

# EARTHQUAKES AND THE EARTH'S SPHERES



# EARTHQUAKES AND THE EARTH'S SPHERES

## **What is an Earthquake?**

An earthquake is a sudden motion or trembling of the Earth caused by the abrupt release of energy that is stored in rocks. Before the plate tectonics theory was developed, geologists recognized that earthquakes occur frequently in some regions and infrequently in others, but they did not understand why. Modern geologists know that most earthquakes occur along plate boundaries, where huge tectonic plates separate, converge, or slip past one another.

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## **STRESS:**

Stress is defined as the force per unit area of a material.

## **STRAIN:**

Strain is defined as extension per unit length.

## **HOOKE'S LAW:**

Stress is directly proportional to strain.

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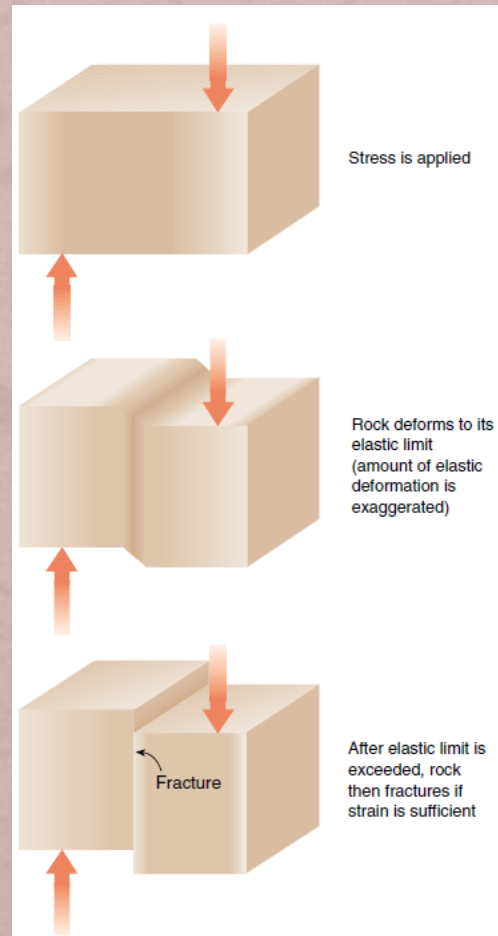
**How do rocks store energy, and why do they suddenly release it as an earthquake?**

Stress is a force exerted against an object. Tectonic forces stress rocks. The movement of lithospheric plates is the most common source of tectonic stress.

When an object is stressed, it changes volume and shape. If a solid object is stressed slowly, it first deforms in an elastic manner: When the stress is removed, the object springs back to its original size and shape. Rocks also deform elastically when tectonic stress is applied (Fig).

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**How do rocks store energy, and why do they suddenly release it as an earthquake?**



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Every rock has a limit beyond which it can't deform elastically. Under certain conditions, when its elastic limit is exceeded, a rock continues to deform like putty. This behavior is called plastic deformation. A rock that has deformed plastically retains its new shape when the stress is released (Fig).

Earthquakes do not occur when rocks deform plastically. Under other conditions, an elastically stressed rock may rupture by brittle fracture (Fig). The fracture releases the elastic energy, and the surrounding rock springs back to its original shape. This rapid motion creates vibrations that travel through the Earth and are felt as an earthquake.

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Although tectonic plates move at rates between 1 and 16 centimeters per year, friction prevents the plates from slipping past one another continuously. As a result, rock near a plate boundary stretches or compresses. When its accumulated elastic energy overcomes the friction that binds plates together, the rock suddenly slips along the fault, generating an earthquake. The rocks may move from a few centimeters to a few meters, depending on the amount of stored energy.

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## **EARTHQUAKE WAVES:**

A wave transmits energy from one place to another. Thus, a drumbeat travels through air as a sequence of waves, the Sun's heat travels to Earth as waves. Waves that travel through rock are called seismic waves. Earthquakes produce seismic waves.

*Seismology* is the study of earthquakes and the nature of the Earth's interior based on evidence from seismic waves.

# EARTHQUAKES AND THE EARTH'S SPHERES

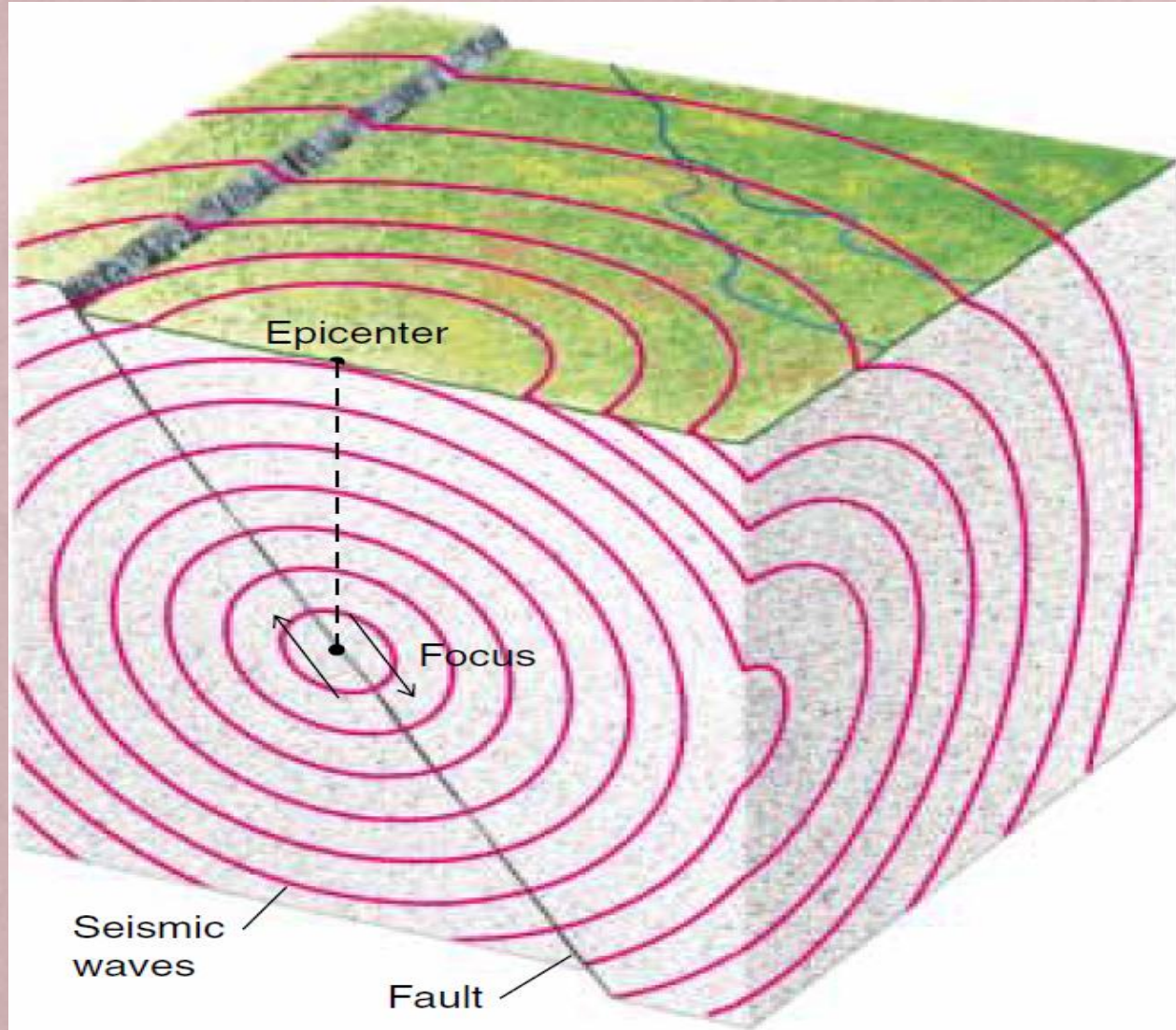
## **TYPES Of WAVES:**

An earthquake produces several different types of seismic waves.

**Body Waves:** travel through the Earth's interior. They radiate from the initial rupture point of an earthquake, called the focus (Fig). The point on the Earth's surface directly above the focus is the epicenter. During an earthquake, body waves carry some of the energy from the focus to the surface.

**Surface Waves:** then radiate from the epicenter along the Earth's surface. Although the mechanism is different, surface waves undulate across the ground like the waves that ripple across the water after you throw a rock into a calm lake.

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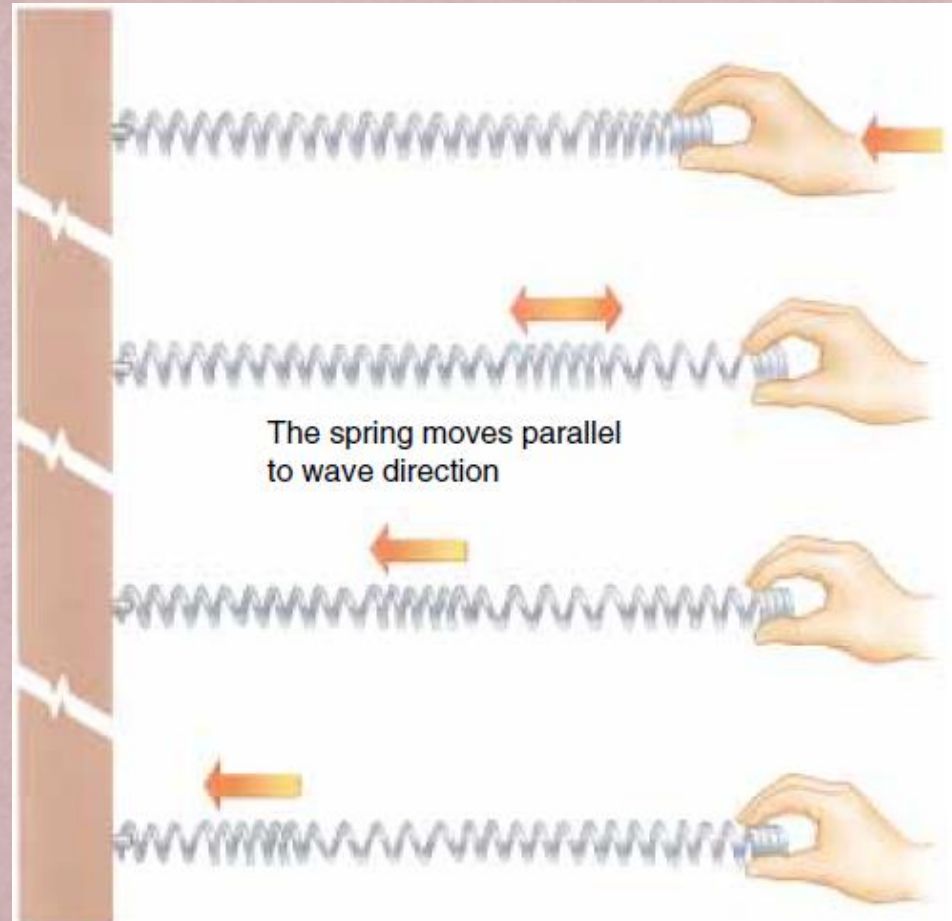


# EARTHQUAKES AND THE EARTH'S SPHERES

## TYPES OF WAVES:

### Body Waves:

Two main types of body waves  
Travel through the Earth's interior.  
First one is "*P wave*" (also called compressional wave) is an elastic wave that causes alternate compression and expansion of the rock.



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## **TYPES Of WAVES:**

### **Body Waves:**

P waves travel at speeds between 4 and 7 kilometers per second in the Earth's crust and at about 8 kilometers per second in the uppermost mantle. As a comparison, the speed of sound in air is only 0.34 kilometer per second, and the fastest jet fighters fly at about 0.85 kilometer per second. P waves are called primary waves because they are so fast that they are the first waves to reach an observer.

P waves travel through air, liquid, and solid material.

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## **TYPES Of WAVES:**

### **Body Waves:**

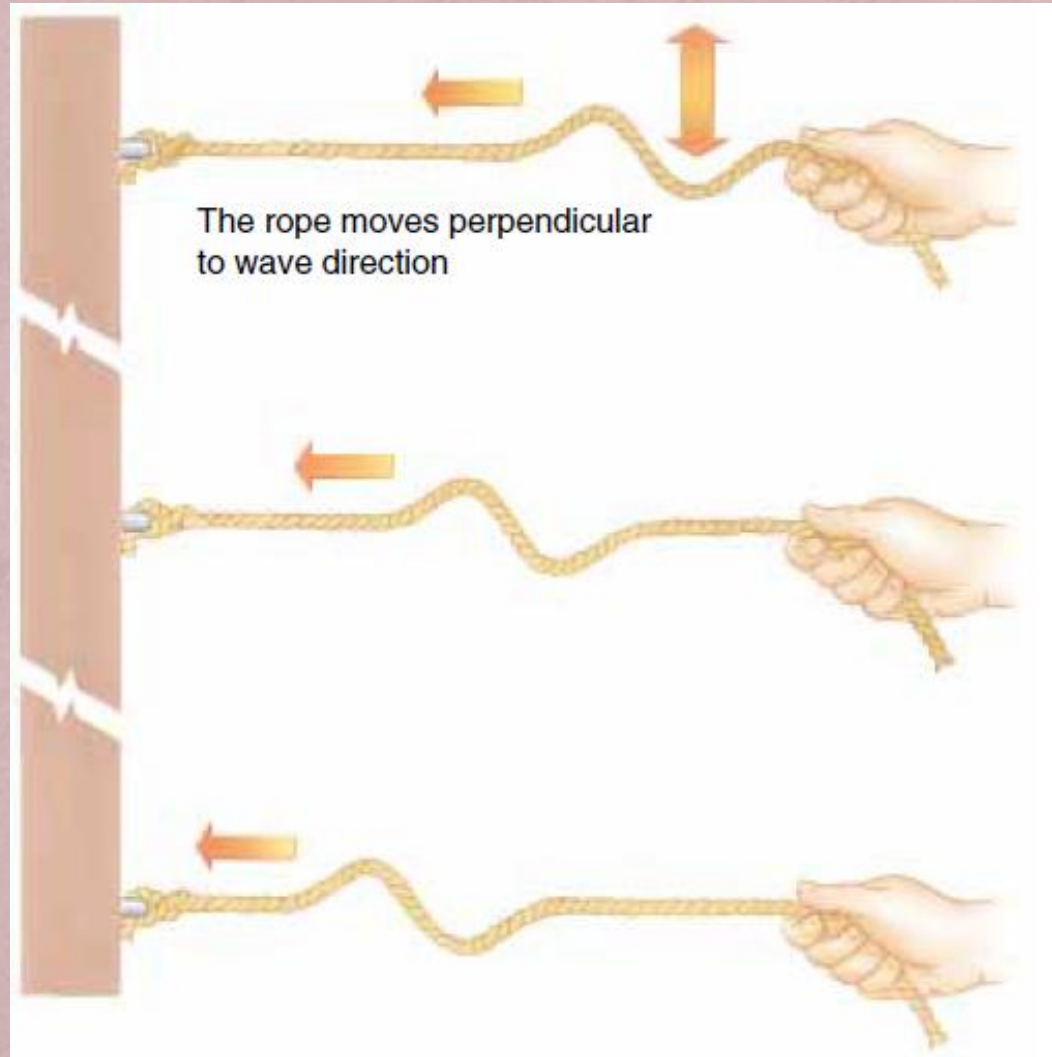
A second type of body wave, called an S wave, is a shear wave. S wave produces shear stress in rock and gives the wave its name. S waves are slower than P waves and travel at speeds between 3 and 4 kilometers per second in the crust. As a result, S waves arrive after P waves and are the secondary waves to reach an observer.

Unlike P waves, S waves move only through solids. Because molecules in liquids and gases are only weakly bound to one another, they slip past each other and thus cannot transmit a shear wave.

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## TYPES OF WAVES:

### Body Waves:



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## **TYPES Of WAVES:**

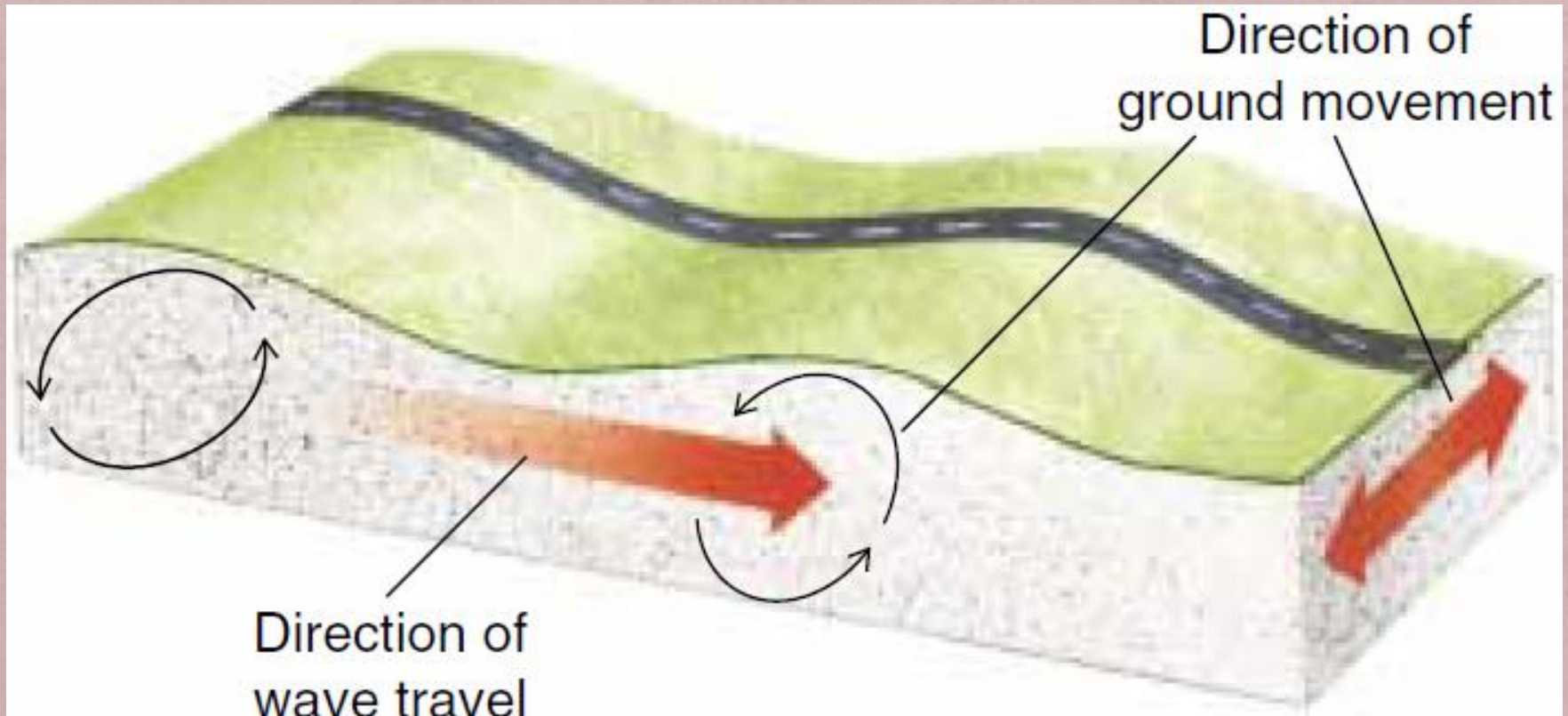
### **Surface Waves**

Surface waves travel more slowly than body waves. Two types of surface waves occur simultaneously in the Earth (Fig). A Rayleigh wave moves with an up-and-down rolling motion like an ocean wave. Love waves produce a side-to-side vibration. Thus, during an earthquake, the Earth's surface rolls like ocean waves and writhes from side to side like a snake

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## TYPES OF WAVES:

### Surface Waves



# EARTHQUAKES AND THE EARTH'S SPHERES

## TYPES OF EARTHQUAKES:

**1. SHALLOW FOCUS** earthquakes are commonly occurring “crustal” earthquakes, caused by faults and movements of the continental plates. These are earthquakes with their focus nearer the surface of the earth. Shallow focus earthquakes are usually of large spread, causing greater damage at the surface or the earth’s crust. These occur quite frequently and at random. However, being of smaller magnitudes and at lesser depths, very often they are not even felt. Nevertheless, about 75 % of the world’s energy released from earthquakes is from shallow-focus ones.

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## TYPES OF EARTHQUAKES:

**2. DEEP FOCUS** earthquakes or “*Intra Plate*” earthquakes, occur within the sub-ducting oceanic plates as they move beneath the continental plates. Appearing along fault lines, these are earthquakes with focus much deeper within the earth. A deep focus earthquake occurs when two tectonic plates slide towards one another followed by subduction. They happen as huge quakes with larger magnitudes, as a great deal of energy is released with the forceful collision of the plates.

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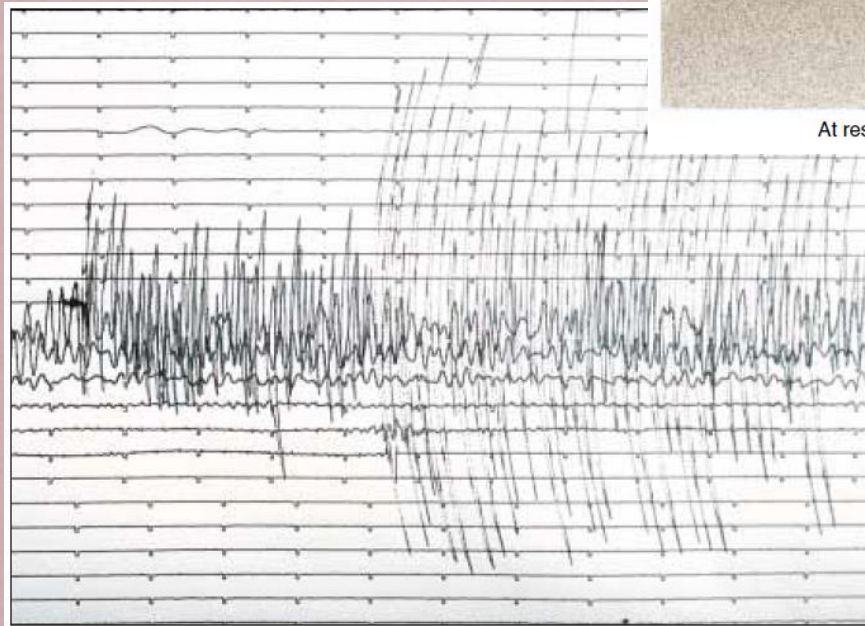
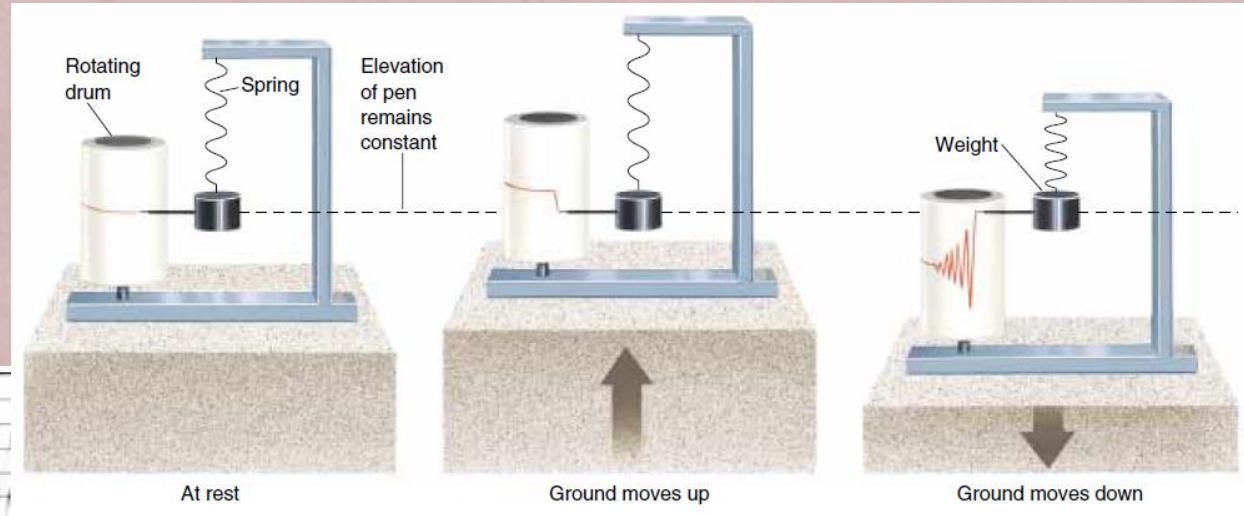
## MEASUREMENT OF SEISMIC WAVES:

A seismograph is a device that records seismic waves. In early seismographs a pen attached to the weight was aimed at the zero mark on a piece of graph paper (Fig.). The graph paper was mounted on a rotary drum that was attached firmly to bedrock. During an earthquake, the graph paper jerked up and down, but inertia kept the pen stationary. As a result, the paper moved up and down beneath the pen. The rotating drum recorded earthquake motion over time. This record of Earth vibration is called a seismogram (Fig).

Modern seismographs use electronic motion detectors which transmit the signal to a computer.

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## MEASUREMENT OF SEISMIC WAVES:



# EARTHQUAKES AND THE EARTH'S SPHERES

## MEASUREMENT OF EARTHQUAKE STRENGTH:

We can measure the strength of an Earthquake into two ways.

### *Magnitude & Intensity*

**Magnitude:** In 1935 *Charles Richter* devised the Richter scale to express earthquake magnitude. Richter magnitude is calculated from the height of the largest earthquake body wave recorded on a specific type of seismograph. The magnitude of an earthquake is determined from the logarithm of the amplitude of waves recorded by seismographs.

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## MEASUREMENT OF EARTHQUAKE STRENGTH:

On the Richter Scale, magnitude is expressed in whole numbers and decimal fractions. For example, a magnitude 5.3 might be computed for a moderate earthquake, and a strong earthquake might be rated as magnitude 6.3. Because of the logarithmic basis of the scale, each whole number increase in magnitude represents a tenfold increase in measured amplitude; as an estimate of energy, each whole number step in the magnitude scale corresponds to the release of about 31 times more energy than the amount associated with the preceding whole number value.

$$\textit{Magnitude} = \log_{10}(\textit{Amplitude}) + \textit{Correction Factor}$$

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## MEASUREMENT OF EARTHQUAKE STRENGTH:

### RICHTER SCALE of earthquake energy:

Each level is **10** times stronger than the previous level

	<u>Description</u>	<u>Occurrence</u>	<u>In Population</u>	<u>Movement</u>
1	SMALL	DAILY	every minute	small
2	SMALL	DAILY	every hour	small
3	SMALL	DAILY	every day	small
4	SMALL	DAILY	every week	moderate sudden
5	MODERATE	MONTHLY	every 10 years	strong sudden
6	MODERATE	MONTHLY	every 30 years	strong sudden
7	MAJOR	MONTHLY	every 50 years.	severe sudden
8	GREAT	YEARLY	every 100 years	very severe
9	GREAT	YEARLY	every 300 years	very severe
10	SUPER	RARELY	every 1000 years	extreme

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## MEASUREMENT OF EARTHQUAKE STRENGTH:

**Intensity:** is the effect of an Earthquake on the Earth's surface

Numerous intensity scales have been developed over the last several hundred years, but the one currently used in U.S. is the Modified Mercalli (MM) Intensity Scale.

Developed in 1931 by the American seismologists Harry Wood and Frank Neumann, based on scale developed in 1902 by Italian seismologist Giuseppe Mercalli.

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## **MEASUREMENT OF EARTHQUAKE STRENGTH:**

Scale is composed of 12 increasing levels of intensity that range from imperceptible shaking to huge destruction.

Roman numerals.

It does not have a mathematical basis; instead it is an arbitrary ranking based on observed effects.

MMI assigned to a specific site after an EQ has a more meaningful measure of severity to the nonscientist than the magnitude because intensity refers to the effects actually experienced at that place.

# EARTHQUAKES AND THE EARTH'S SPHERES

## MEASUREMENT OF EARTHQUAKE STRENGTH:

- I. Not felt except by a very few under especially favorable conditions.
- II. Felt only by a few persons at rest, especially on upper floors of buildings.
- III. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
- IV. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.

# EARTHQUAKES AND THE EARTH'S SPHERES

## MEASUREMENT OF EARTHQUAKE STRENGTH:

V. Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.

VI. Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.

VII. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.

VIII. Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.

# EARTHQUAKES AND THE EARTH'S SPHERES

## MEASUREMENT OF EARTHQUAKE STRENGTH:

IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

XI. Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.

XII. Damage total. Lines of sight and level are distorted. Objects thrown into the air.

# EARTHQUAKES AND THE EARTH'S SPHERES

## **EARTHQUAKE DAMAGE:**

Most earthquake fatalities and injuries occur when falling structures crush people. Structural damage, injury, and death depend on the magnitude of the Earthquake, its proximity to population centers, rock and soil types, topography, and the quality of construction in the region.

# EARTHQUAKES AND THE EARTH'S SPHERES

## **EARTHQUAKE DAMAGE:**

### **How rock and soil influence earthquake damage?**

In many regions, bedrock lies at or near the Earth's surface and buildings are anchored directly to the rock. Bedrock vibrates during an earthquake and buildings may fail if the motion is violent enough. However, most bedrock returns to its original shape when the earthquake is over, so if structures can withstand the shaking, they will survive. Thus, bedrock forms a desirable foundation in earthquake hazard areas.

# EARTHQUAKES AND THE EARTH'S SPHERES

## **EARTHQUAKE DAMAGE:**

### **How rock and soil influence earthquake damage?**

In many places, structures are built on sand, clay, or silt. Sandy sediment and soil commonly settle during an earthquake. This displacement tilts buildings, breaks pipelines and roadways, and fractures dams. To avert structural failure in such soils, engineers drive steel or concrete pilings through the sand to the bedrock below. These pilings anchor and support the structures even if the ground beneath them settles.

# EARTHQUAKES AND THE EARTH'S SPHERES

## EARTHQUAKE DAMAGE:

### **How rock and soil influence earthquake damage?**

If soil is saturated with water, the sudden shock of an earthquake can cause the grains to shift closer together, expelling some of the water. When this occurs, increased stress is transferred to the pore water, and the pore pressure may rise sufficiently to suspend the grains in the water. In this case, the soil loses its shear strength and behaves as a fluid. This process is called *liquefaction*.

When soils liquefy on a hillside, the slurry flows downslope, carrying structures along with it.

# EARTHQUAKES AND THE EARTH'S SPHERES

## EARTHQUAKE DAMAGE:

**How rock and soil influence earthquake damage?**

### LANDSLIDES

Landslides are common when the Earth trembles.

### TSUNAMIS

When an earthquake occurs beneath the sea, part of the sea floor rises or falls (Fig. 10–18). Water is displaced in response to the rock movement, forming a wave. Sea waves produced by an earthquake are often called tidal waves, but they have nothing to do with tides. Therefore, geologists call them by their Japanese name, *Tsunami*.

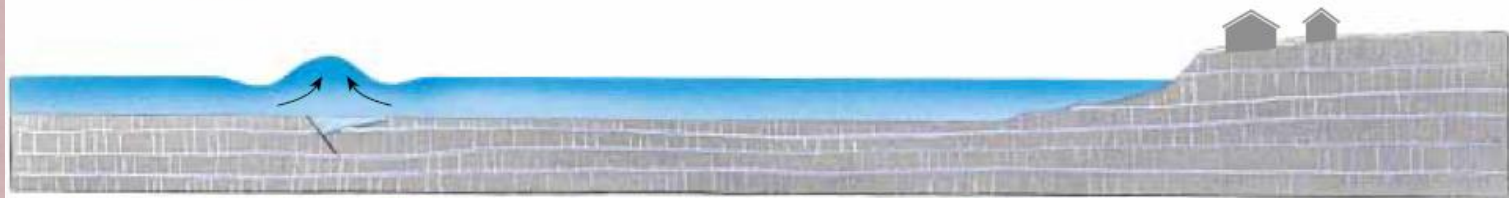
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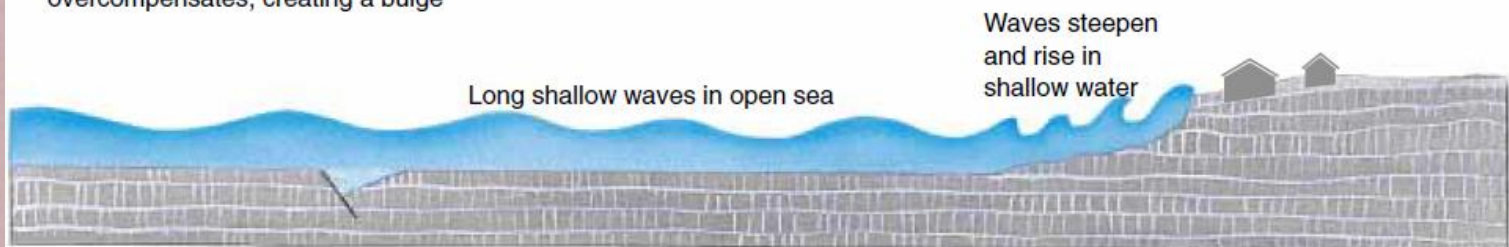
(a) Normal state, before earthquake



(b) Earthquake! Sea floor drops, sea level falls with it



(c) Water rushes into low spot, and overcompensates, creating a bulge



(d) Tsunami generated

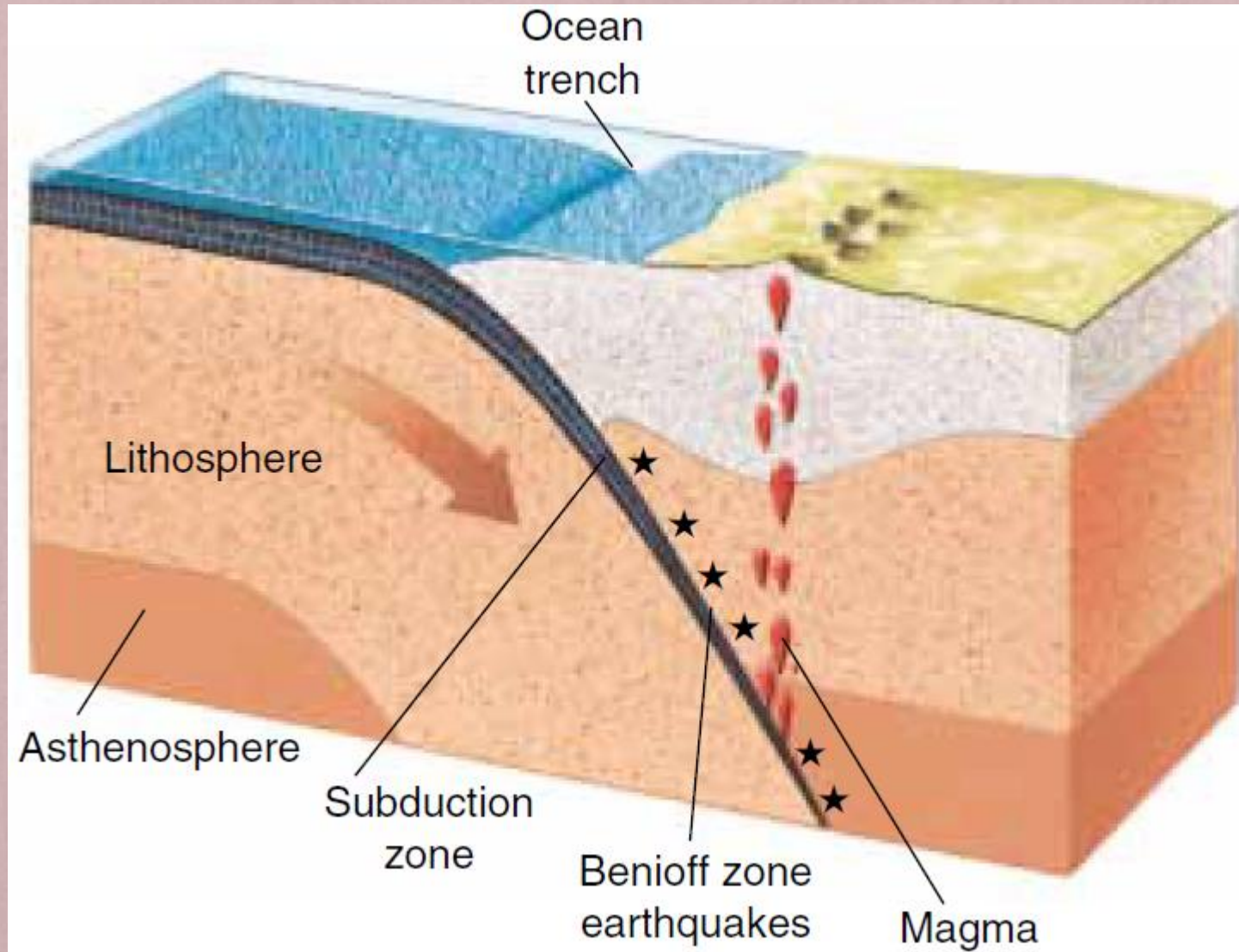
# EARTHQUAKES AND THE EARTH'S SPHERES

## **EARTHQUAKES AND TECTONIC PLATE BOUNDARIES :**

### **Earthquakes At Subduction Zones:**

In a subduction zone, a relatively cold, rigid lithospheric plate dives beneath another plate and slowly sinks into the mantle. In most places, the subducting plate sinks with intermittent slips and jerks, giving rise to numerous earthquakes. The earthquakes concentrate along the upper part of the sinking plate, where it scrapes past the opposing plate (Fig). This earthquake zone is called the Benioff zone, after the geologist who first recognized it. Many of the world's strongest earthquakes occur in subduction zones.

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## **EARTHQUAKES AND TECTONIC PLATE BOUNDARIES :**

### **Earthquakes at divergent plate boundaries**

Earthquakes frequently shake the mid-oceanic ridge system as a result of faults that form as the two plates separate. Blocks of oceanic crust drop downward along most mid-oceanic ridges, forming a rift valley in the center of the ridge. Only shallow earthquakes occur along the midoceanic ridge because here the asthenosphere rises to within 20 to 30 kilometers of the Earth's surface and is too hot and plastic to fracture

# EARTHQUAKES AND THE EARTH'S SPHERES

## **STUDYING THE EARTH'S INTERIOR:**

Earth is composed of a thin crust, a thick mantle, and a core. The three layers are distinguished by different chemical compositions. Scientists have learned a remarkable amount about the Earth's structure even though the deepest well is only a 12-kilometer hole in northern Russia. Scientists deduce the composition and properties of the Earth's interior by studying the behavior of seismic waves.

# EARTHQUAKES AND THE EARTH'S SPHERES

## **STUDYING THE EARTH'S INTERIOR:**

Some of the principles necessary for understanding the behavior of seismic waves are as follows:

1. In a uniform, homogeneous medium, a wave radiates outward in concentric spheres and at constant velocity.
2. The velocity of a seismic wave depends on the nature of the material that it travels through. Thus, seismic waves travel at different velocities in different types of rock. In addition, wave velocity varies with changing rigidity and density of a rock.

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## **STUDYING THE EARTH'S INTERIOR:**

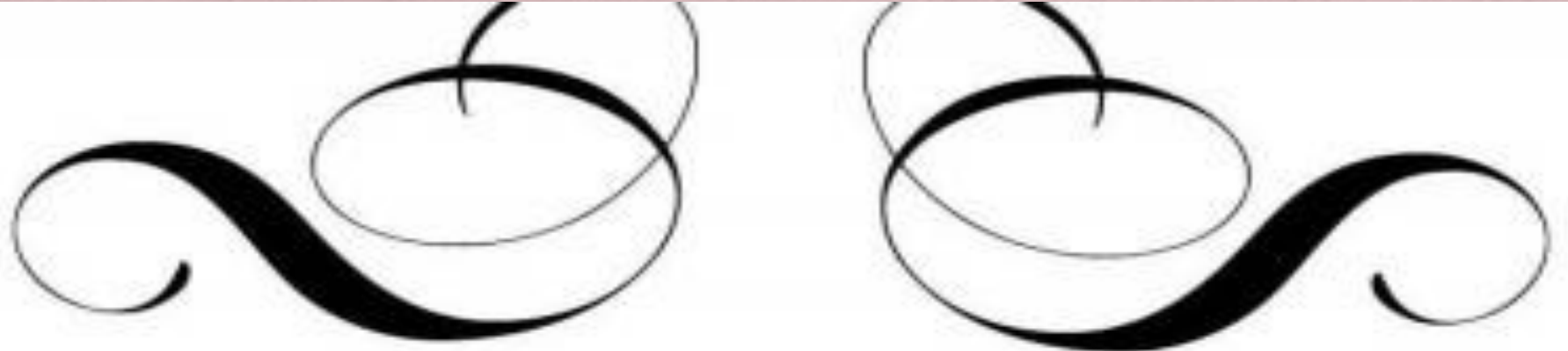
3. When a wave passes from one material to another, it refracts (bends) and sometimes reflects (bounces back). Both refraction and reflection are easily seen in light waves.
4. P waves are compressional waves and travel through all gases, liquids, and solids, whereas S waves travel only through solids.

# EARTHQUAKES AND THE EARTH'S SPHERES

## Questions:

1. *Define Stress and Strain. What Hook's Law states?*
2. *How do rocks store energy, and why do they suddenly release it as an earthquake?*
3. *Define Seismology?*
4. *How many types of seismic waves? Describe briefly.*
5. *Define Focus and Epicenter?*
6. *What is difference between Magnitude and Intensity?*

# EARTHQUAKES AND THE EARTH'S SPHERES



*Thank You*

