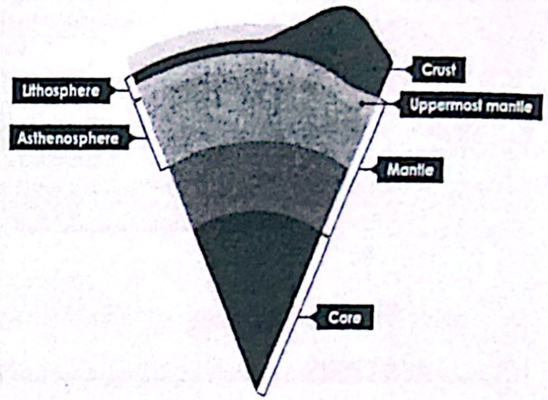
PLATE TECTONICS SUMMARY NOTES

1. INTERNAL STRUCTURE OF EARTH

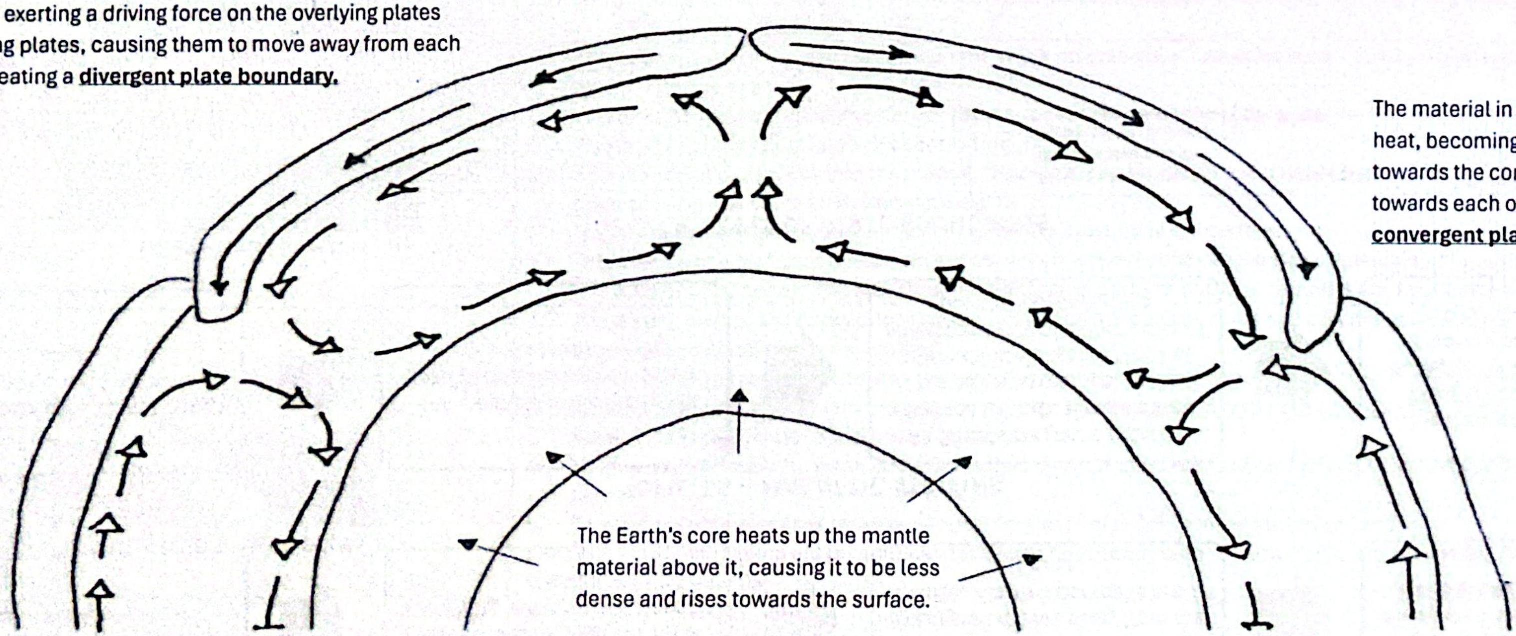
LAYER	DESCRIPTION
Crust	• The crust is the outermost layer. • It is also the thinnest layer at about 6 to 70km in thickness. • Made up of oceanic and continental crust.
Lithosphere	• Made up of crust & uppermost mantle.
Mantle	• The mantle lies above the core. • Temperatures here range from 1,000 to 3,700°C. • This layer is about 2,900km thick. • Consist of lower mantle and upper mantle (asthenosphere + uppermost mantle)
Core	• The core is the innermost layer. • Consist of inner core 7 outer core. • It is the hottest layer, with temperatures ranging from 4,400 to 6,000°C. It is also the thickest layer of about 3,300km in thickness.



2. MECHANISM IN PLATE MOVEMENT (WHAT IS DRIVING THE MOVEMENT OF PLATES?)

The rising material in the mantle spreads under the more rigid crust, exerting a driving force on the overlying plates and pushing plates, causing them to move away from each other → creating a **divergent plate boundary.**

The material in the mantle then loses heat, becoming denser and sinking towards the core. This pulls plates towards each other → creating a **convergent plate boundary.**



The Earth's core heats up the mantle material above it, causing it to be less dense and rises towards the surface.

The mantle material loses heat and sinks towards the core. The mantle material gets heated up again, and the process repeats.

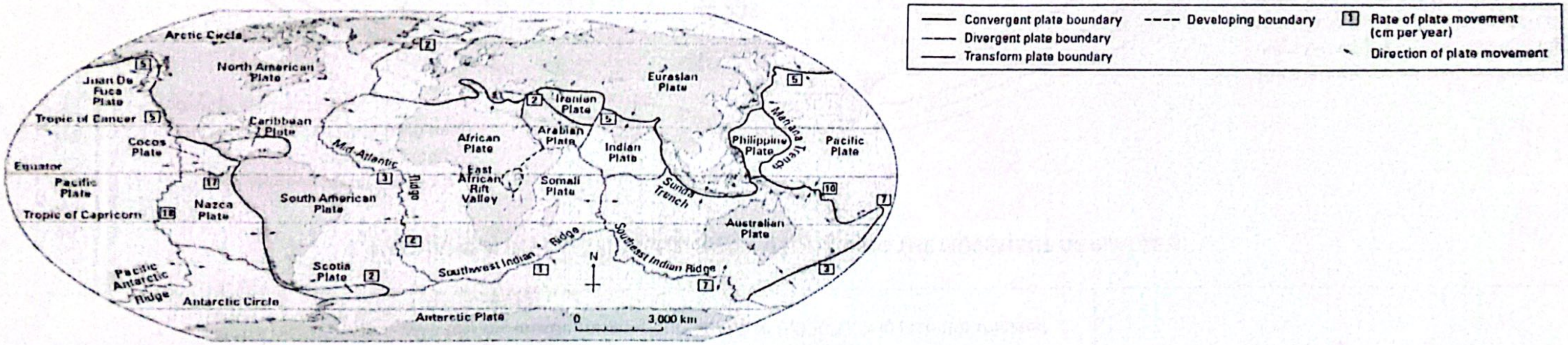
TOPIC 1.2 – SEAFLOOR SPREADING

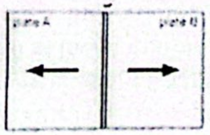
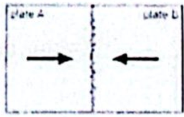
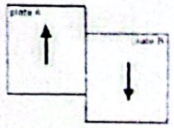
Seafloor spreading happens @ divergent plate boundary → When plates move apart and magma rises through the crack, solidifying and form new oceanic crust → As process continues, rocks nearest to the mid oceanic ridge (youngest) moves away from the ridge, where older rocks are found. → This supports plate tectonic theory as it should movement of plates & creation of new crust

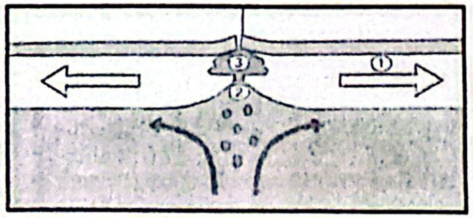
TOPIC 1.3 – MAGNETIC STRIPING

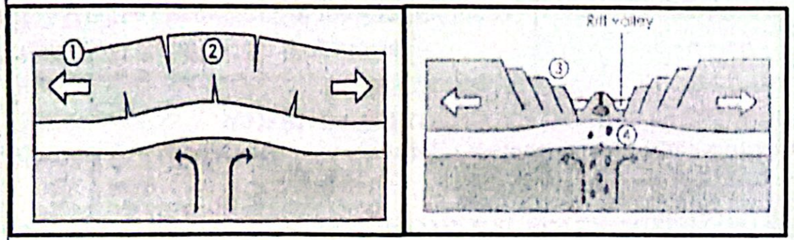
When magma rises at mid-ocean ridges and cools to form new crust → iron minerals in the rock align itself Earth's magnetic North at that time. → As Earth's magnetic polarity reverses periodically creating a zebra-like assymetrical pattern alternatiing alongside strips of reverse polarity on either sides of the mid-oceanic ridge → This shows that new crust is being created and pushed outward, thus proves seafloor spreading and supports the theory of plate tectonics

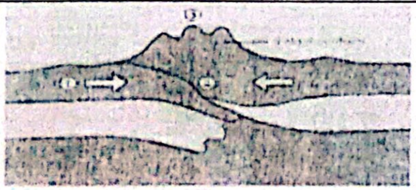
TOPIC 1.4 TYPES OF PLATE BOUNDARIES

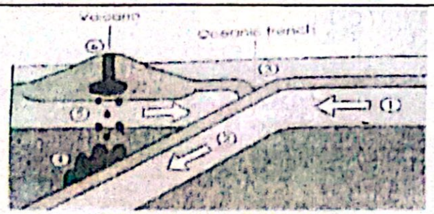
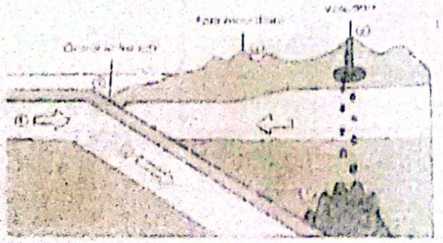


TYPE OF PLATE BOUNDARY	DIVERGENT	CONVERGENT		TRANSFORM
				
		Without subduction	With subduction (Sinks under)	
Describe the movement of plate	Plates are moving away from each other	Plates colliding with each other (both plates are less dense/ equal in density)	Plates colliding with each other + the denser plate subducts under the less dense plate	Plates sliding past each other
Type of plate	Continental-continental Oceanic-oceanic	Continental- continental	Oceanic-continental Oceanic-oceanic	Continental-continental
Forces/ stress involved	Tensional	Compressional	Compressional Slab-pull force	Shear stress
Type of landform created as a result of these movement	C-C: rift valley O-O: mid-oceanic ridges + underwater volcanoes + seafloor spreading	Fold mountains (form by breaking, buckling & folding)	O-C: Fold mountains, volcanoes, oceanic trench O-O: the denser oceanic plate will sink under the less dense oceanic plate → Underwater volcanoes → island arc	Fault lines usually points of stress/ pressure buildup which can lead to earthquakes

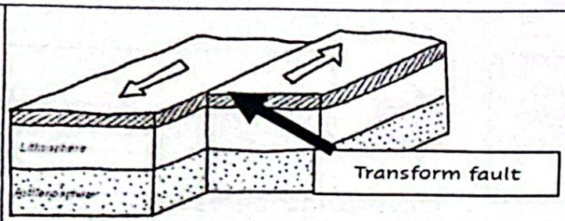
<table>
<tr><td rowspan="2">DIVERGENT</td><td>OCEANIC-OCEANIC
</td><td>1. The rising magma from the mantle rises through the surface and spread under the plates above, pulling plates apart.
2. Parts of the mantle to melt forming magma.
3. Magma rises through the cracks in the plates → solidifies forming rocks, which makes up the new oceanic crust → forming a mid-oceanic ridge (underwater mountain chain)
4. Continuous magma rising through cracks may eventually form underwater volcanoes.

EXAMPLE: North American-Eurasian oceanic plate → Mid Atlantic Ridge</td></tr>
<tr><td colspan="2">

CONTINENTAL-CONTINENTAL
1. The rising magma from the mantle rises through the surface and spread under the plates above, pulling plates apart
2. Rocks weaken and eventually fracture, forming parallel faults.
3. Over time, the centre part of the plate weakens along the faults → collapses/ sink downwards to form a deep rift valley with steep sides.
4. Parts of the mantle to melt forming magma → Continuous magma rising through cracks may eventually form volcanoes.
EXAMPLE: African plate (Nubian plate- Somalian Plate → Great East African Rift Valley & volcanoes such as Mount Kenya & Kilimanjaro)</td></tr>
<tr><td>CONVERGENT</td><td>
CONTINENTAL-CONTINENTAL</td><td>1. The sinking limb of the convection current in the magma pulls 2 continental plates together, causing it to converge and collide into one another.
2. As both continental plates are too buoyant to subduct, subduction did not happen.
3. Instead, immense pressure causes rocks to be uplifted and buckled → forming fold mountains.

EXAMPLE: Continental Eurasian -Continental Indo-Australian plate converging forming Himalayan Mountain range.</td></tr>
<tr><td rowspan="2">CONVERGENT</td><td>
OCEANIC-OCEANIC</td><td>1. The sinking limb of the convection current in the magma pulls 2 oceanic plates together, causing it to converge and collide into one another.
2. Two oceanic plates collide, the denser plate subducts beneath the other plate.
3. This forms a deep depression → oceanic trench
4. As subducting plate sinks into the mantle, the high pressure forced water out of oceanic crust → lowering melting point causing mantle to melt, forming magma
5. Magma rises through the weak areas in the Earth's crust up to the surface.
6. This forms a chain of underwater volcanoes, which when reaches above water surface, forms volcanic island.
EXAMPLE: Oceanic Pacific- Oceanic Philippine plate → Mariana trench & Mariana volcanic islands</td></tr>
<tr><td>
OCEANIC-CONTINENTAL</td><td>1. The sinking limb of the convection current in the magma pulls oceanic and continental plates together, causing it to converge and collide into one another.
2. The denser oceanic plate subducts beneath the continental plate → forms an oceanic trench in the subduction zone
3. As subducting plate sinks into the mantle, the high pressure forced water out of its oceanic crust → lowering melting point → causing mantle to melt, forming magma
4. Magma rises through the weak areas in the Earth's crust up to the surface, forming volcanoes on the continental plates.
5. Immense pressure causes rocks to be uplifted and buckled → forming fold mountains.
EXAMPLE: Oceanic Nazca plate- continental South American plate → Peru-Chile Trench, Andes fold mountains, Nevado del Ruiz volcano</td></tr>
</table>

TRANSFORM



No crust is created/ destroyed at this boundary.

Stress caused by the plate movement produce a fault (zone of fractures)
As plates slide past each other, it creates a built-up of pressure in between. Over time, this pressure build up will snap and suddenly release a huge amount of energy.
This caused vibration and movement in the Earth's crust → forming earthquakes.

EXAMPLE: Pacific- North American plate → San Andreas fault in California, USA

TOPIC 2.1: EARTHQUAKES

EARTHQUAKES

: refer to the shaking of the Earth's ground due to the sudden release of energy in the Earth's lithosphere.

1. MAGNITUDE	Measure of seismic energy
2. INTENSITY	The degree of shaking caused by an earthquake at a given place and decreases with distance from the earthquake epicentre
3. EPICENTRE	The point on the Earth's surface directly above the focus
4. FOCAL DEPTH & FOCUS	Focus: the point in the Earth's crust where seismic waves are released (origin of the earthquake) Focal depth is the distance from Earth surface to the point inside the earth where the earthquake started

FORMATION OF EARTHQUAKES

1. Where do earthquakes usually occur?
2. What happens at the various plate boundaries? →
3. What happens when the plates move? Is it a smooth or uneven/rough movement? →
4. What happens after the accumulation of stress/ pressure? What is the threshold?

At plate boundaries → it contains deep fractures/ faults in the crust & movement due to the convection current pulling/ pushing the plates → This movement creates pressure & friction along the plate boundaries → This may cause some parts of the plates to get locked, causing stress to build up → Over time, the stress increased to a point where it exceeds the strength of the rocks, it will eventually snap → stored energy is released in the form of seismic waves which can be strong enough to be felt as earthquakes

TOPIC 2.2: VOLCANOES

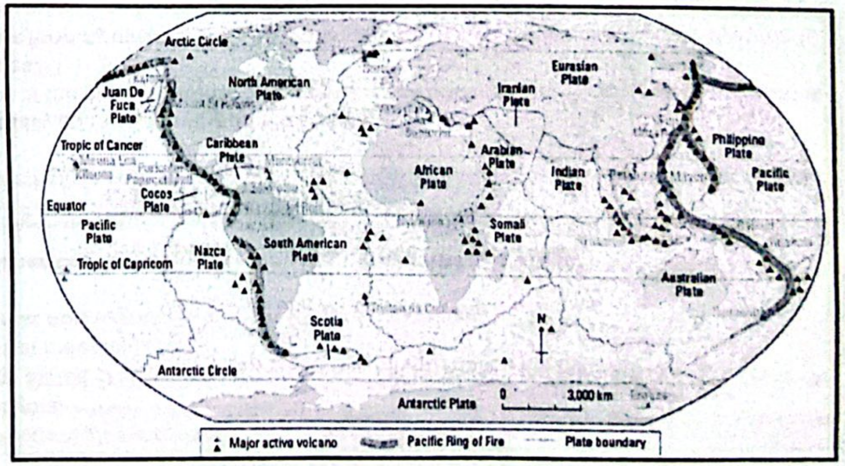
VOLCANOES → A landform formed by magma ejected from the mantle onto the earth's surface.

WHERE CAN YOU FIND VOLCANOES IN THE WORLD?

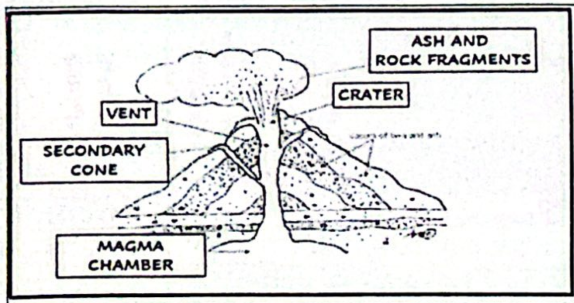
STATEMENT 01: along Pacific Ring of Fire
EVIDENCE: along the outlines of the Pacific Ocean.

STATEMENT 02: along plate boundaries (convergent).
EVIDENCE: South America & Nazca plate/ Australian plate & Pacific plate/ Pacific Plate & North American plate.

STATEMENT 03: along plate boundaries (divergent)
EVIDENCE: Arabian & African plate / between African & Somali Plate/ North American-Eurasian Plate



CROSS SECTION OF VOLCANO & IMPORTANT TERMS



MAGMA	Molten rock found below the earth's surface and builds up within the crust to form a magma chamber
MAGMA CHAMBER	A reservoir of molten rock beneath the earth's crust.
LAVA	Magma that reaches the surface of our planet through a volcano vent
CRATER	The bowl-shaped opening created by solidified lava around the vent, forming the volcanic cone.
ASH AND ROCK FRAGMENTS	When a volcano erupts, lava, ash and rock fragments are released. The force of the volcanic eruption depends on the amount of pressure and gas in the magma.
VENTS	Openings in the earth's surface with a pipe leading into the magma chamber.
SECONDARY CONE	A new exit route to the surface for magma if the vent may become blocked or the volcano itself may be fractured during volcano formation.
CALDERA	A large depression formed due to the collapse of the sides of the crater due to loss of structural support caused by an explosive eruption.
VISCOSITY	The stickiness of the lava or its resistance to flow.

VISCOSITY OF LAVA

LOW-SILICA LAVA (BASIC)	HIGH-SILICA LAVA (ACIDIC)
Lower viscosity	High viscosity
Allows gases to escape easily & flow more easily through the vent before reaching the surface	trapped gases within the magma are not readily released → build-up of pressure below the earth's surface
Less violent & less explosive volcanic eruptions	gas expand and magma rises → more explosive and violent eruptions
Outer layer of the cooling lava forms a thin crust upon reaching surface Higher temp of 1100-1200ºC	The eruption ejects Ejects lava, ash, rock fragments and gases into the surrounding environment. Lower temperature (800-100ºC)
Take a longer time to solidify	Solidifies quickly
Volcanoes created have gentle slopes.	Volcanoes are tall & have steep slopes

d. TYPES OF ERUPTIONS

Hawaiian **Strombolian** **Vulcanian** **Pelean** **Plinian**	**Least explosive, least viscous lava** ↓ **Most explosive, most viscous lava**

DIFFERENT TYPES OF LAVA → AFFECT THE WAY THE VOLCANO ERUPT → INFLUENCE THE WAY THE VOLCANO LOOKS

e. TYPES OF VOLCANOES

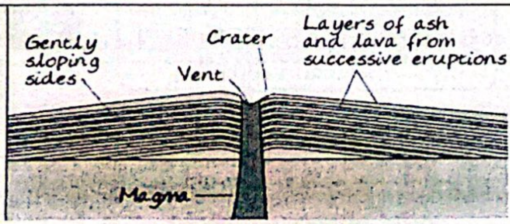
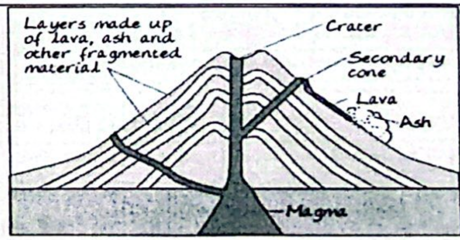
DIAGRAM	 **SHIELD VOLCANO**	 **STRATOVOLCANO**

PLATE BOUNDARY	Constructive (divergent)	Convergent with subduction
SHAPE	Broad-base with gentle slopes Shorter in height	Narrow base with steep slopes Taller in height
MATERIAL EJECTED	Lava	Lava, ash, burnt rocks /cinders, pyroclastic flow
LAVA CHARACTERISTIC	Thin, fluid lava –low in silica content, high temperature, high water content	Thick, viscous lava – high in silica content, lower temperature, low water content
ERUPTION FREQ	Frequent eruptions	Infrequent with long dormant periods
VIOLENCE OF ERUPTION	Gentle eruptions – less trapped gases in pipe	Violent eruptions - lots of trapped gases & pipes may be sealed up by thick lava

TOPIC 2.4 IMPACTS OF EARTHQUAKES & VOLCANIC ERUPTIONS ON HUMANS & NATURAL SYSTEMS

NATURAL SYSTEMS

- natural processes that occur on Earth, interaction between living and non-living things

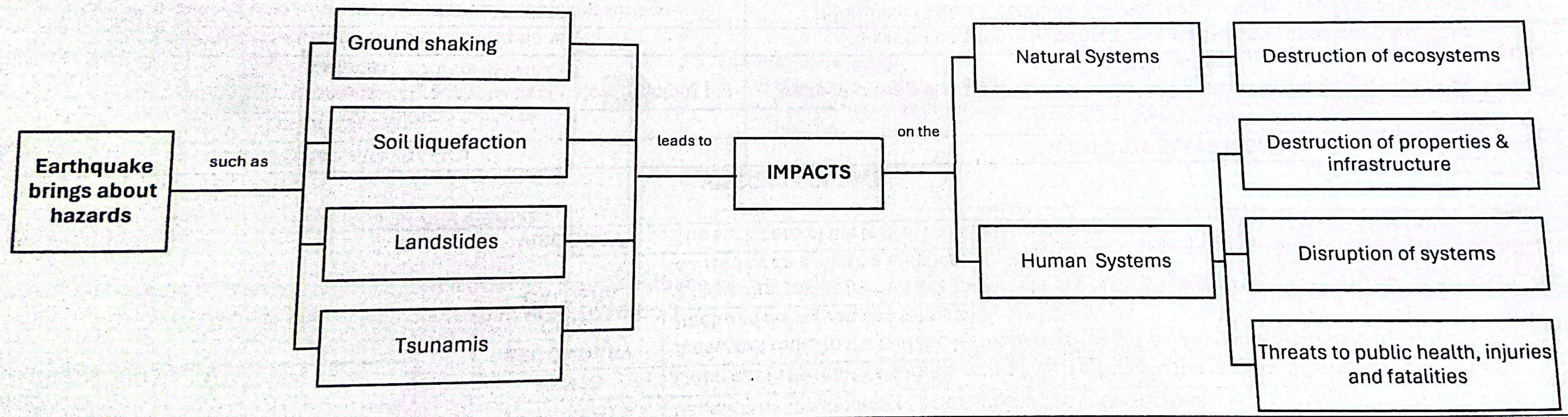
Eg. ecosystems

HUMAN SYSTEMS

- Human-led processes & interconnected human activities

E.g. services, SOL/ QOL, properties & infrastructure

Earthquake hazards are often localised, generally located within the same geographic region as the earthquake. As most earthquakes are found along plate boundaries, their hazards are also found near the plate boundaries. However, there are **<u>some hazards that are not localised</u>** as they may spread beyond the geographical regions they occurred in.



HAZARD		Describe with examples	Explain how it impacts natural/ human systems
GROUND SHAKING	NATURAL	**EXAMPLE: 2010 Christchurch earthquake in New Zealand** - many trees were damaged and more than 300 damaged trees had to be removed	• Trees may fracture and get uprooted → forests experience tree death and injury, resulting in forest and biodiversity loss. • Habitats get damaged → reduce food sources and breeding grounds for land species → resulting in loss of biodiversity & possibility of extinction • Ruptured gas pipelines and chemical factories may cause leakage into the water bodies → polluting water supply

	HUMAN	**2010 Mw 7.0 earthquake in Haiti** • more than 250,000 houses destroyed as they collapsed due to violent ground shaking • Water pipes were ruptured • An estimated of more than 220,000 people were killed **2018 Palu earthquake in Indonesia** • mobile signal towers were destroyed • People did not receive text messages about the incoming tsunami, which killed more than 1,000 people.	• The violent ground shaking, which can last from several seconds to a few minutes → buildings and bridges weakened and eventually collapse, trapping people, making it difficult to rescue people or supply emergency aid → causes injuries and loss of lives. • The ground shaking may also disrupt essential services such as water, gas and electricity. Violent ground shaking can snap water and gas pipes, electricity and communication cables → result in water shortages and fire outbreaks + affecting communication → delay reaction time for people to get to safety → higher death and injury toll & affect rescue efforts
SOIL LIQUEFACTION: violent ground shaking causes saturated, loose soil to lose its soil structure turning into a thick fluid.	**NATURAL**	**2010 – 2011 earthquakes in Christchurch, New Zealand** • Liquefied soil entering rivers. • Many broken sewage pipes released untreated waste into its rivers → resulted in the reduction in species such as the caddisflies	• Trees on liquefied soil may tip over and get damaged, causing forest and biodiversity loss. The liquefied soil may enter rivers and smother aquatic plants, causing them to die. • Sewage pipes may be broken, and untreated waste materials may pollute rivers, which can in turn kill aquatic species → leading to loss of biodiversity and possibility of species extinction
	HUMAN	**2010 – 2011 Christchurch, New Zealand earthquakes** • triggered severe liquefaction, as the city lies on a former swamp area where soils are loose and saturated. • More than 60,000 residential buildings and infrastructure covering about one-third of the city area were damaged	• Liquefaction can cause buildings and other infrastructure above the soil, such as roads, bridges and elevated highways to sink in and tip over → people may not be able to escape and get to safety & rescue efforts may be difficult → leading to higher injury toll & death toll • Liquefaction can cause land to sink in → leading to rupturing of water and gas pipes as well as electricity cables → people would not have access to clean water and loss of electricity may hamper rescue & medical efforts
LANDSLIDES: violent ground shaking forms cracks on steep slopes, loosening the rocks and soil & move downslope.	**NATURAL**	**EXAMPLE: 2018 earthquake in Papua New Guinea** • triggered landslides that caused huge amounts of debris to enter the rivers, causing floods that destroyed forests, polluted waters and killed fish.	Falling debris can bury huge areas of forest and wetlands & Rivers can get polluted by the huge debris, which can kill aquatic life. The debris can also block rivers, causing massive floods → can damage nearby ecosystems
	HUMAN	**2008 Great Sichuan Earthquake in China (Mw 7.9)** • triggered more than 15,000 landslides, destroying many buildings and infrastructure • In total, about 20,000 deaths were caused by these landslides **Landslide at Hongyan Resort, China after the 2008 Earthquake** • 51 people were killed in this landslide	• The debris from landslides can bury villages and farms, killing many people and destroying properties and infrastructure. • Roads and railways can be blocked, making it difficult for rescue efforts → higher casualty & death toll • Communication cables and pipes carrying water and gas can snap, disrupting essential services → people may be left without water for days → may increase casualty and death toll

FORMATION OF TSUNAMIS

An undersea earthquake causes the seabed to be displaced/ moved from its original position → This cause a large volume of water to be moved (Forming a wave of great length, low height <1m & traveling at high speeds~800km/h) → On approaching shore, greater friction with shallow seabed slows waves down & waves increased in height up to 15m or more & @ 30-50km/h = devastate coastal areas → Before a tsunami occurs, the sea may recede from the shore because sea water fills the void caused by the seabed displacement.

TSUNAMIS: series of ocean waves which can be caused by undersea earthquakes, volcanic eruptions and landslides. Tsunamis can travel over large distances and devastate huge areas of coastline.

Tsunamis do not necessarily reach the land as a series of giant breaking waves. Instead, they often look like a very rapidly rising tide or walls of water. The waves may keep coming every 5 to 60 minutes. The first wave may not be the largest and often it is the waves that come later that are the biggest. Tsunamis are very destructive because of **their high speed and volume**. When they hit the shore, they can flood coastal areas more than a kilometre inland.

	Describe with examples	Explain how it impacts natural/ human systems
NATURAL	**2011 Tohoko, Japan earthquake** • about 70,000 pine trees were knocked down and washed away in Iwate, leaving only one pine tree. • The tsunami also hit the Pacific islands [Midway Atoll] → the devastation to ecosystems was severe. Entire bird nesting sites were lost, as four successive waves flood huge areas of the island. • More than 100,000 Layson Albatross Chicks were killed • Thousands of Bonin petrels were buried alive, and thousands of fish were washed ashore, where they eventually suffocated.	• Huge amounts of seawater → flood the coastal areas → damaging habitats for animals • Huge waves may also carry debris from the nearby affected areas → may pollute the ecosystem → damaging the habitats for animals → leading to a loss of biodiversity and possibility of species extinction
HUMAN	**2011 Tohoku Earthquake (Mw 9.0)** • Triggered a 40m height tsunami • Coastal city of Sendai badly affected; half of its people killed • Many areas were flooded and polluted by debris • Strong waves destroyed buildings and infrastructure **2004 Indian Ocean tsunami triggered by Mw 9.1 undersea earthquake** • Tsunami waves hit the coasts of 11 Indian Ocean countries, from Indonesia, to India and even as far away as Africa. • More than 230,000 people were killed and entire coastlines and habitats were destroyed	• Fast moving waters and the large amounts of debris carried by the waves can snap electricity and communication cables, disrupting supply of these services → may delay rescue efforts and hamper communication with survivors → increase casualty toll • Roads and railways can be damaged by the waters, making it difficult for rescue efforts → higher casualty & death toll • Sweeping waters can drown people & large amounts of debris carried in by the waves can hit and kill people → leading to higher death toll

<u>RISKS & BENEFITS LIVING NEAR VOLCANOES → required to link to impacts</u>

<u>SOCIAL IMPACT</u>
- How people's lives are affected
- (health levels, death toll etc., ability to afford basic needs/ ability to earn income)

ECONOMIC IMPACT
- How is the country's economy affected
- How would govt spending be affected

ENVIRONMENTAL IMPACT
- How would the environment be affected?
- Pollution levels?

RISK		DESCRIBE WITH EXAMPLES	EXPLAIN
DESTRUCTION BY VOLCANIC MATERIALS & LANDSLIDES	When volcanoes erupt, it ejects volcanic materials such as lava, ash, volcanic rocks and pyroclastic flow → cause destructions of houses, infrastructure like transport networks, basic services like power lines and water supply which negatively affect people	• Eruption of **Nevado del Ruiz in the Andes mountains, South America in 1985** • Released pyroclastic flow which mixed with the glacial ice → resulting to lahars which covered the town of Armero → killed more than 20,000 people. • **Sep 2014 Mt Ontake, Tokyo** : Killed over 40 people who were hiking in the area near the volcano.	Lead to loss of lives & their properties → caused survivors suffer trauma and need counselling to recover, cause a decline in mental health → lower QOL
		• Eruption **of Kilauea in Hawaii in 1963** and still ongoing • Destruction of many homes and highways (Lava flows destroyed 181 residences within the first 8 years of eruption) 12 km of highway have been covered by flows during the past 14 years & losses are estimated at $61 million.	Caused damages to infrastructure → would incur more economic losses where more govt spending needs to be channelled into repair works
		Lava with high temp. (500°C to 1400°C) may burn areas it goes through. 1963 catastrophic eruption of **Mount Agung in Bali** killed a thousand people & others starved to death after ash smothered their crops.	As volcanic materials can be poisonous and damaging, it caused a destruction to the environment where it passes through [damages crops & trees]

EFFECT ON WEATHER	gases ejected from a volcanic eruption such may react with water vapour which reflects sun's energy back into space → affect the amount of solar radiation on earth → influence temperatures on Earth	1. **In 1815 eruption of Mount Tambora in Indonesia** caused global temperatures to drop as much 1.7°C. 2. **Mount Pinatubo eruption in 1991** caused a temporary 0.5°C drop in global temperatures. o 847 people lost their lives, 300 killed by collapsing roofs and 100 by lahars. o Houses and bridges destroyed and needed replacing and Manila airport had to be closed o Farmland destroyed by falling ash and pumice, unusable for years, the 1991 harvest was destroyed and 650,000 people lost their jobs	This is as the volcanic gases such as sulphur dioxide would react with water vapour to form sulphur- based particles. These particles reflect the sun's energy back into space and temporarily cool the temperatures on earth. This process is known as **global cooling → would lead to other effects as well**
POLLUTION	ash particles releases gases such as carbon dioxide, sulphur dioxide and carbon monoxide which are harmful to people & can be carried by wind and disrupt activities in the air	1. Traditional **sulphur miners of East Java** suffer from poisoned lungs and skin full of burns and scars. • The miners have little protective gear. • Only used a damp cloth to cover the nose and mouth as they cannot afford gloves and gas masks • These miners are paid $10 – 15/day. • 74 miners have died after being overpowered by fumes that can suddenly swirl from cracks in the rock	The gases released by the volcano may be harmful and poisonous → people in the surrounding areas most affected as they inhaled these gases → respiratory problems → lower levels of health → lower QOL
		1. In 2015, **Mount Raung in East Java** ejected ash into the air for nearly a week • Affect air travel as ash melts coats inside of the engine and affects fuel flow of airplanes → can cause engines to shut off. 2. In 2010 the **Eyjafjallojukull volcano** produced ash clouds • Posed danger to aircraft engines and structures • Caused the closure of the air space over Europe • Caused delays to 1.2million passengers and cost the airline industry US$1.8 billion.	Volcanic ash may disrupt economic activities of a country, especially air travel → economic losses → affect economic growth

BENEFITS OF LIVING NEAR VOLCANOES

		DESCRIBE WITH EXAMPLES	EXPLAIN
FERTILE SOIL	**Fertile volcanic soil** (lava and ash from volcanic eruption break down to form fertile soil after thousands of years) → lava and ash contains minerals and nutrients that is pure from the source	**Mount Merapi, Indonesia** • Villages are found along the slopes of the volcano. • Volcanic ash enriches the soil as it contained minerals which would be available after the rocks are broken down after thousands of years • Volcanic soil in Java & Bali, Indonesia support the cultivation of crops such as tea, coffee and rice. Farmers on Java can harvest three crops of rice in a season.	The fertile soil would allow farmers to enjoy more crop yield → more crops available for sale → earn more income → better purchasing power as they can afford goods and services → **better SOL** & increase in supply of food → would not experience starvation & malnutrition→ better levels of health → **improve QOL**
GEOTHERMAL ENERGY	**Geothermal energy** (the heat in the earth's crust when groundwater comes up it heats up and erupts as hot water or steam which can be harnessed)	**Japan** • The best natural hot springs in the world, referred to as "onsen" • These geothermally heated springs are scattered across the country in both indoor and outdoor facilities • These waters are considered to have restorative properties with natural minerals that are thought to heal aches and pains, ease and prevent illnesses, and generally maintain a healthy body.	This would allow people to enjoy and relax themselves → feel happier and contented and since the water are considered to have restorative properties → improve health levels of people → improve QOL
		1. **Iceland:** Almost 90% of the homes are heated by geothermal power (does not produce soot or GHG that pollute air and global warming. 2. A new geothermal plant famous for its natural hot springs and volcanic activity in **Kumamoto, Japan** (First to open in Japan since 1999) • Even though its contribution to Japan's electric demands may be very small, it is valuable. Japan is one of world's most seismically active nations, geothermal resources estimated to be able to generate as much as 23 million kilowatts of energy, the third largest amount in the world.	This would allow electricity to be provided by geothermal energy, reducing the demand for fossil fuels which in turn would reduce the amount of greenhouse gases that would be produced, reducing the effect of climate change.

PRECIOUS STONES & MINERALS	**Precious stones and minerals, building materials** (volcanic rocks can be rich in precious in stones like diamonds and after millions of years they can be extracted)	Diamonds are heated and pressurised carbon that are cooled in magma pipes beneath the earth's surface. • E.g. Kimberlite is a type of igneous rock which may contain diamonds, named after the town of **Kimberley in South Africa** • The diamonds were first mined in the 1870's and are still producing diamonds today • The mining industry of South Africa, one of the best developed in the world, forms a crucial part of South Africa's economy. Sales of minerals and mineral products contribute about 16% of the GDP & the mining sector directly employs approximately 550,000 people.	The diamond industry can provide jobs to the people → people able to earn money → higher purchasing power to afford to buy goods and services → better SOL the diamond industry can earn a lot of profits due to the sale of its diamonds → contribute to country's economic growth
TOURISM	**Tourism** (volcanic areas offer a variety of activities for tourists to engage in)	1. **In Bali, Mount Agung's** rock and sand that were thrown up by the eruption were used to build hotels, restaurants, and villas for hordes of foreign tourists, who started arriving in the 1970s. Tourism remains Bali's biggest industry 2. **Mount Fujiyama, Japan** • Site of great natural beauty and it is one of the main tourist attractions of Japan. • Of the 10 364 000 international tourists who visited Japan in 2013, more than 50% had planned a visit to the Mt Fuji to enjoy the scenic beauty. • Hot springs of Japan like the Kusatsu and Manza are also highly favoured by tourists. These hot springs have minerals like sulphur which is believed to have medicinal properties that can cure skin related diseases.	Both these attractions located near the volcanoes → increase in tourist arrivals in Japan → demand for tourist related services like those of guides, hotel managers, etc. increased → This possibly created more jobs for the locals of Japan → Increase in the number of jobs results in increase in income. The increase in income will lead to **economic growth** for the country. As a result, the locals can afford more goods and services like food → **increase SOL**

TOPIC 3 – DISASTER RISK MANAGEMENT & ACHIEVING SUSTAINABLE DEVELOPMENT

DISASTER RISK: potential damage/ danger posed by the disaster to properties, people and infrastructure in a given period of time BEFORE ANY human intervention.

Disaster risk management: plans & actions by humans taken to prevent disaster risks BEFORE + reduce disaster risks DURING + manage disaster risks AFTER the disaster has occurred.

IT IS NECESSARY TO MANAGE DISASTER RISKS — in order to prevent:

- Environmental consequences
  - areas can be buried by landslides triggered by tectonic hazards
  - damage ecosystems
- Social consequences
  - can cause loss of lives & injuries
  - cause homelessness & no access to basic services such as water
  - contaminated water & food supplies may cause diseases, affecting people's physical and mental well being
- Economic consequences
  - Infrastructure and properties destroyed = affect SOL as money is directed for repair thus no money for basic needs
  - government need to spend money to rebuild = direct money away from other spending such as on healthcare & education, thus affecting development

ALL THIS CAN HINDER THE DEVELOPMENT OF A COUNTRY!

WHY DISASTER RISKS DIFFER ACROSS PLACES (HOW SEVERE THE DANGER IS WITHOUT ANY HUMAN INTERVENTION)

FACTORS	EARTHQUAKES	VOLCANIC ERUPTION
NATURE OF HAZARD	**1. DURATION OF SHAKING** (longer duration of ground shaking → higher likelihood of building collapse) E.g. 2011 Tohoku EQ – 6 minutes **2. TIMING OF SHAKING** (People can react faster to the earthquake when they are awake as they are more alert) E.g. Oaxaca, Mexico, 2012: 7.6 magnitude @12PM → Death Toll: 2 Taiwan 1999: 7.6 magnitude @ 2AM → Death toll: 2415	**Chemical composition of magma** o **Low silica magma** → less viscous (flow easier) → gentle effusive eruption [2018 Kilauea, Hawaii destroyed 600 homes, 24 injuries] o **High silica magma** → more viscous (flow slower) → explosive eruption [2010 Mount Merapi Indonesia resulted in pyroclastic flow for 3km and volcanic bombs over 10km]
VULNERABLE CONDITIONS	**1. Quality of building design and construction** o EQ don't kill people, but buildings do when they collapse. Poor building design = higher chance of collapsing & trapping/ injuring people o [e.g. 2010 Port-au-Prince, Haiti EQ – most buildings are made up of poor materials & poorly reinforced → 90% of buildings near epicentre destroyed] **2. Soil & rock properties** o When soil is saturated & loose → ground shaking may cause liquefaction (saturated soil temporarily loses strength and behaves like a liquid) → buildings may sink/ tip over o Soft loose soil will shake more intensely → highly likely for buildings to collapse o [e.g. 2010 Port-au-Prince, Haiti EQ – most areas are on relatively soft soil → more than 220k buildings collapse]	**1. Availability of water (ground/ surface) that can cause lahars** o Water available → lahars develop → bury & destroy properties o E.g. 1991 Mount Pinatubo, Philippines → heavy rain triggered a lot of lahars → 100k houses destroyed **2. Prevailing wind conditions spreading tephra/ volcanic ash** o Strength & direction of wind will affect tephra distribution → stronger wind would cause a larger spread hundred kilometres away o E.g. 1991 Mount Pinatubo, Philippines → ashfall & tephra spread over a large distance due to fast wind speed (20m/s)
EXPOSURE TO HAZARD	**1. Population density** o Higher popn density → more people in buildings → higher likelihood of being trapped & injured o E.g. Alaska, 1964 earthquake, Population Density= 0.5/km2, Death toll: 131 Indonesia, 2004 earthquake, Population Density= 125 / km2, Death toll: 150, 000 **2. Distance from epicentre** o **The greater the distance from the epicenter, the lower the impact of the earthquake.** o Energy is <u>dissipated</u> further away from the epicenter. o E.g. Christchurch, New Zealand, 2011 earthquake, <10 km from epicenter → Death toll: 185 Rhodes, Greece, 2008 earthquake, 70km from epicenter → Death toll: 11	**Presence of human settlements → increase exposure of people to volcanic hazards** • people who choose to live near volcanoes due to fertile soil despite the high risk of being injured when volcanic eruption happen • E.g. Mount Sinabung is an active volcano in Indonesia. Despite its recent eruption in 2010, people continue to live and work near the restricted zone from the volcano

WHY DO PEOPLE CONTINUE TO LIVE IN HIGH RISK AREAS?

They continue to live there because they can respond in various ways:

Fatalistic approach [Accept and resist evacuation. Typical for less developed countries who have limited access and knowledge]	**Acceptance approach** [Live with the risk due to the potential benefits offered in the area]	**Adaptation approach** [Well prepared for earthquakes]

MEASURE	DESCRIBE WITH EXAMPLES		EXPLAIN HOW THIS HELP TO MANAGE DISASTER RISK	SUCCESS/ LIMITATIONS
LANDUSE PLANNING TO REDUCE EXPOSURE	• Minimise development in high risk areas • Strict guidelines or laws to control development • Hazard mapping to identify areas at risk based on past tectonic disaster data	**EXAMPLE: JAPAN** • strict zoning regulations and building codes in place to ensure that new construction projects adhere to seismic safety standards. • In high-risk seismic zones, Japanese authorities impose land use restrictions to limit development and occupation. Certain areas may be designated as no-build zones or restricted development zones, where construction of new buildings or critical infrastructure is prohibited or strictly regulated to minimize exposure to seismic risks. • After 1933 tsunami → residential landuse near coastal areas were shifted to higher ground	Lesser buildings are at risk of collapsing as authorities ensure buildings are build on 'safer' areas → lower risk as people would not be stuck under building debris → able to escape → lower death toll & minimise damage Risk of damage reduced → reduced spending for rebuilding	• Costly as government need to acquire over unsafe land. • Existing owners might be reluctant to give up land. • Countries with limited land may not be feasible
HAZARD RESISTANT BUILDING DESIGN & MONITORING + WARNING SYSTEMS TO REDUCE VULNERABILITY	• Earthquake resistant building design that can withstand ground shaking such as shock absorbers, dampers in buildings to absorb vibrations. • Reinforcing buildings with diagonal cross braces to retain building shape	**EXAMPLE: TAIPEI 101, Taiwan** • Building has a weighted damper (a massive pendulum-like device) installed near the top of the tower. It counteracts the building's sway caused by winds and seismic activity, reducing structural stress and minimizing the risk of damage during earthquakes	With such fittings installed for buildings, it can minimise the damage during earthquakes as the building is able to withstand the ground vibrations → less likely to collapse and damage → able to protect people and properties inside → reduce death toll & possibility of property damage	• Expensive • Costly and untested until earthquakes occur.
	• Use of devices to detect seismic waves & ground deformation. • Earthquake early warning systems use earthquake science to alert devices and people when shaking waves generated by an earthquake are expected to arrive attheir location.	**EXAMPLE: JAPAN** 1. Japan Meteorological Agency (JMA): operates a large seismic network comprising seismometers, accelerometers, and other instruments strategically positioned across the country → detect ground motion and seismic waves generated by EQ providing real-time data 2. **J-ALERT:** one of the world's most advanced seismic early warning systems → utilizes data from seismic sensors to detect initial tremors of EQ & issue automated alerts to government agencies, emergency responders, and public via television, radio, and smartphone applications → provides valuable seconds to minutes of warning before strong shaking reaches populated areas 3. **Earthquake Early Warning (EEW) systems** → network of sensors and monitors → alerts sent to smart devices to inform people & provide advanced warning to people **2011 Tohoku EQ → a signal was sent to stop bullet trains → saved thousands of passengers**	With such warning systems → provide a few seconds to minutes heads up advanced warning → allowing people to take protective actions such as seeking shelter and stopping trains and industrial processes → able to get to safety→ reduce likelihood of getting hurt or death → reduce death toll	• Limited Predictability • Short Warning Times • Technological and Infrastructure Limitations • False Alarms and Public Trust • High Costs of Installation and Maintenance

INCREASING PREPAREDNESS FOR RESPONSE & RECOVERY FOR COMMUNITY RESILIENCE	• Raising public awareness through education (Posters and signs/ workshops) • Carrying out frequent evacuation drills. • First aid trainings	• Provide people with knowledge of hazards & how to respond (e.g. seeking shelter away from hazards, sealing windows & doors • Drills enable people to be familiar with evacuation routes (e.g. 2011 Tohoku EQ – 3,000 students of Kamaishi City survived as schools had disaster prevention education programmes which included drills) **EXAMPLE: JAPAN** • The nationwide drill is held annually on Sept 1, known in Japan as Disaster Prevention Day, which comes on the anniversary of the 1923 Great Kanto Earthquake that killed more than 100,000 people and levelled Tokyo.	Through such drills, people would be prepared and know how to act during an EQ → able to evacuate on time → reduce loss of lives, hence lowering death toll	• Lack of resources esp. developing countries • Lack of capability of community to organize themselves • Lack of efforts to educate & train community

RESPONSE STRATEGIES (SHORT TERM RESPONSES (immediately after the EQ)

RESPONSE	DESCRIBE WITH EXAMPLES	EXPLAIN HOW THIS HELP TO MANAGE THE IMPACTS	SUCCESS/ LIMITATIONS?
SEARCH & RESCUE EFFORTS	Search & rescue efforts deployed by govt immediately after the occurrence of EQ to help to search for people who may be trapped in collapsed buildings. Aim to rescue people in a shortest time with minimal risk to survivors. Usually have skilled rescuers and specialised equipment such as heat sensors & listening devices. **EXAMPLE: JAPAN 2011 TOHOKU EQ** • Sent out 100,000 members of the Self-Defence Forces • Rescue workers had a limited time of 3 days to rapidly search through two towns for as many survivors as possible.	Able to get to survivors fast → people do not need to endure being stuck under debris → reduce likelihood of crush syndrome/ dehydration → reduce death toll	Able to save people who are trapped in the collapsed buildings & debris Time is limited to rescue, people may not survive for so long
TIMELY EVACUATION	• Moving people from areas at risk of hazards as quickly as possible to safer locations to reduce the loss of lives. • Evacuate people to temporary shelters where food, water and medical supplies are provided. • Evacuate people to higher ground E.g. 2011 Tohoku EQ – 3,000 students of Kamaishi City survived as they were able to evacuate to higher grounds → saved from tsunami E.g. Mount Merapi 2020 warning issued → mass evacuation local communities that involved more than 700 evacuation centres, saving more than 10,000 lives.	Moving people from areas at risk of hazards as quickly as possible to safer locations → reduce the loss of lives.	Cooperation from people may be an issue

PROVISION OF BASIC SOCIAL AND PSYCHOLOGICAL SERVICES Govt & various agencies would set up emergency shelters to provide temporary shelters for those who are homeless as they lost their house to the EQ	**EXAMPLE: JAPAN 2011 TOHOKU EQ** - established emergency shelters in schools, community centers, temples, and other public buildings in the affected areas. - swiftly organized the distribution of emergency supplies, including blankets, bedding, clothing, hygiene kits, and basic household items, to residents in emergency shelters. Japanese Red Cross Society and local governments, coordinated the distribution. - Japan deployed mobile kitchen units and food distribution centers to affected areas → /prepared and distributed hot meals, ready-to-eat food packs, and drinking water to survivors in emergency shelters and makeshift settlements. - Japan collaborated with international humanitarian organizations, such as the United Nations World Food Programme (WFP) and the International Federation of Red Cross and Red Crescent Societies (IFRC → provided additional resources, expertise, and logistical support to enhance the delivery of humanitarian assistance to affected communities. - Medical teams and emergency responders were deployed to provide medical care, psychosocial support, and counseling services to survivors experiencing physical injuries, trauma, and emotional distress	These shelters provided temporary accommodation for displaced individuals and families who lost their homes in the disaster + provision of food & medical supplies allow those affected to continue surviving while trying to navigate their situation after → reduce number of people homeless & hungry → less likely to be sick → slightly improve health levels & lower casualty toll Provision of mental health services and counseling support → addressed the mental health needs of survivors → can express emotions, share experiences → reducing feelings of isolation, promoting healing and recovery → facilitated the restoration of social cohesion, community bonds, and collective resilience, → essential for rebuilding communities	Helps survivors cope with the disaster Provide shelter for the homeless May not be sufficient, countries may not have the means to provide extensive aid Maybe be subjected to cramped and unhygienic conditions Can help injured victims or psychologically disturbed victims with their trauma & restore their livelihoods However, depending on the extent of trauma, it may be challenging

RECOVERY STRATEGIES = LONG TERM RESPONSES (weeks or months after the EQ)

RESPONSE	DESCRIBE WITH EXAMPLES	EXPLAIN HOW THIS HELP TO REDUCE SEVERITY OF DAMAGE CAUSED BY EQ	SUCCESS/ LIMITATIONS?
REBUILDING OF INFRASTRUCTURE - Rebuilding of affected areas after the earthquake to allow life to return to normalcy	**EXAMPLE: JAPAN 2011 TOHOKU EQ** The bank of Japan pumped US$183 billion into the economy. - provided emergency funding to banks and financial institutions affected by the disaster to ensure their continued operation and prevent disruptions to the flow of credit. - This funding was to support lending to businesses and households, facilitate reconstruction efforts, and bolster economic recovery in the affected regions. - A significant portion of the funds was directed towards supporting reconstruction efforts in the Tohoku region. This included financing infrastructure projects, housing construction, and the revitalization of local economies to aid in the recovery and rebuilding process. -	This funding help affected businesses and individuals to pick themselves up after the disaster and recover from it → through employment opp provided Helping reconstruction efforts helped affected people to rebuild their homes & properties → helped displaced individuals and families regain stability, improve living conditions, and rebuild their lives after the disaster.	Stricter building codes ensures higher safety levels Able to help to stimulate economy and to restore the normal functions of the society May take a long time to rebuild Not fully protected from all kinds of hazard
RETROFITTING SURVIVING BUILDINGS WITH HAZARD-RESISTANT FEATURES	**EXAMPLE: JAPAN 2011 TOHOKU EQ** - By 2016, majority were rehoused in settlements enhanced with tsunami resistant features. - In a port town, the ground level of sites for new houses was raised by 10m and 2 more seawalls were built.	This allow affected communities to rebuild their lives after disaster & minimising their vulnerability and exposure to hazards → able to continue and move on with life after disaster	Lack of resources Lack of cooperation between various stakeholders

DISASTER RISK MANAGEMENT

seperation

↳ After disaster

NATURE OF HAZARDS

1. EARTHQUAKES

DURATION OF SHAKING
- longer ground shaking = higher disaster risk/ damage

TIME OF SHAKING
- If happen @ night = higher disaster risk/ damage as people are not awake

2. VOLCANIC ERUPTIONS

- **CHEMICAL COMPOSITION OF MAGMA**
  - if nagna is low-silica = gentle effusive eruption → slightly lower disaster risk
  - if magma is high silica = explosive eruption → higher disaster risk

VULNERABILITY

1. EARTHQUAKES

QUALITY OF BUILDING DESIGN & CONSTRUCTION
- good quality building design = lower disaster risk/ damage

SOIL & ROCK PROPERTIES
- If soil is saturated & loose = may cause liquefaction → higher disaster risk/ damage

2. VOLCANIC ERUPTIONS

AVAILABILITY OF SURFACE & GROUNDWATER
- can cause lahars to develop → higher disaster risk

PREVAILING WINDS
- can cause tephra (volcanic ash) to spread further away

VULNERABILITY CAN BE REDUCED BY:

1. HAZARD-RESISTANT BUILDING DESIGNS
- buildings that can withstand ground shaking

2. MONITORING & WARNING SYSTEMS
- predictions and send warnings to allow people to evacuate

can help to achieve

EXPOSURE

dangers by any human action

1. EARTHQUAKES

POPULATION DENSITY
- Higher population density = higher disaster risk/ damage

DISTANCE FROM EPICENTRE
- the closer the distance from epicentre = higher disaster risk/ damage

2. VOLCANIC ERUPTIONS

- **PRESENCE OF HUMAN SETTLEMENTS**
  - if volcanic eruption happen near human settlements = higher disaster risk/ damage

EXPOSURE CAN BE REDUCED BY LANDUSE PLANNING:

- minimise development @ high risk areas
- strict guidelines to control development in such areas
- rank areas according to levels: high/medium/low

can help to achieve

COMMUNITY RESILIENCE: HELP COMMUNITIES TO BUILD TO RESIST, ADAPT AND RECOVER FROM IMPACTS TIMELY

Increasing community preparedness:

1. Public awareness through public education
2. first aid training
3. conducting evacuation drills

can help to achieve

Migitation efforts

Prepare before any disaster.

POSSIBLE CHALLENGES IN BUILDING COMMUNITY RESILIENCE:

1. EXTENT OF RESOURCES
   a. Developing countries make lack resources to invest in hazard resistant buildings & landuse planning
2. CAPABILITY OF COMMUNITY TO ORGANISE ITSELF
   a. Lack of effort to educate & train people
   b. Political instability
   c. corruption = loss of funding

RESPONSE STRATEGIES (SHORT TERM)

↳ Immediately after

1. SEARCH & RESCUE EFFORTS
2. TIMELY EVACUATION
3. PROVISION OF BASIC SOCIAL & PSYCHOSOCIAL SERVICES TO AFFECTED COMMUNITIES

RECOVERY STRATEGIES (LONG TERM)

weeks/months after the disaster

1. RESTORING & IMPROVEMENT OF FACILITIES AND LIVING CONDITIONS OF AFFECTED COMMUNITIES

POSSIBLE CHALLENGES

1. LACK OF RESOURCES & FINANCES
2. CHALLENGE TO GET RELEVANT STAKEHOLDERS TO COLLABORATE & INTEGRATE DISASTER MANAGEMENT PRACTICES INTO THEIR PRACTICES