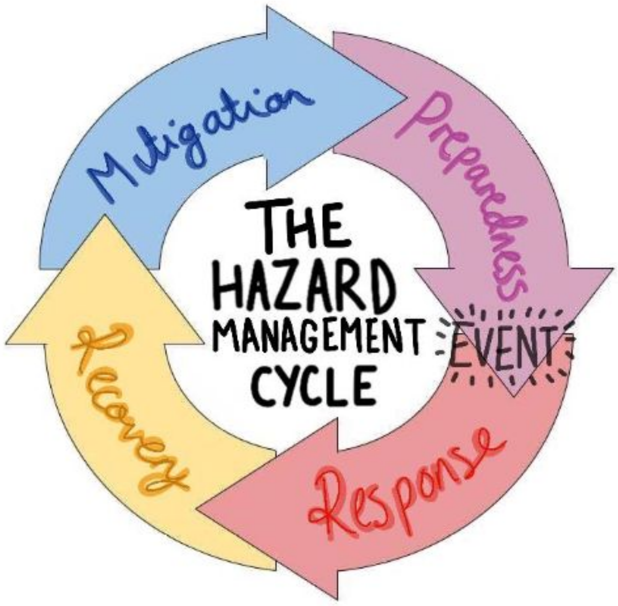
- **Restoring** the area to the same or better quality of life
- Area back to **normal** - ecosystem restored, crops regrown
- **Infrastructure** rebuilt
- Mitigation efforts for **future event**



The model also works as a **control line** to compare hazards. An **extremely catastrophic hazard** would have a **steeper curve** than the average and would have a **slower recovery time** than the average, for example. This has been indicated by the blue line.

The Hazard Management Cycle

The Hazard Management Cycle outlines the stages of responding to events, showing how the same stages take place after every hazard.



Preparedness	Response	Recovery	Mitigation
Being **ready** for an event to occur (public awareness, education, training)	**Immediate action** taken after event (evacuation, medical assistance, rescue)	**Long-term responses** (restoring services, reconstruction)	Strategies to **lessen effects of another hazard** (barriers, warning signals developed, observatories)

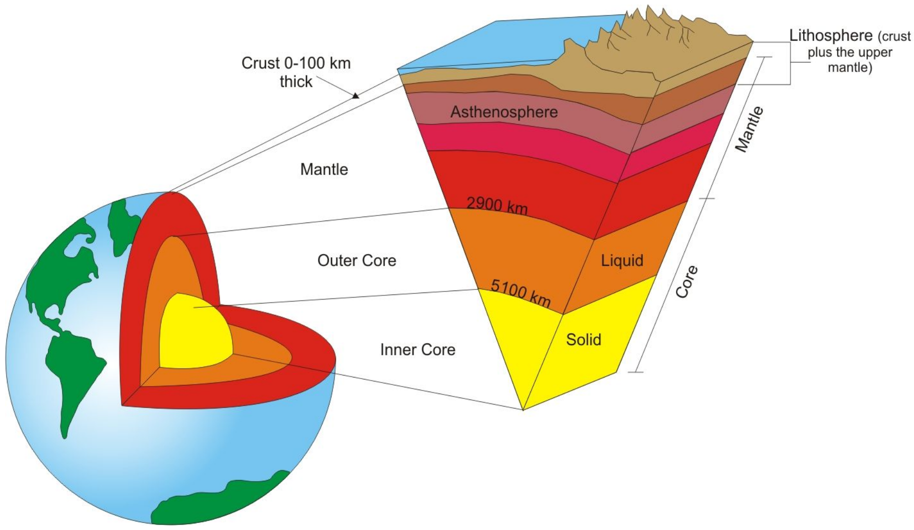
Evaluating the Effectiveness of Models

Hazard models are useful, but the **unpredictability** of hazards makes the models less effective at accurately representing human responses to hazards. It may be useful to ask some questions when evaluating how effective these models are:

- Can they be **applied** to every hazard? Are some hazards more complicated and require a more **complex model**? It may be useful to apply each of your case studies to these models and see how they compare.
- Does the model take any **aspects of hazards** into account such as **level of development**?
- Is there any **timeframe**? Do the models accurately lay out the time taken for a full response and how this changes due to **aspects of the hazard** such as intensity?
- Could the model be **less vague**/ include more steps that can be applied to all hazards?
- Does the model present hazards **currently**? Are there any alterations that could be made to account for hazards affected by **climate change**? Will the model eventually not represent human responses at the time (e.g. could the cycle stop because hazards will occur more frequently than the mitigation strategies will occur)?

Plate Tectonics

Structure of the Earth



(Source:https://www.leeds.ac.uk/ruskinrocks/Earth%20Structure.html

Inner core Solid ball of iron/nickel Very hot due to **pressure** and **radioactive decay** (contains elements such as uranium that give off heat when they decompose) This heat is responsible for **Earth's internal energy**, and it spreads throughout
Outer core ● Semi-molten ● Iron/nickel

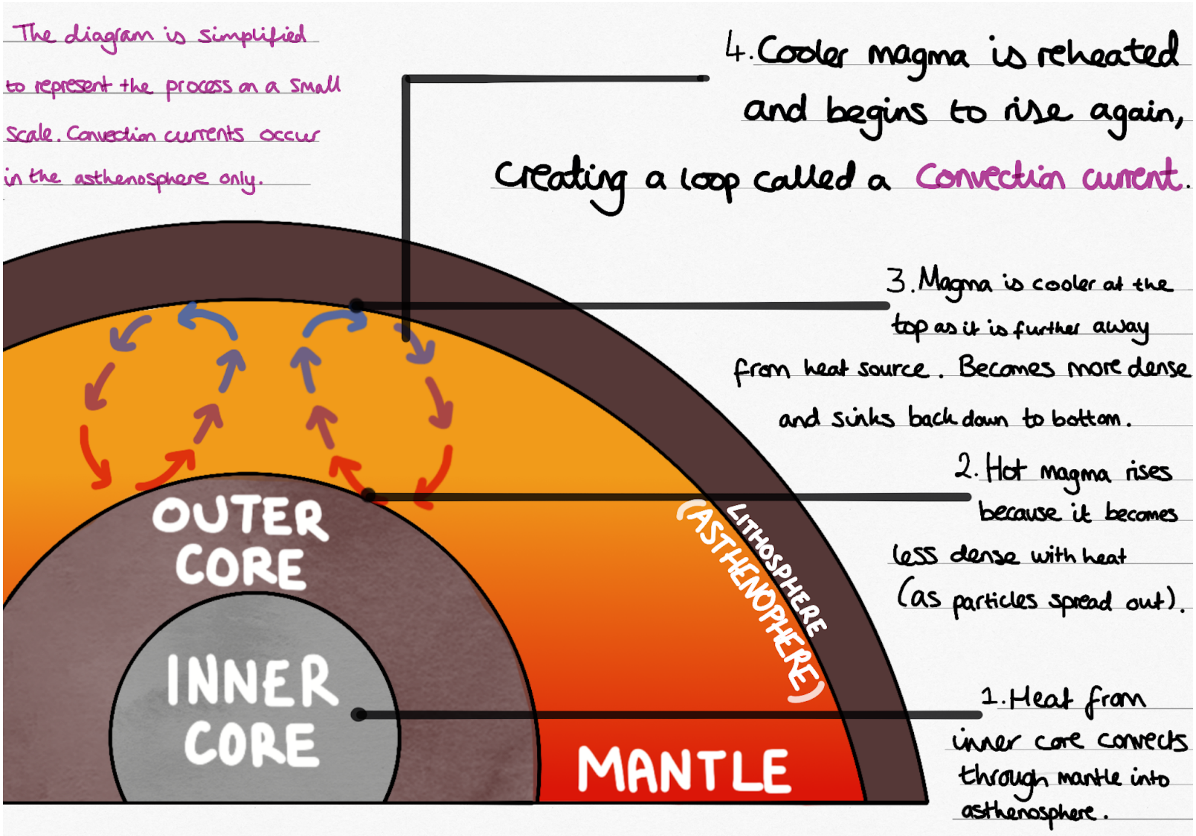
Mantle	Asthenosphere	Lithosphere
Mainly solid rock, and the rocks are high in silicon. However, the very top layer of the mantle is semi-molten magma, which is known as the **asthenosphere**. The **lithosphere** rests on top.	**Semi-molten** layer constantly moves due to flows of heat called **convection currents**. Movements are powered by **heat from core**. **Lithosphere** above.	Broken up into **plates**. Majority of the lithosphere is within mantle. The top of the lithosphere is the **crust** which is the land and sea we live on.

Crust The thin top of the lithosphere **Oceanic crust** is **dense** and is destroyed by **plate movement, continental crust** is **less dense** and is **not destroyed**.

Plate tectonic theory

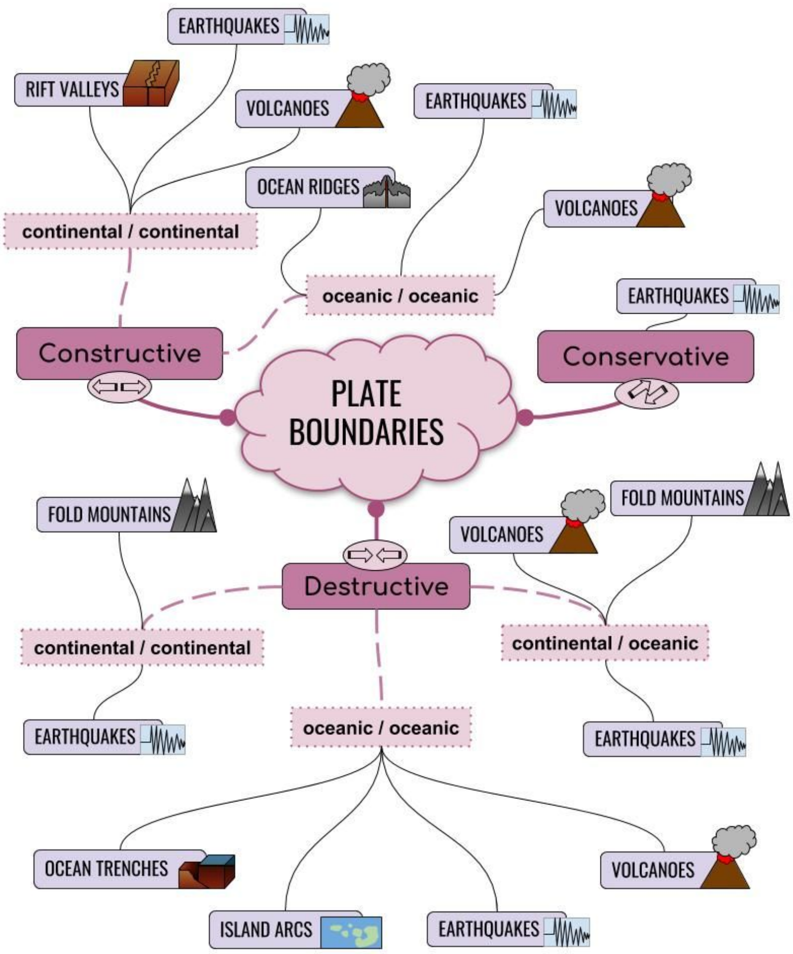
The lithosphere is broken up into **large slabs of rock** called **tectonic plates**.

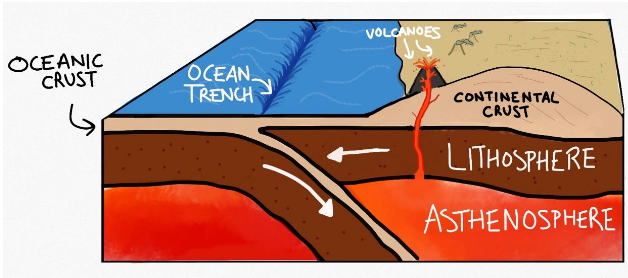
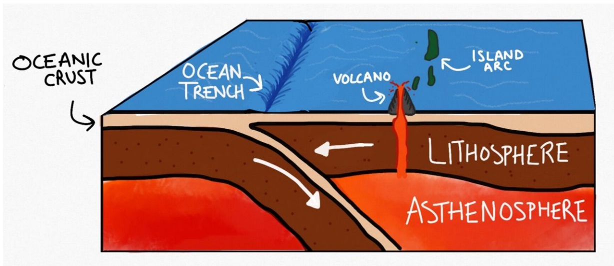
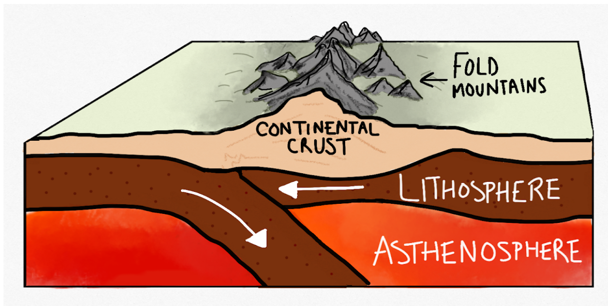
These plates **move** due to the **convection currents** in the asthenosphere, which push and pull the plates in different directions. Convection currents are caused when the less dense magma rises, cools, then sinks. The edges of where plates meet are called **plate boundaries** (or plate margins).



Different Plate Boundaries

At plate boundaries, different plates can either move **towards each other** (**destructive** plate margin), **away from each other** (**constructive** plate margin), or **parallel** to each other (**conservative** plate margin). Different landforms are created in these different interactions. This spider diagram outlines what landforms and processes occur at the boundaries.

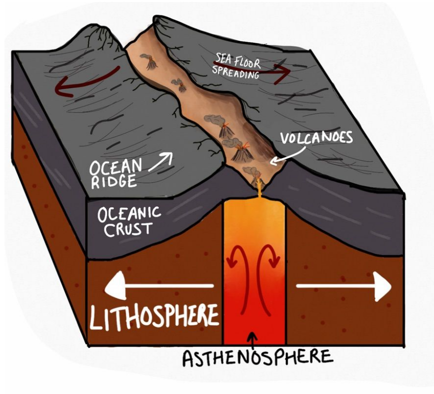


Destructive plate boundaries	
Continental and oceanic: • Denser oceanic plate **subducts** below the continental. • The plate subducting leaves a deep **ocean trench**. • **Fold mountains** occur when sediment is pushed upwards during subduction. • The oceanic crust is melted as it subducts into the asthenosphere. • The extra magma created causes **pressure** to build up. • Pressurised magma forces through weak areas in the continental plate • Explosive, high pressure volcanoes erupt through the continental plate, known as **composite volcanoes**.	
Oceanic and oceanic: • Heavier plate **subducts** leaving an ocean trench. Fold mountains will also occur. • Built up pressure causes **underwater volcanoes** bursting through oceanic plate. • Lava cools and creates new land called **island arcs**.	
Continental and continental: • Both plates are not as dense as oceanic so lots of **pressure builds.** • Ancient oceanic crust is subducted slightly, but there is **no subduction of continental crust.** • **Pile up** of continental crust on top of lithosphere due to pressure between plates. • **Fold mountains** formed from piles of continental crust.	

Constructive plate boundaries

Oceanic and oceanic:

- Magma rises in between the **gap left by the two plates separating**, forming new land when it cools.
- Less explosive underwater volcanoes formed as magma rises.
- **New land** forming on the ocean floor by lava filling the gaps is known as **sea floor spreading** (as the floor spreads and gets wider).

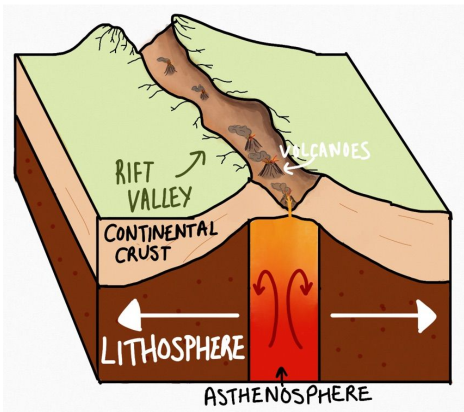


Evidence

There is sufficient evidence to prove plate movement, and **sea floor spreading** (theorised by **Harry Hess** in the 1940s) provides some of this proof. **Paleomagnetism** is the study of rocks that show the magnetic fields of the Earth. As new rock is formed and cools the magnetic grains within the rock align with the magnetic poles. Our poles (North and South) **switch** periodically. Each time these switch the new rocks being formed at plate boundaries **align in the opposite direction** to the older rock. On the ocean floor either side of constructive plate boundaries, Geologists observed that there are **symmetrical bands** of rock with **alternating bands of magnetic polarity**. This is evidence of sea floor spreading.

Continental to continental:

- Any land in the middle of the separation is forced apart, causing a **rift valley**.
- Volcanoes form where the magma rises.
- Eventually the gap will most likely fill with water and separate completely from the main island.
- The lifted areas of rocks are known as **horsts** whereas the valley itself is known as a **graben**.



There are further forces influencing how convergent boundaries occur -

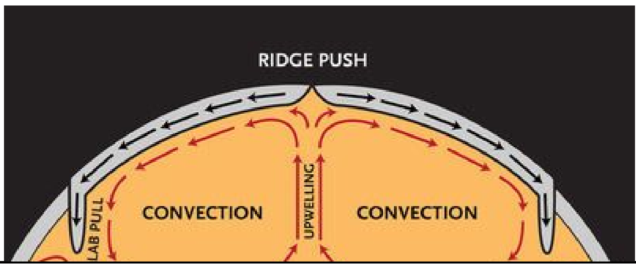
Ridge push:

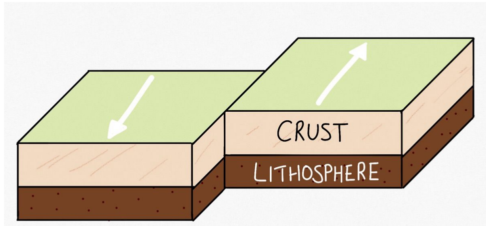
The **slope** created when plates move apart has **gravity acting upon it** as it is at a **higher elevation**. Gravity pushes the plates further away, widening the gap (as this movement is influenced by gravity, it is known as **gravitational sliding**).

Slap pull:

When a plate **subducts**, the plate sinking into the mantle **pulls the rest of the plate** (slab) with it, causing further subduction.

Source: CK-12 Foundation



Conservative plate boundary	
Between any crust, the **parallel plates** move in **different directions** or at **different speeds**. No plates are destroyed so no landforms are created. When these plates move, a lot of pressure is built up. On oceanic crust, this movement can displace a lot of water. On continental crust, **fault lines** can occur where the ground is cracked by the movement.	

Hotspots

Hotspots are areas of volcanic activity that are **not related to plate boundaries**. Hot **magma plumes** from the mantle rise and **burn through** weaker parts of the crust. This can create **volcanoes and islands**. The plume stays in the same place but the **plates continue to move**, which sometimes causes a **chain of islands** (such as Hawaii).

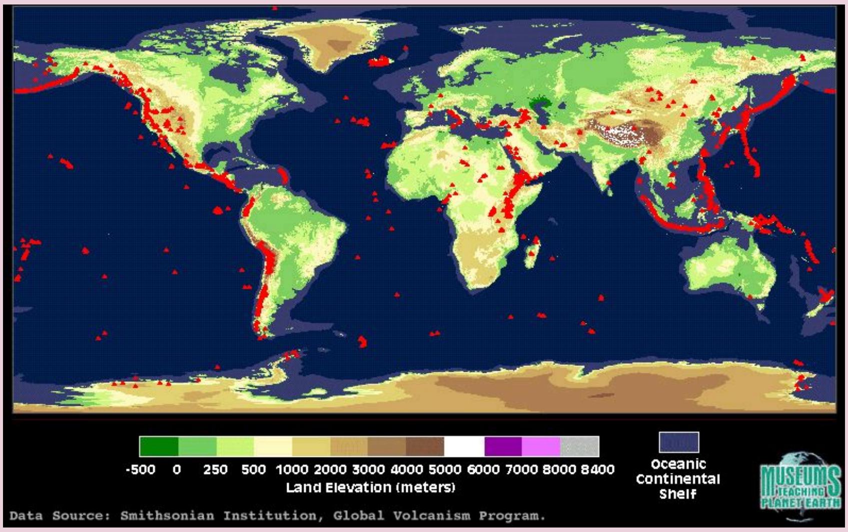
Volcanic Hazards

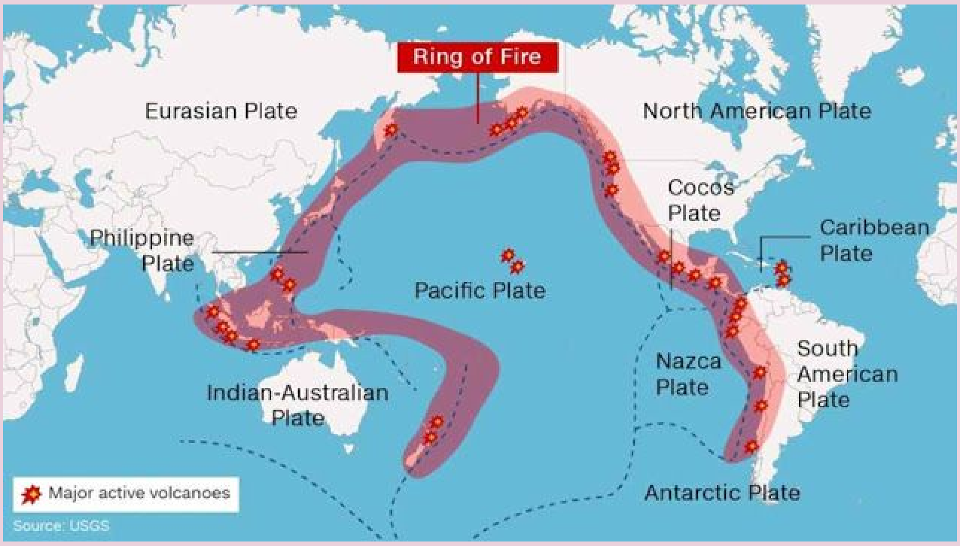
As previously mentioned, volcanoes occur on plate boundaries where **plates melt** and **magma erupts** through a plate. Alternatively, they may occur on hotspots too.

The hazards associated with volcanoes are not just lava; there are a number of hazards caused either directly from the eruption or as a secondary effect:

- **Lava flows** - lava can flow quickly or slowly depending on its **viscosity**. Silica makes lava **viscous** and slow, which is common in **explosive** eruptions.
- **Lahars** (mudflows) - caused by a number of reasons, usually by melting ice at high latitudes
  Image: Lahar in the Tambour River, Guatemala. Courtesy of @ConredGuatemala / twitter
- Glacial floods (**jökulhlaups**) - when temperatures are high from magma, glaciers or ice sheets at high temperatures quickly melt and a large amount of water is discharged
- **Tephra** - any type of rock that is ejected by a volcano
- **Toxic gases** - released during some eruptions, even CO_2 can be toxic as it can replace oxygen as it is heavier
- **Acid rain** - caused when gases such as **sulfur dioxide** are released into the atmosphere
- **Nuées ardentes**/pyroclastic flows - clouds of burning hot ash and gas that collapses down a volcano at **high speeds**. Average speeds of around 60 mph but can reach 430 mph.


Nuée ardente au Karymsky
Photo : Jean-Pierre Kloster

<table>
<tr><td>Spatial Distribution</td><td>Along constructive or destructive plate boundaries, or located on hotspots.


The Ring of Fire is an area of high volcanic and earthquake activity located in the Pacific, and the majority of large volcanoes occur within this 25,000 mile belt.

</td></tr>
<tr><td>Magnitude</td><td>Vulcanicity is measured using the Volcanic Explosivity Index(VEI). The more powerful, the more explosive. The scale is logarithmic from VEI 2 and onwards. Multiple features are considered when calculating the VEI, including how much tephra is erupted, how long it lasts, how high the tephra is ejected etc.
Intense high magnitude eruptions are explosive whereas calmer, lower magnitude eruptions are effusive.</td></tr>
<tr><td>Frequency</td><td>Frequency of eruptions varies per volcano. Volcanoes are classed as either active, dormant or extinct. An estimated 50-60 volcanoes erupt each month, meaning volcanic eruptions are always frequent (and some volcanoes erupt constantly). Usually, a higher frequency eruption means the eruptions are effusive whereas low frequency means the eruptions are explosive.</td></tr>
<tr><td>Regularity</td><td>Volcanic eruptions are regular in that the eruptions on each type of boundary are similar (e.g. eruptions on destructive boundaries will regularly be explosive)</td></tr>
</table>

	Sometimes eruptions may be irregular and not fit patterns.
Predictability	Regularity of eruptions can help estimate when eruptions will take place (i.e. every 10 years). Seismic activity, gases releasing, elevation etc. can all indicate an imminent eruption, but there is no **definite** predictions to a volcanic eruption.

	TYPE OF VOLCANIC HAZARD			
EFFECT	**Environmental**	**Economic**	**Social**	**Political**
Primary	- **Ecosystems damaged** through various volcanic hazards - Wildlife killed	- **Businesses** and industries destroyed or disrupted	- People **killed** - **Homes destroyed** from lava/pyroclastic flows	- **Government buildings** and other important areas destroyed or disrupted
Secondary	- Water acidified by **acid rain** - Volcanic gases contribute to **greenhouse effect** (global warming)	- **Jobs lost** - Profit from **tourism** industry	- **Fires** can start which puts lives at risk - **Mudflows** or **floods** - Trauma - Homelessness	- **Conflicts** concerning government response, food shortages, insurance etc.

Hazards can be responded to by **preventing** them directly, being **prepared** for the next hazard, **mitigating** the effects, or completely **adapting** your lifestyle to limit the hazard's effects.

RESPONSE AND RISK MANAGEMENT TO VOLCANIC HAZARDS

PREVENTION

Volcanic eruptions cannot be prevented.

Only the risk to people can be prevented by not allowing people near volcanic hazards (e.g. preventing building around volcanoes).

PREPAREDNESS

Monitoring increases the notice of volcanic eruptions, meaning warnings can be given out.

Education on volcanoes in areas of risk so people know what to do if there is a volcanic eruption.

Evacuation procedures planned.

Training response teams.

MITIGATION

Direct intervention to the volcano, e.g. concrete blocks to steer lava away from areas at risk.

Strengthening buildings that are at risk of mudflows or ash pileup.

Evacuation and exclusion zones.

Mitigating effects on health by having emergency aid and rescue.

ADAPTATION

Move away from area at risk.

Capitalise on opportunities, such as encouraging tourism.

Change profession so it is less likely to be affected by volcanic hazards.

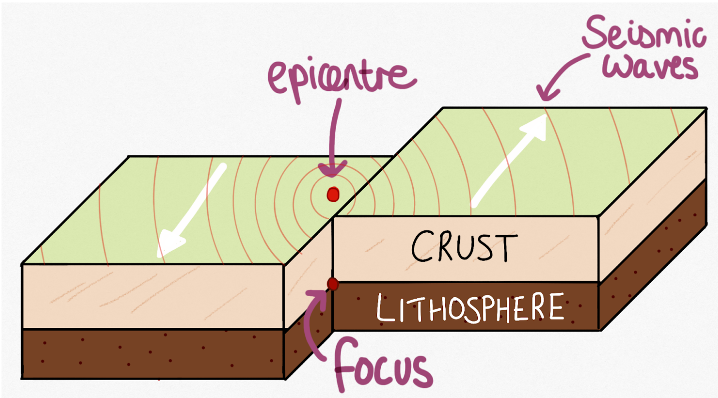
Seismic Hazards

Plates do not perfectly fit into each other, meaning they do not move in **fluid** motions. At all boundaries, plates can become stuck due to the **friction between plates**.

You can try this by moving **one palm** of your hand **against the other**, and it is clear that at some points there is more friction between irregularities and bumps, causing the hands to become stuck slightly.

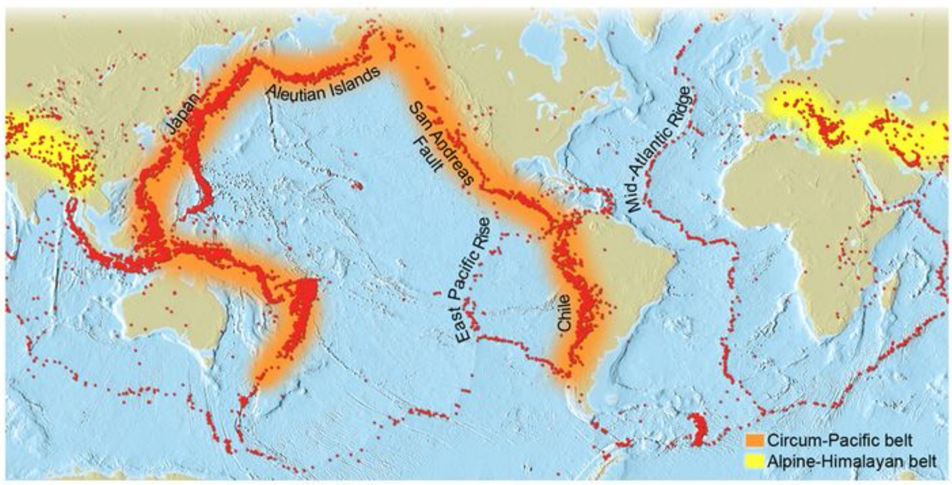
When the plates are stuck, the **convection currents** in the asthenosphere continue to push, which builds the pressure. It builds so much that it cannot be sustained and the plates eventually **give way**. All of this pressure is released in a sudden movement, causing a **jolting motion** in the plates This jolt is responsible for **seismic** movement spreading throughout the ground in the form of **seismic waves** (or shock waves).

The **focus** is the point underground where the earthquake originates from. The **epicentre** is the area above ground that is **directly above** the focus.



Spatial Distribution

Along **all boundaries.**



Distribution of nearly 15,000 earthquakes with magnitudes equal to or greater than 5 for a 10-year period.

The Ring of Fire accounts for 90% of the world's Earthquakes (shown in the diagram as the Circum-Pacific belt).
The Alpine-Himalayan belt accounts for 5-6% of the world's earthquakes.

Magnitude

Seismicity is measures using the **logarithmic Richter Scale** which is a measure of the strength of seismic waves.

The **Modified Mercalli Intensity Scale** is also used, which is a rate of the destruction caused (originally the Mercalli scale when developed in 1884, but the name was changed after 1931 when it was modified). Unlike the Richter scale, the Mercalli scale has a definite end at 12 (XII as it is in roman numerals). The Mercalli scale is **subjective**, meaning sometimes it is disputed as it is dependent on human development being present rather than the strength of the seismic waves.

Modified Mercalli Intensity Scale

I	Instrumental: detected only by instruments	VII	Very strong: noticed by people in autos Damage to poor construction
II	Very feeble: noticed only by people at rest	VIII	Destructive: chimneys fall, much damage in substantial buildings, heavy furniture overturned
III	Slight: felt by people at rest Like passing of a truck	IX	Ruinous: great damage to substantial structures Ground cracked, pipes broken
IV	Moderate: generally perceptible by people in motion Loose objects disturbed	X	Disastrous: many buildings destroyed
V	Rather strong: dishes broken, bells rung, pendulum clocks stopped People awakened	XI	Very disastrous: few structures left standing
VI	Strong: felt by all, some people frightened Damage slight, some plaster cracked	XII	Catastrophic: total destruction

(Source: https://missnickles.wordpress.com/earth-science/)

The magnitude of the earthquake is also dependent on the **depth of focus**. Conservative boundaries have the **shallowest** boundaries, meaning they are closer to the epicentre and the seismic waves are stronger. Destructive boundaries usually have deeper focuses, meaning the seismic waves are spread over a larger area before they reach the epicentre. This is dependent on the earthquake.

Frequency

Earthquakes are frequent around the world and occur **every day** at boundaries. Hundreds of smaller magnitude earthquakes that cannot be felt by humans occur every day, whereas the larger earthquakes are less frequent.

Regularity

Earthquakes follow no pattern and are **random** so there is irregularity between events.

Predictability	Earthquakes are almost impossible to predict. **Microquakes** may give some indication but the magnitude cannot be predicted as how strong they are is **random**.

Hazards caused by seismic events:

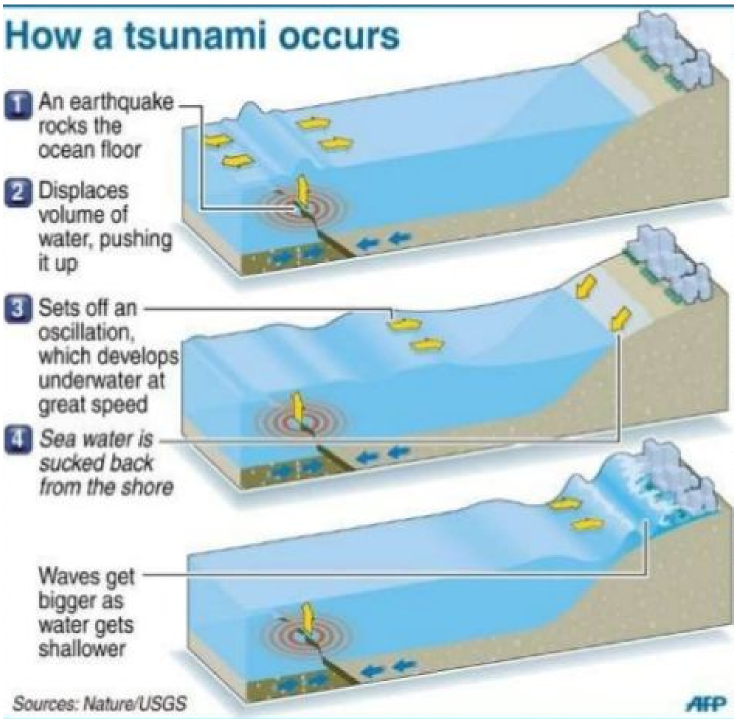
- **Shockwaves** (seismic waves) - When two plates move side by side, friction builds up and pressure increases; this pressure is stored as **potential energy**, it cannot move so it just builds up. When the pressure becomes too much, the plates eventually move. All of the energy that has been built up must go somewhere, so it is transferred into **kinetic energy**, which is released and vibrates throughout the ground. The further away from the focus, the weaker the shockwaves, as the energy is transferred into the surroundings.
- **Tsunamis**

When an oceanic crust is jolted during an earthquake, all of the water above this plate is **displaced**.

The water travels fast but with a low **amplitude** (height).

As it gets closer to the coast, the sea level decreases so there is friction between the sea bed and the waves.

This causes the waves to slow down and gain height, creating a wall of water that is on average 10 feet high, but can reach 100 feet.



- **Liquefaction** - When soil is saturated, the vibrations of an earthquake cause it to act like a liquid. Soil becomes weaker and more likely to **subside** when it has large weight on it.

Image: Liquefaction in Christchurch, New Zealand. Source:Stuff.co.nz

- Landslides and avalanches - Movement in soil or snow will cause it to become unstable.

	TYPE OF SEISMIC HAZARD			
EFFECT	**Environmental**	**Economic**	**Social**	**Political**
Primary	- Earthquake can cause **fault lines** which destroy the environment - Liquefaction	- Businesses destroyed	- Buildings **collapse**, killing/injuring people and **trapping** them.	- Government buildings destroyed
Secondary	- **Radioactive materials** and other dangerous substances leaked from power plants - Saltwater from tsunamis flood **freshwater** ecosystems -Soil **salinisation**	- **Economic decline** as businesses are destroyed (tax breaks etc.) - High **cost of rebuilding** and insurance payout - Sources of income lost	- Gas pipes **rupture**, starting fires which can kill - Water supplies are contaminated as pipes burst, spreading **disease** and causing floods - Tsunamis which lead to **damaging flooding**	- Political unrest from food shortages or water shortages - Borrowing money for international aid - Can be initial chaos and '**lawlessness**' e.g. looting

RESPONSE AND RISK MANAGEMENT TO SEISMIC HAZARDS

PREVENTION

The majority of seismic hazards cannot be prevented. Earthquakes and tsunamis will occur regardless.

Liquefaction of soils can be prevented through soil stabilisation (gravel columns can be put in the ground).

Avalanches can be prevented through controlled explosions.

PREPAREDNESS

Earthquake prone areas (such as Japan) have extensive awareness strategies and education in place e.g. Drop, Cover, Hold On.

Earthquake warning systems and tsunami warning systems after an earthquake.

Evacuation plans and training.

MITIGATION

Search and rescue, immediate emergency aid, evacuation (short term).

Demolishing older, unsafe buildings.

Tsunami wave breaks and sea walls.

ADAPTATION

Move away from area at risk.

Capitalise on opportunities, such as encouraging tourism.

Insurance if living in places of risk.

Changing lifestyle choices e.g. moving valuable items so they cannot fall.

Building specially designed 'earthquake proof' buildings.

Storm Hazards

A **tropical storm** is a **low pressure**, spinning storm with high winds and torrential rain.

Hurricane Florence from the International Space Station

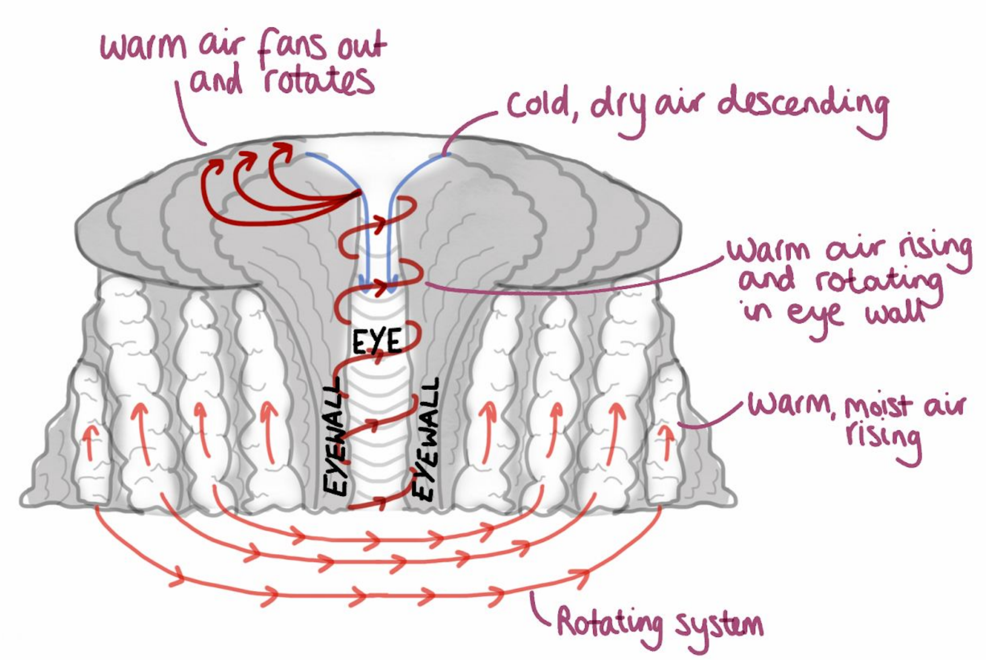
There are certain **conditions** for a tropical storm to form and develop:

- **Temperature:** Ocean temperatures must be around **26 - 27°C** and at least 50 metres deep. Warm water provides the storm with **energy**.
- **Air pressure:** Must be in areas of **unstable air pressure** - usually where areas of high pressure and low pressure meet (**convergence**) - so that warm air rises more readily and clouds can form (this air must also be humid for cloud formation). Warm air rises because it is **less dense** than cold air.
- **Wind shear:** Winds must be present for the **swirling motion** to form, but not too strong or the storm system will be **ripped apart** in the early stages.
- **Rotation:** Tropical storms only form around the equator, but no less than **5° on either side**. The **Coriolis Effect** is the effect of the **Earth's rotation** on weather events. The storm spins because the Earth is spinning; but there is **no Coriolis Effect at the equator**, hence why these storms will only form a certain distance away from it.
- **A trigger:** a pre-existing thunderstorm, a spot of very high sea surface temperature, an area of low pressure and many other factors can act as a **trigger** for a storm to develop, which will only further develop when the **other conditions are present**.

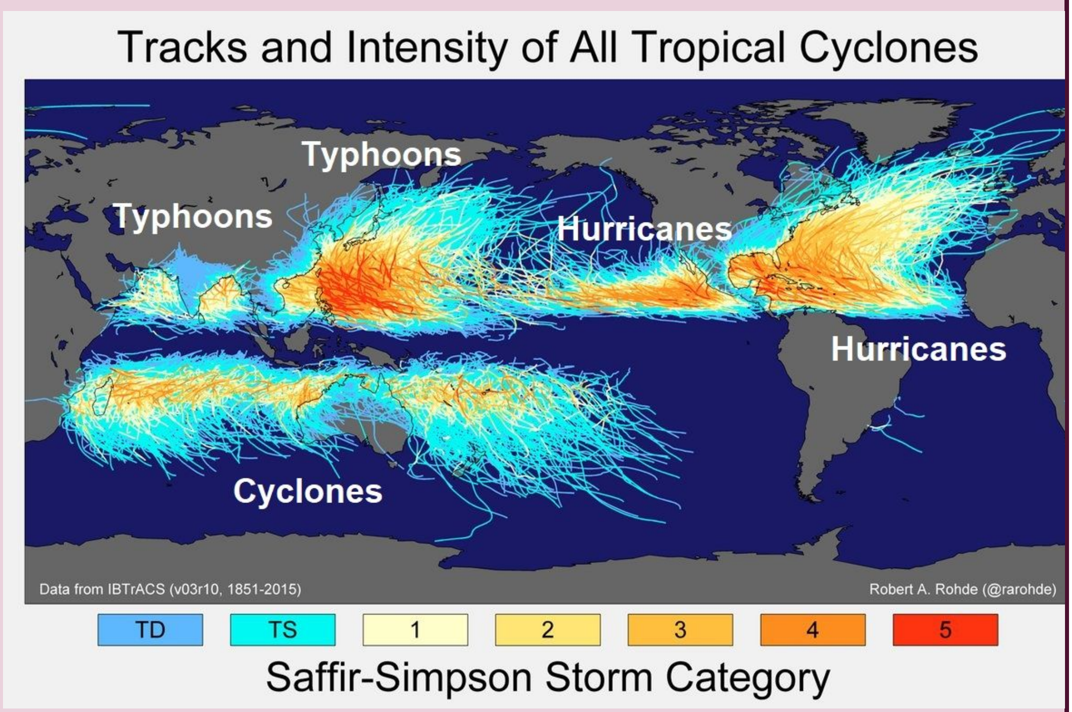
Formation

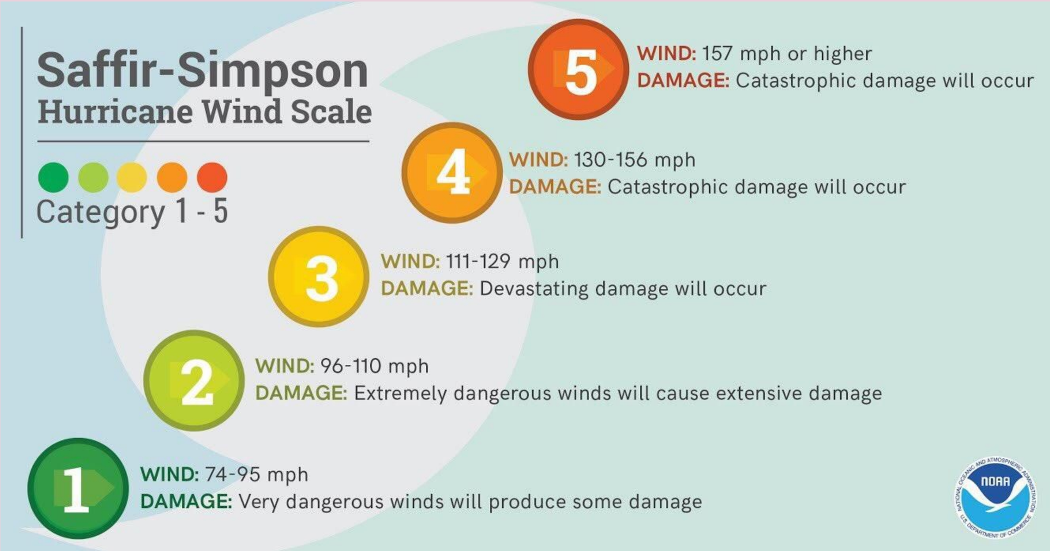
1. **Warm, moist air rises**, leaving an area of **low pressure below**. This causes warm air from surrounding areas of higher pressure to **move into this low pressure area** and rise too. Overall, **warm air is constantly rising** and accumulating in the atmosphere.
2. When the warm air rises, it **cools**, condensing into **thunderstorm clouds**.
3. The whole system is spinning due to the **Coriolis effect**. In the **southern** hemisphere, the storms spin **clockwise**; in the **northern**, **anticlockwise**.
4. The **constant additions of energy** from the warm air causes the storm to spin faster and generate higher wind speeds. At **39 mph** the storm can be classed as a **tropical storm**.
5. The **eye** of the storm is in the centre. This is an area spanning around **30 miles wide** that is of **extremely low pressure** (can be 15% lower pressure than areas outside of the storm). Cool, dry air (cool from the higher altitudes and the moisture has been transferred into the system) descends in the eye, causing the weather to be relatively **calm and cloud free**. The more intense the storm, the clearer the eye.
6. Surrounding the eye is the **eyewall**, the most **intense and powerful** area of the storm. **Warm, moist air rapidly rises** here, with extremely **high winds and torrential rain**. When winds reach **74 mph**, it becomes a hurricane/cyclone/typhoon.

A cross section of a tropical storm is thought to look something like this:



7. When the tropical storm reaches a coast, the **low pressure and high winds** will cause a large amount of sea water to be **taken into the system** and then released as a high wave called a **storm surge**.
8. When the storm reaches **land**, it no longer has a **supply of energy** (warm, moist air from the sea) and the eye eventually **collapses**. Heavy rain can persist for days.

Spatial Distribution	
Magnitude	Measured on the **Saffir-Simpson Scale** (A scale of 1-5) based on wind speed and thus power of the storm.



Frequency

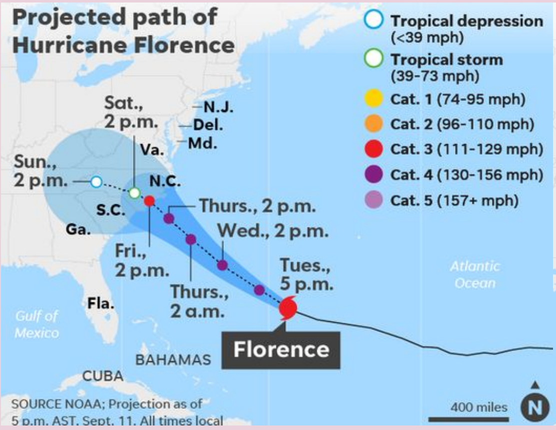
Tropical storms form in the Northern Hemisphere from June-November, and the Southern Hemisphere from November-April. The majority of tropical storms do not develop into strong storms and do not reach land. Tropical storms that are **higher magnitude** and reaching land are thought to be increasing in frequency.

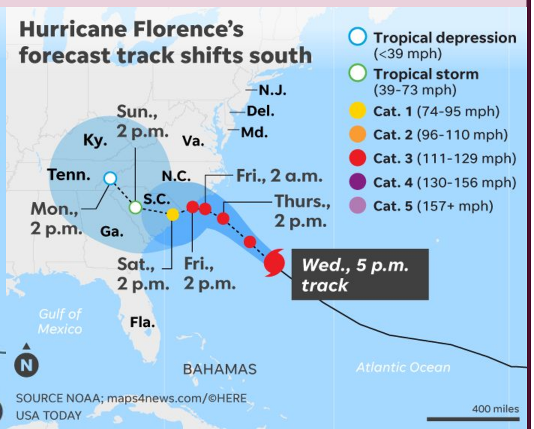
Regularity

Tropical storms are **irregular** because although they occur in the **same areas**, their path does not follow a set route - the route taken is **dependent on the storm** and the climatic conditions.

Predictability

Tropical storms form **away from land** meaning **satellite tracking** of cloud formations and movement can be tracked and the general route can be predicted. These projected path of Hurricane Florence estimates to the hour when the hurricane will hit. The first picture tracks 5 days in advance, the second picture is the day after. Note how the tracking changes within 24 hours.





The closer the hurricane gets, the easier it is to predict. Storm surges can also be predicted based on the pressure and intensity of the storm.

From past storms and climatic trends, the **probability** of a storm hitting an area can also be predicted. Scientists have predicted how many years it will take for a tropical storm to hit certain areas.

Hazards caused by tropical storms:

- **High winds** - over **300km/h** and therefore very strong. Hurricane winds are strong enough to blow a house down, and also blow heavy debris at high speeds, which can obviously cause damage and injure anyone who comes into contact.
- **Flooding** - coastal/river flooding from **storm surges** and **heavy rain**. River flooding also sends more floodwater to other places, which can cause areas outside of the tropical storm's path to flood also.
- **Landslides** - due to soil becoming **heavy** when wet with high levels of rain
- **Storm surges** - Large **rise in sea levels** caused by low pressure and high winds, pushing water towards the coast

	TYPE OF STORM HAZARD			
EFFECT	**Environmental**	**Economic**	**Social**	**Political**
Primary	- Beaches **eroded** -Sand displaced - Coastal **habitats** such as coral reefs are destroyed	- Businesses destroyed - **Agricultural land** damaged	- **Drowning** - **Debris** carried by high winds can injure or kill - Buildings destroyed	- Government buildings destroyed
Secondary	- River flooding/ **salt water** contamination - **Animals displaced** from flooding e.g. alligators -Water sources **changing course** from blockages	- **Rebuilding** and **insurance** payout - Sources of income lost - Economic decline from sources of income destroyed	- Homelessness - **Polluted water** supplies spread disease - Food shortages from damaged land	- Issues paying back international aid - Pressure for government to do more about **global warming**

RESPONSE AND RISK MANAGEMENT TO STORM HAZARDS

PREVENTION

In current climates and weather conditions, tropical storms cannot be avoided.

Strategies to mitigate climate change could prevent higher category storms.

PREPAREDNESS

Awareness through education of what to do during a tropical storm.

Evacuation plans and training.

Satellite image tracking to manage the areas that are at risk.

Storm warning systems and television broadcasts tracking the storm.

MITIGATION

Search and rescue, immediate emergency aid, evacuation (short term).

Strengthening the home through door barricades, roof strengthening etc.

Clearing loose debris before storms.

ADAPTATION

Move away from area at risk.

Design buildings to withstand high winds and flood damage.

Flood defenses such as houses on stilts, coastal walls, river levees etc.

Wildfire Hazards

Wildfire: A large, **uncontrolled** fire that quickly spreads through vegetation.

Image: Wildfires in California
(Source: Stuart Palley)

Conditions favouring intense wildfires

Vegetation Type

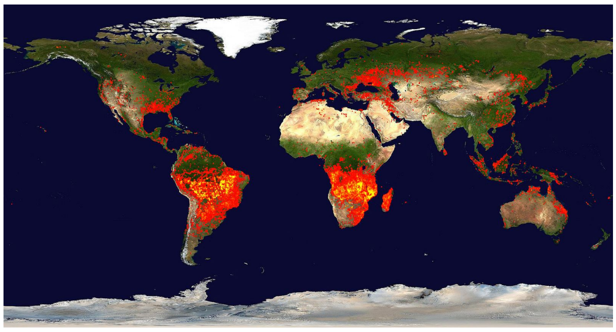
Thick, close together vegetation allows fires to spread **quickly** and easily. **Trees and thick bushes** lead to more intense wildfires; grasslands do not burn as intensely. Vegetation with **flammable oils** - like eucalyptus - causes more intense fires also.

Fuel Characteristics

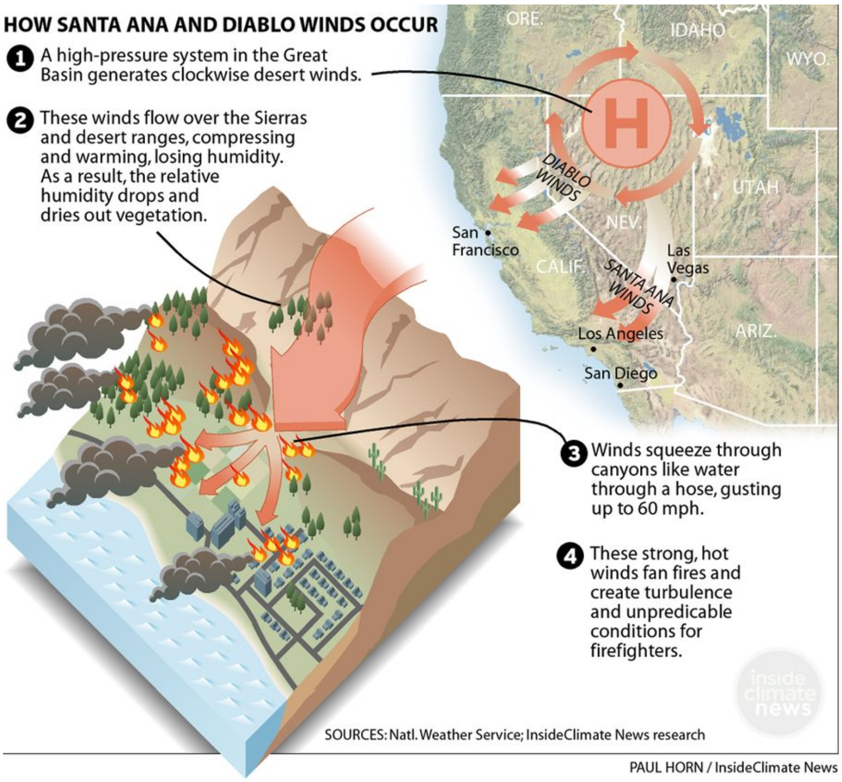
Vegetation should be **dry** to allow it to catch. **Finer** vegetation causes fires to spread **quicker**, but larger, **thicker** forms of vegetation burns for longer and more intensely.

Climate and Recent Weather

Wildfires can occur anywhere in the world, but the most common areas wildfires occur in are located on this map (from 2010).
(Source:https://www.nasa.gov/topics/earth/features/wildfires.html)



Wildfires occur in a climate that has **enough rainfall to have sufficient plant growth**, but considerable dry spells and droughts to **dry out the fuel**. Areas with **dry seasons** such as California allow for intense wildfires. **Wind** also causes fires to spread quicker.



Many **climatic events** can make wildfires grow more intense and extend wildfire seasons. The **Santa Ana Winds** and **Diablo Winds** in California, for example, cause more wildfire damage.

El Niño (warm phase) and **La Niña** (cold phase) are also climatic events that are thought to affect wildfire prevalence. The effects of these phenomena vary throughout the world, but in California El Niño is thought to provide warmer, wetter seasons to grow vegetation, and La Niña's dryer seasons create more wildfires. Information about the effects of El Nino can be found on this Met Office video: (https://www.youtube.com/watch?v=WPA-KpldDVc)

Recent temperature increases have caused an **increase** in the number of **wildfires** and an increase the **length of wildfire seasons**.

"Forest fires in the western US have been occurring nearly five times more often since the 1970s and 80s. Such fires are burning more than six times the land area as before, and lasting almost five times longer."

(https://www.dw.com/en/how-climate-change-is-increasing-forest-fires-around-the-world/a-19465490)

There are also arguments that despite climate change, wildfires are not increasing everywhere. Studies have shown that this is somewhat true; between 1998 and 2015 globally burned area declined about 24 percent. However, this may also be down to **agricultural productivity** and **land use change** as there are less areas that **can** be burned, i.e. less forestry. There is more on this theory on The Washington Post.
(https://www.washingtonpost.com/news/energy-environment/wp/2017/06/29/despite-global-warming-scientists-find-that-wildfires-are-actually-burning-less-land/)

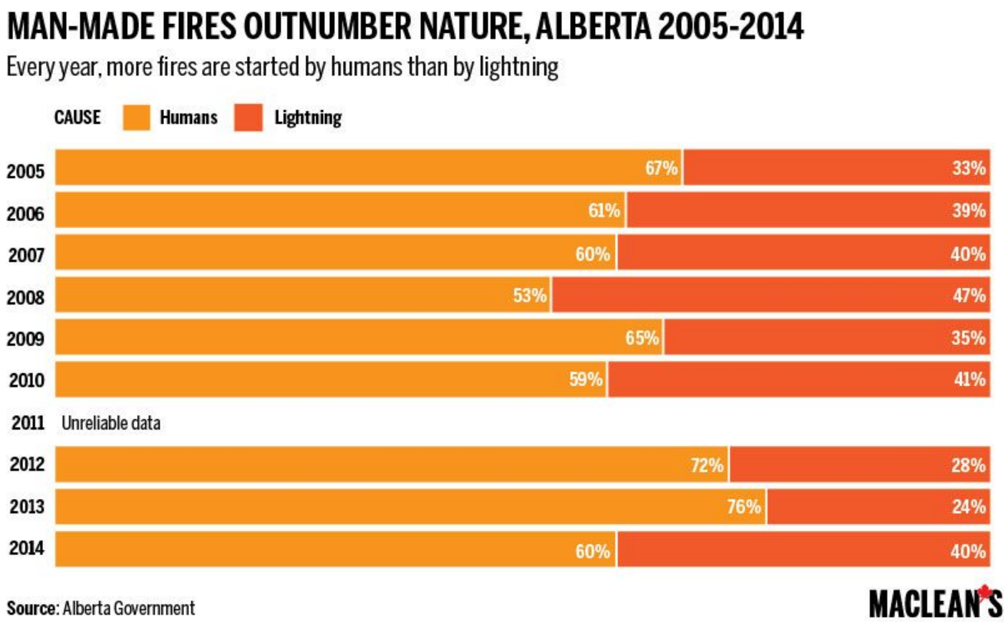
Fire Behaviour

Fires spread quickly on **hills** as the heat rises. Fire can also **'jump'** across rivers and into areas due to **lit debris** which causes it to **spread**. Wildfire does not just spread in one way; there are three main types of wildfire burning.

- **Crown fires** burn the entire tree from **bottom to top**, which is classed as the most dangerous and destructive type of fire.
- **Surface fires** only burn the **leaf litter**, meaning they are easy to extinguish.
- **Ground fires** burn at the dry peat or vegetation **beneath the surface**, and move slowly through the dried underground. Due to them being underground, they can be difficult to put out and can actually continue to burn throughout the year if the weather conditions allow it.

Causes of Wildfires

Wildfires can be caused **naturally** or by **humans**. The majority of the time, wildfires are caused by human activity. Humans may start fires **accidentally** or through **arson**.
Natural causes include lightning (being the biggest cause), volcanoes and even spontaneous; **Human causes** can be lit cigarettes, barbeques, agriculture, train lines and more.



	HAZARD			
EFFECT	**Environmental**	**Economic**	**Social**	**Political**
Primary	- **Air pollution** from ash -**Water pollution** -Habitats destroyed in fire -**Toxic gases** released in burning	- Businesses destroyed - Agricultural land damaged - Cost of **fighting fires** (firefighters, helicopters, water)	-People killed or injured in fires - Homes destroyed - People go **missing** during evacuations	- Government buildings destroyed
Secondary	- Removing **invasive species** and stimulating seed **germination** - **Migration** patterns of animals affected -Increased **CO_2** from fires could heighten the greenhouse effect	- High cost of rebuilding and insurance payout - Sources of income lost - Discouraging visitors, losing **tourism** sector -**Planes** cancelled	-Homelessness - Food shortages from destroyed agricultural land - **Health problems** such as asthma from **smoke inhalation**	- Borrowing money for international aid - Pressure for government to do more about global warming due to increased frequency

Risk Management

Prevention and Preparedness

In the current climate, wildfires overall will never be eradicated entirely. However, **public awareness** can prevent the ignition of wildfires and prepare people for wildfires. In areas of risk, campaigns teach people the dangers of leaving fires burning in forest areas through barbeques or cigarettes. **Smokey Bear** is a 70 year-old U.S. mascot used to **provide information** on preventing wildfires, with the intention of becoming a well-known figure so that people would recognise the risks.

People can be **prepared** by having evacuation plans, emergency services training and drills, and a personal emergency plan (with food supplies, water, a place to stay etc.).

Warning systems are also a good way for people to be prepared. Broadcasted weather warnings (or 'Red Flag Warnings' as they are commonly referred to as) warn people when the perfect conditions for wildfires are occurring - e.g. hot, dry, upcoming lightning storms. This means people may wish to evacuate and campfire bans can be put in place. **Thermal infrared satellite imagery** shows where wildfires are occurring so that people can stay away from these areas. Therefore, **evacuation zones** can be set up for areas in high risk, and people can be evacuated. There are many live wildfire maps available, including [this one of Canada](https://governmentofbc.maps.arcgis.com/apps/MapSeries/index.html?appid=ef6f11c8c36b42c29e103f65dbcd7538). (https://governmentofbc.maps.arcgis.com/apps/MapSeries/index.html?appid=ef6f11c8c36b42c29e103f65dbcd7538)

Fire danger signs are used in fire-prone areas

Mitigation

Immediate responses to wildfires are mainly concerned with protecting those **directly** at risk and **extinguishing** the fire. Like all hazards, wildfires will need search and rescue teams, immediate aid, and evacuations. To immediately **mitigate** the effects, the fire must be **extinguished** or **diverted**. Firefighters are dispatched on ground to spray water onto the fire. Water and flame retardants are also sprayed onto large areas using aircrafts.

Green Mountains forest fire (Source: A. T. Willett)

Long-term mitigation strategies work to reduce the impacts of wildfires before they occur. **Controlled burnings** are burnings created on purpose to remove flammable materials so that less fuel is available. These burnings are strictly monitored so that they are contained and easily extinguishable. **Fire breaks** (gaps in trees) are also created to limit spread.

30+ feet	Keep flammable objects (lawn mowers, oil or gas cans, propane tanks and wood piles) at least 30 feet away from the home at all times. Move flammables, such as lawn furniture and toys, during wildfire activity.
	Keep roofs, gutters, decks and patios clear of leaves, pine needles or other flammables at all times.
5 feet	Remove flammable mulch and vegetation within 5 feet of the home and replace with nonflammable material.
10 feet	Remove tree or shrub branches that overhang within 10 feet of your house, roof or chimney.
	Keep lawns watered and mowed, or if water-conserving, make sure debris is removed within 30 feet of home.
10 feet	Trim tree limbs 10 feet above the ground (these are called ladder fuels).
⅛ inch	Install 1/8-inch metal mesh screens over vents and under decks to prevent ember intrusion.

Those who live in areas at risk can also do their part in **mitigating** the effects of wildfires by **ensuring their homes do not contribute** to wildfire spread. This guide from the Smokey Bear campaign outlines the steps you can take to lower the risk created by your home and its surroundings. This includes removing flammable materials from the vicinity so that in the event of a fire, your house is less likely to contribute to the spread of the wildfire.

(https://smokeybear.com/en/prevention-how-tos/equipment-use-and-maintenance/how-to-prepare-your-home-for-wildfire)

To limit the effects of **toxic gases** and **material** that contaminates the ecosystem, homes can also be built using materials that will not produce as harmful substances when burnt.

Adaptation

Many who live in fire-prone areas must **adapt** and live with the consequences of wildfires. The expenses of **insurance** and clean-up as well as staying educated become part of everyday life.

With wildfires on the increase though, **globally** we may have to adapt **our** lifestyles in order to stop contributing so significantly to **CO_2 levels**, heightening the greenhouse effect. If temperatures continue to increase, it may lead to **unprecedented** changes in wildfire patterns that may otherwise be avoidable with more eco-conscious decisions to reduce CO_2 emissions.

There is the argument that perhaps we should not intervene in wildfires at all, which can be classed as a **fatalistic outlook**. Many people believe it is not worth the **money or resources** to extinguish wildfires if they are only going to start again, and some should just be left to burn. There are also **ecological benefits** of having wildfires burn, which supports the idea that we should adapt to wildfires and let them burn. Wildfires **eradicate disease** and **stimulate seed germination**.

An example of where extinguishing wildfires may have done **more harm than good** is in Jasper, Alberta. Threatening wildfires have been frequently extinguished in the past, meaning the forest has become **thick and deprived of light**. This has then prevented the growth of silver birch and other trees, and the forest is now mostly pine.

Due to no fires **eradicating diseases or harmful insects**, the **Mountain Pine Beetle** has taken over the forest, which has severely affected the ecosystem and caused many trees to die. Eventually, the species will cause the forest to be destroyed and then naturally regrow, which would have happened by natural wildfires anyway.. Human intervention to protect the forest from wildfires has inadvertently made it more vulnerable, which raises the concern of whether it is a better choice to let fires burn.

More information can be found here

(https://globalnews.ca/news/4335116/jasper-national-park-mountain-pine-beetle-epidemic-plan/)

Forest in Jaspar has died back, as the beetle has affected 93,000 hectares.
(Source: SarahNKraus/ Twitter)