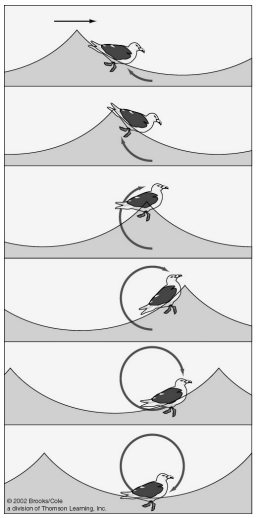
Ocean Waves



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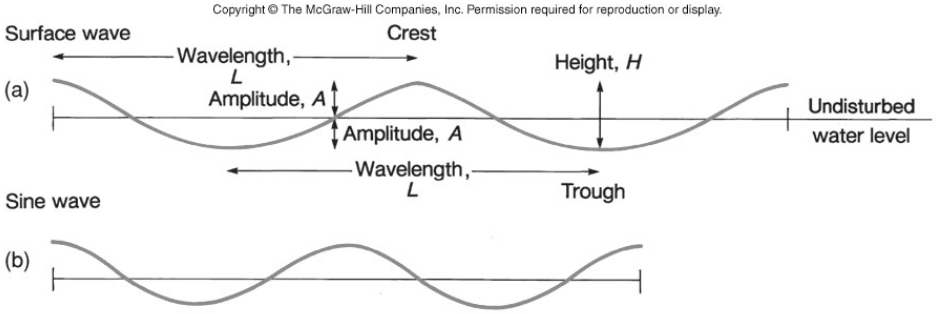


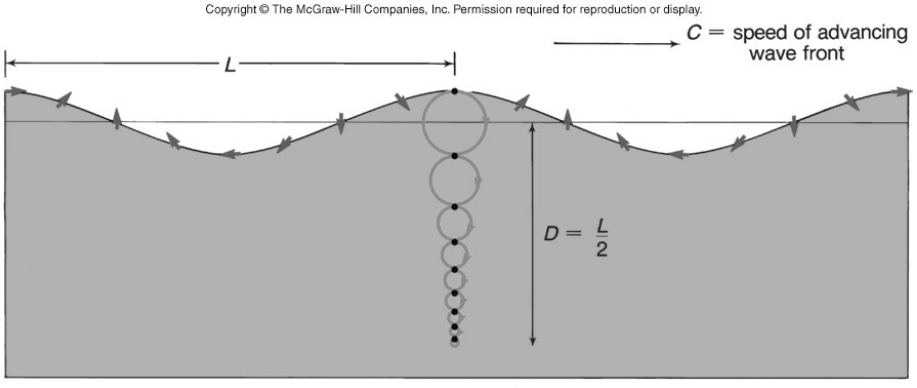
2

A Little Math

- Wave speed = wave length/wave period
- C= L/T

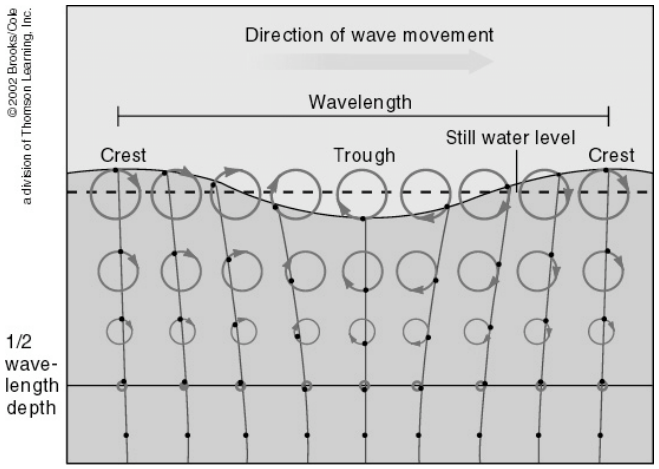
3

Relationship of Wave Length to Depth of Wave Motion



4

Motion of Water as Wave Passes



Water in the crest of the wave move in the same direction as the wave, but water in the trough move in the opposite direction.

5

Classifying Waves

Waves are classified on the basis of:

- Disturbing force
- Free waves vs. forced waves
- Restoring force
- Wavelength

6

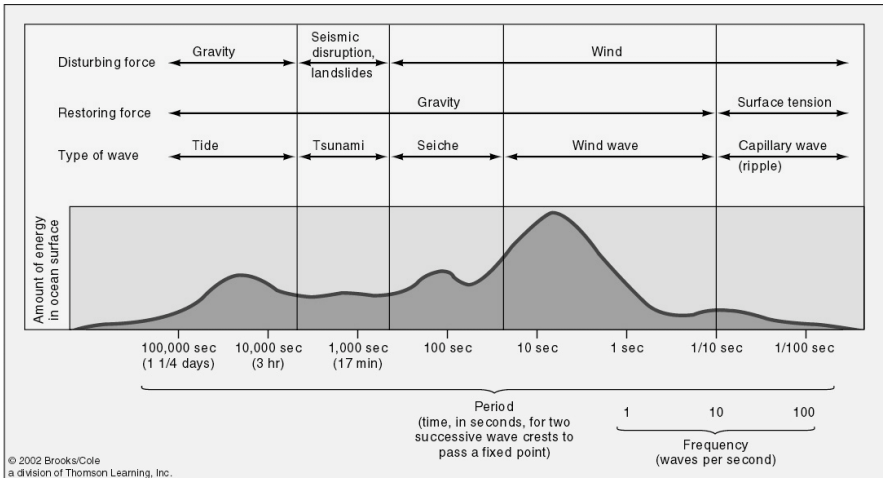
Classifying Waves

Table 10.1 Wavelengths and Disturbing Forces of Important Ocean Waves

Wave Type	Typical Wavelength	Disturbing Force
Wind wave	60–150 m (200–500 ft)	Wind over ocean
Seiche	Large, variable; a function of basin size	Change in atmospheric pressure, storm surge, tsunami
Seismic sea wave (tsunami)	200 km (125 mi)	Faulting of seafloor, volcanic eruption, landslide
Tide	½ circumference of Earth	Gravitational attraction, rotation of Earth

7

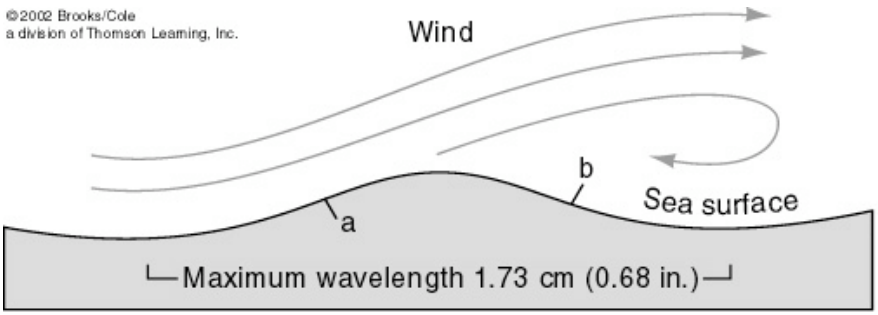
Types of Waves



Waves transmit energy across the ocean's surface.

8

Wind Waves



Wind waves are gravity waves formed by the transfer of wind energy into water. Wind forces convert capillary waves to wind waves.

9

Factors Affecting Wind Wave Development

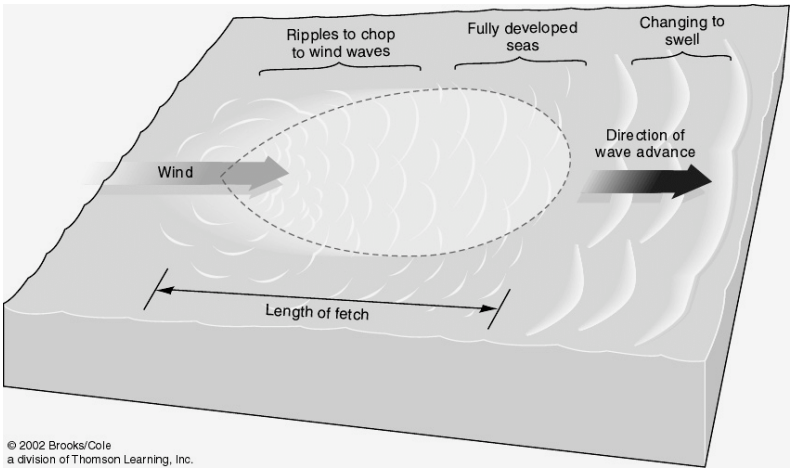
Wind strength - wind must be moving faster than the wave crests for energy transfer to continue

Wind duration - winds that blow for a short time will not generate large waves

Fetch - the uninterrupted distance over which the wind blows without changing direction

10

Factors Affecting Wind Wave Development



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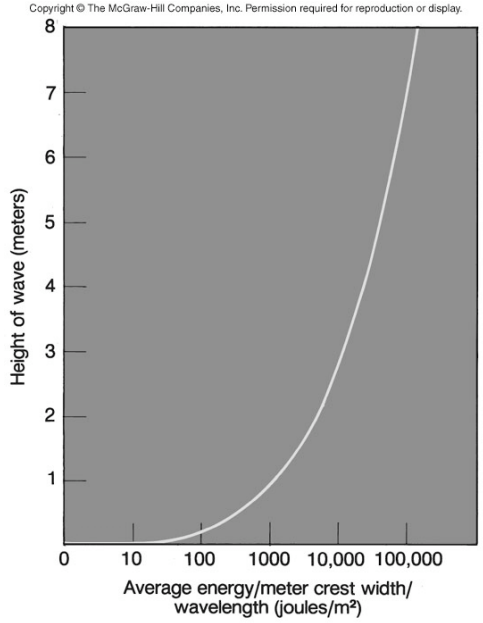
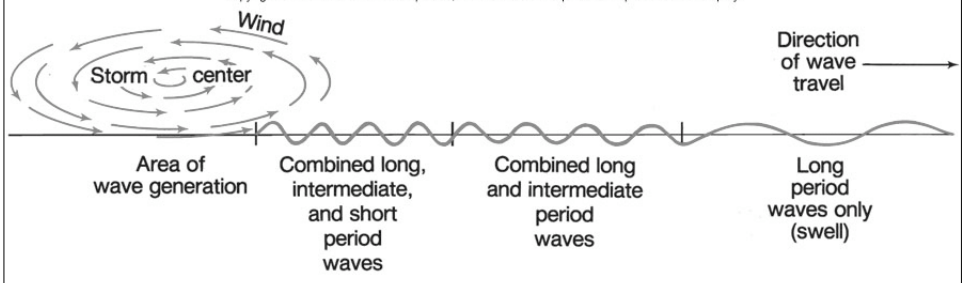


Relationship between wave height and wave energy

12

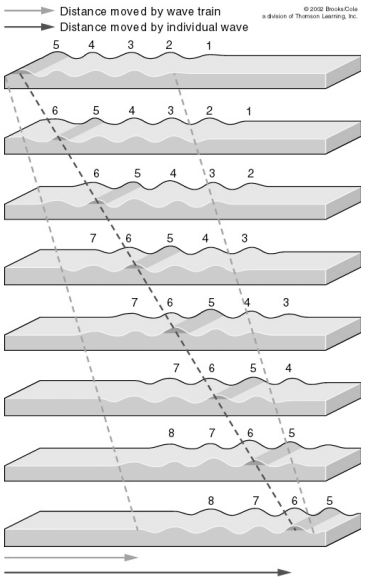
Wave Dispersion



The longer the wave length, the faster the wave speed.

13

Swell Formation and Dispersion



Wave separation, or **dispersion**, is a function of wavelength. Waves with the longest wavelength move the fastest and leave the area of wave formation sooner. The smooth undulation of ocean water caused by wave dispersion is called **swell**.

A wave train.

14

Interference And Rogue Waves

When waves from different directions meet, they **interfere** with one another.

Wave interference can be:

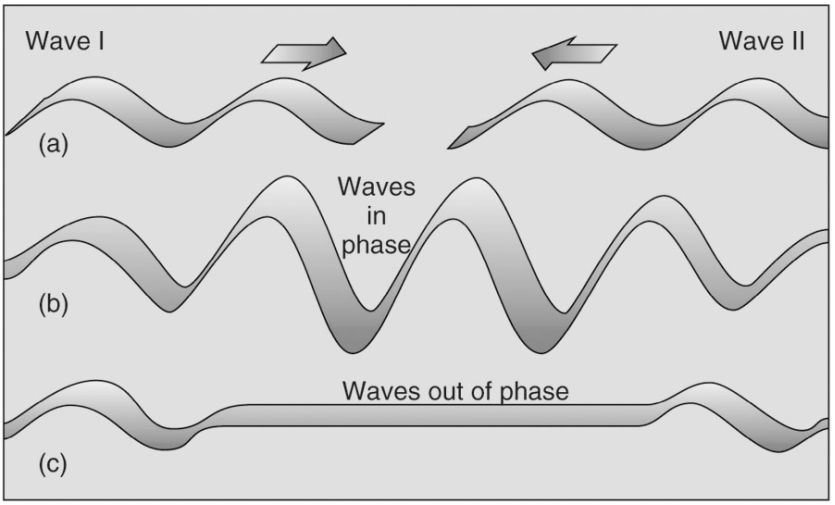
Destructive interference – two waves that cancel each other out, resulting in reduced or no wave

Constructive interference – additive interference that results in waves larger than the original waves

Rogue waves - freak waves that occur due to interference and result in a wave crest higher than the theoretical maximum

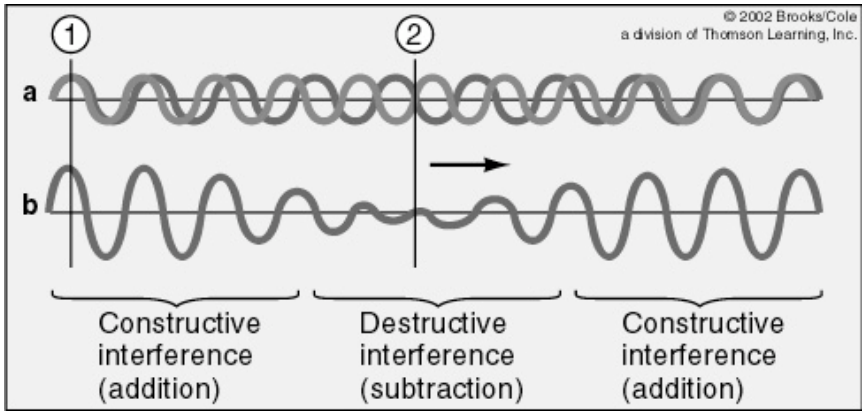
15

Wave Interference



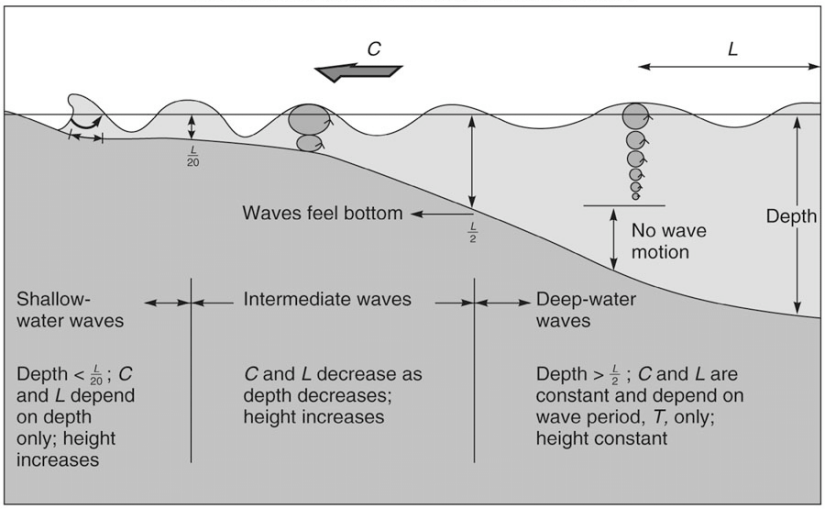
16

Wave Interference



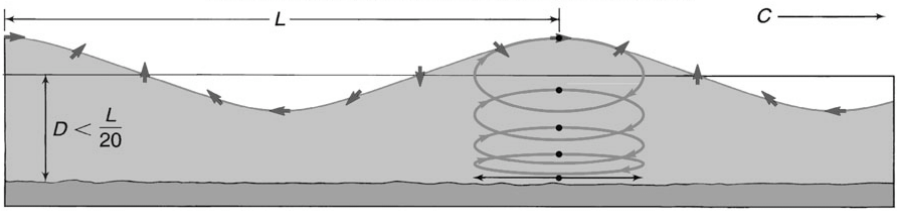
17

Waves Entering Shallow Water



18

Shallow-Water Waves



When waves enter shallow water:

Wave speed decreases

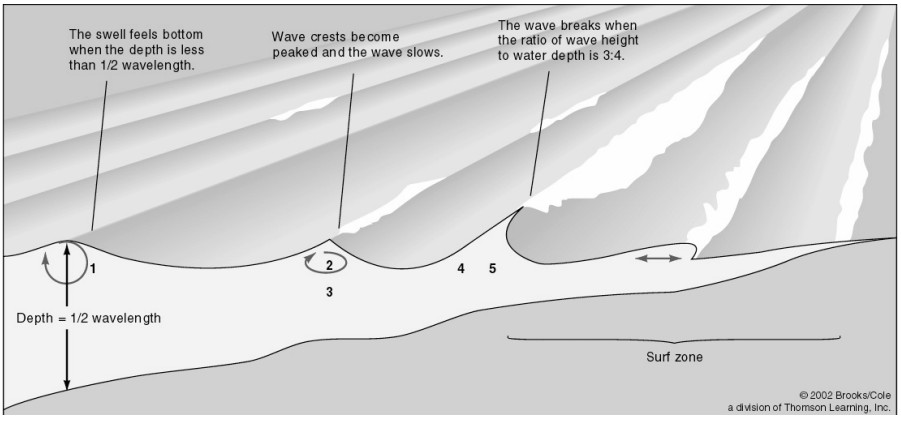
Wave length decreases

Wave period does not change

Wave height increases

19

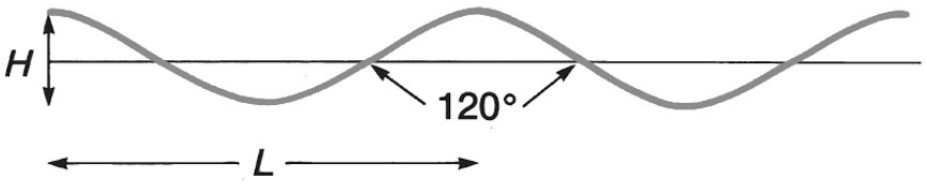
Wind Waves Approaching Shore



What happens when wind waves break against the shore?

20

Wave Steepness



Maximum height for a given wavelength is based on H/L. If H/L > 1/7, wave becomes too steep.

21

Breaking Waves

Plunging waves break violently against the shore, leaving an air-filled tube, or channel, between the crest and foot of the wave. Plunging waves are formed when waves approach a shore over a steeply sloped bottom.

Spilling waves occur on gradually sloping ocean bottoms. The crest of a spilling wave slides down the face of the wave as it breaks on shore.

22

Wave Refraction, Diffraction, and Reflection

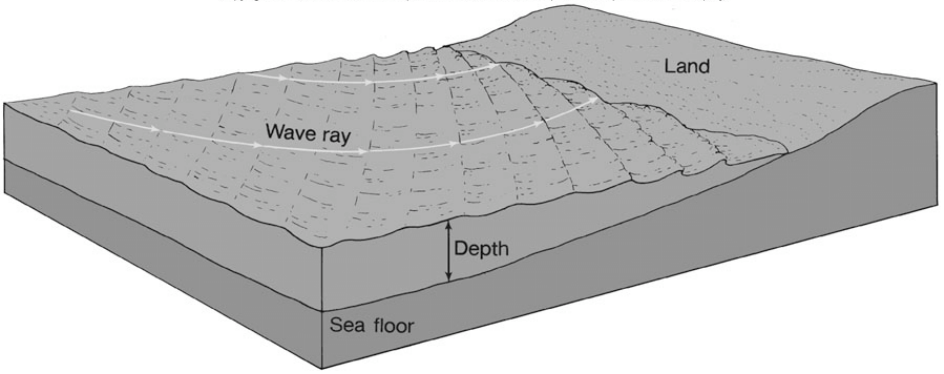
Wave refraction - the slowing and bending of waves in shallow water

Wave diffraction - propagation of a wave around an obstacle

Wave reflection - occurs when waves "bounce back" from an obstacle they encounter. Reflected waves can cause interference with oncoming waves, creating **standing waves**

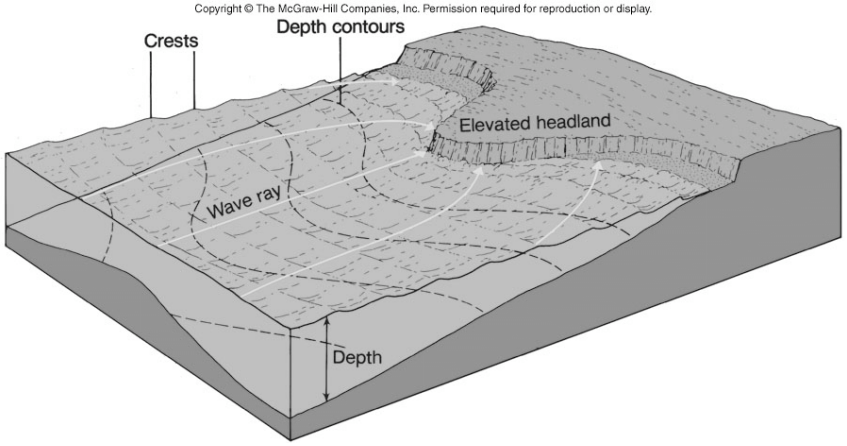
23

Wave Refraction



24

Wave Refraction



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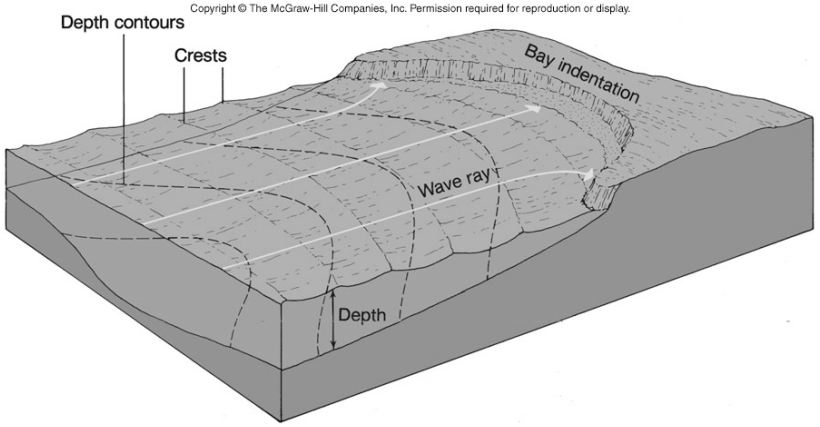
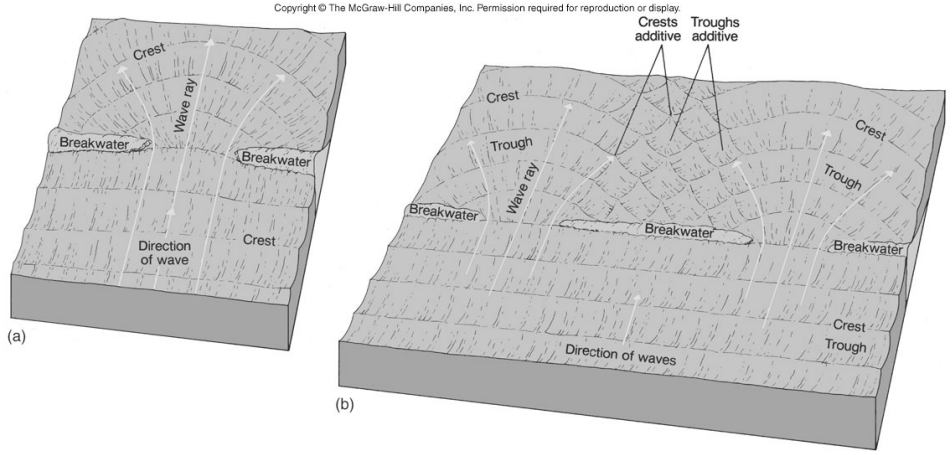


26

Wave Diffraction



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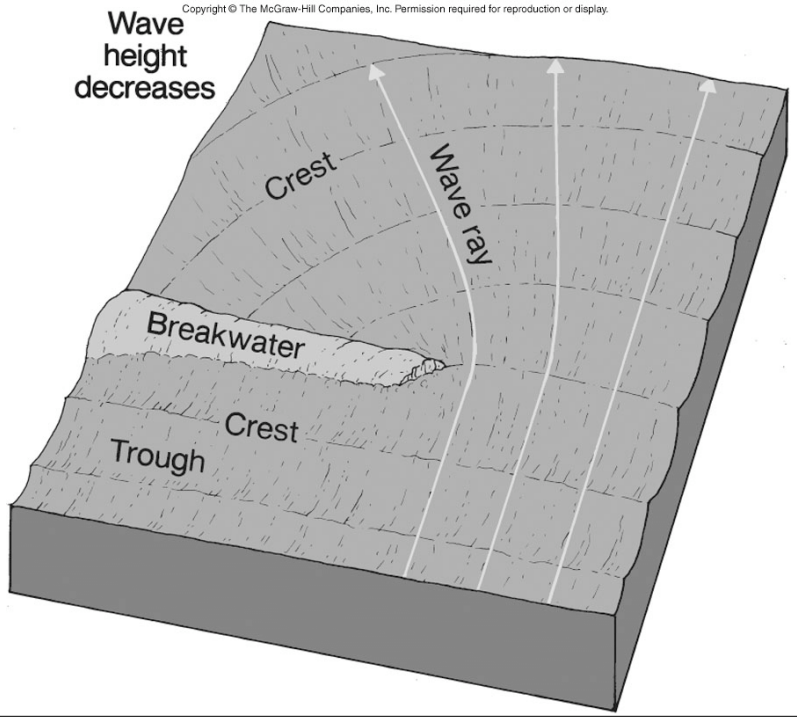
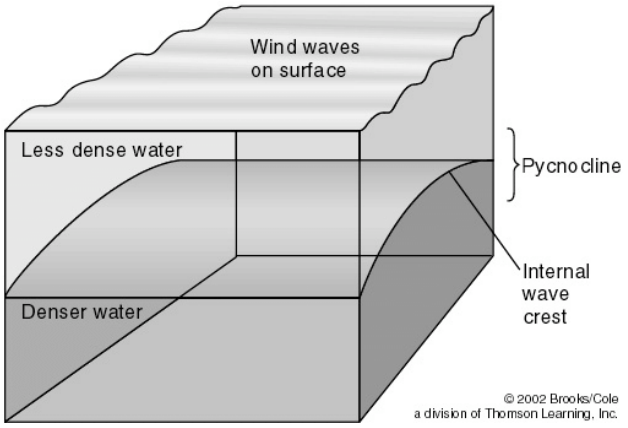


28

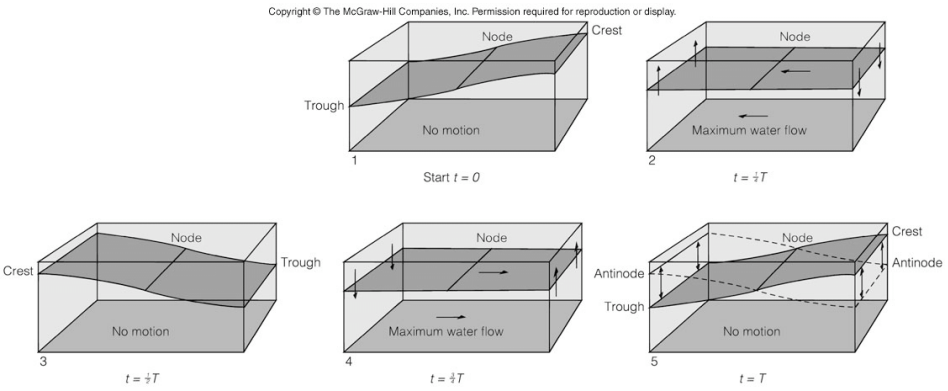
Internal Waves



Waves that occur at the boundaries of water layers with different densities are called internal waves.

29

Standing Waves or Seiches



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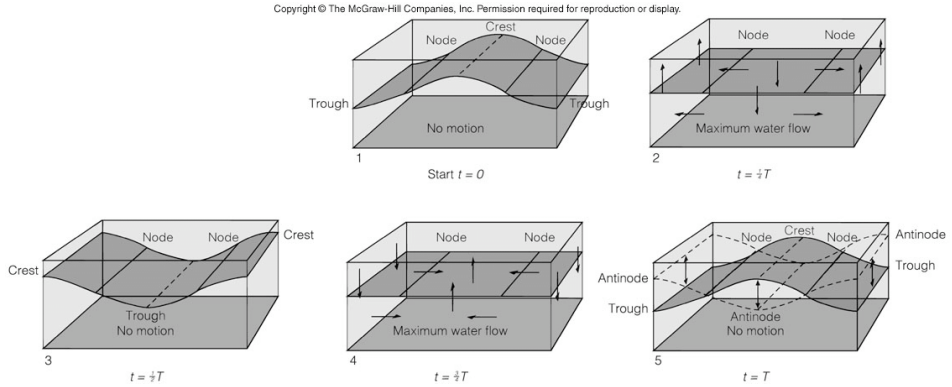

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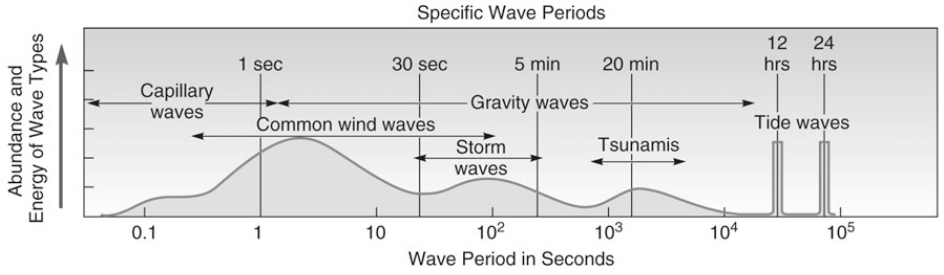

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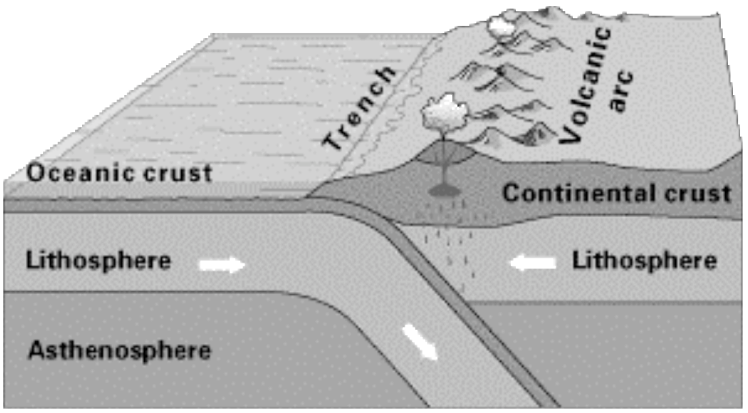


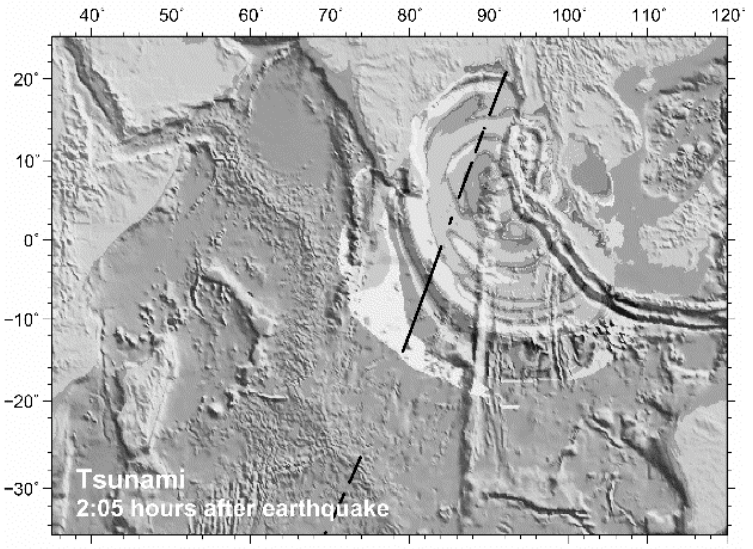
Oceanic-continental convergence

33

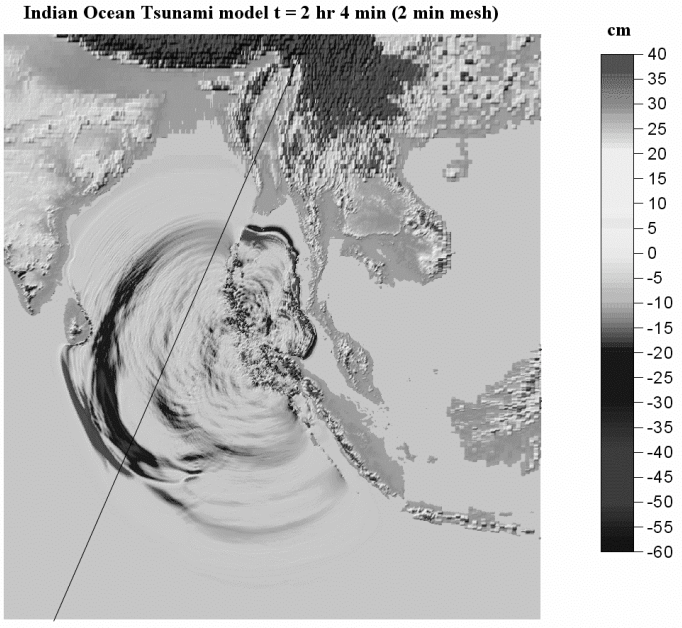
Sumatra-Andaman Island Earthquake

- Magnitude 9.0
- Sunday, Dec. 26, at 7:58 a.m. local time
- 30 km off the west coast of northern Sumatra
- 250 km SSE of Banda Aceh
- Fourth largest in the world since 1964 Prince William Sound, Alaska, quake
- More casualties than any other tsunami in recorded history

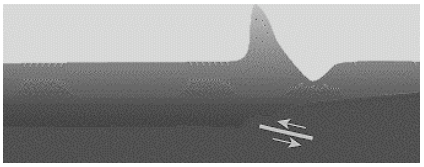
34

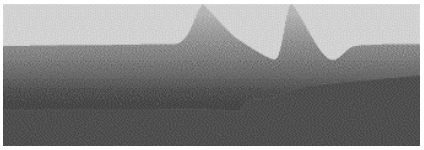

40°
50°
60°
70°
80°
90°
100°
110°
120°
20°
10°
0°
-10°
-20°
-30°
Tsunami
2:05 hours after earthquake

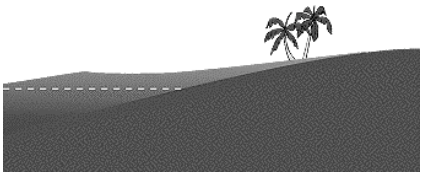
35


Indian Ocean Tsunami model t = 2 hr 4 min (2 min mesh)
cm
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
Model data at 2 hr 5 min

36

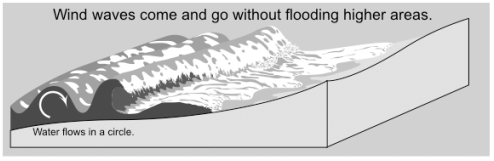


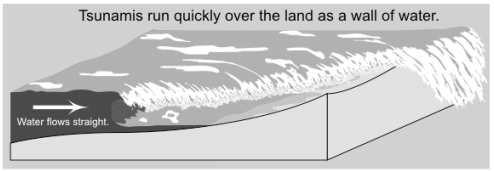




37

Tsunamis are often no taller than normal wind waves, but they are much more dangerous.

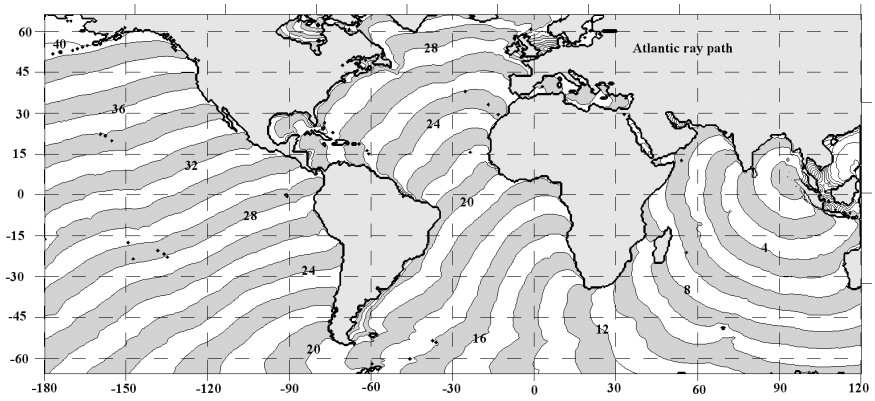




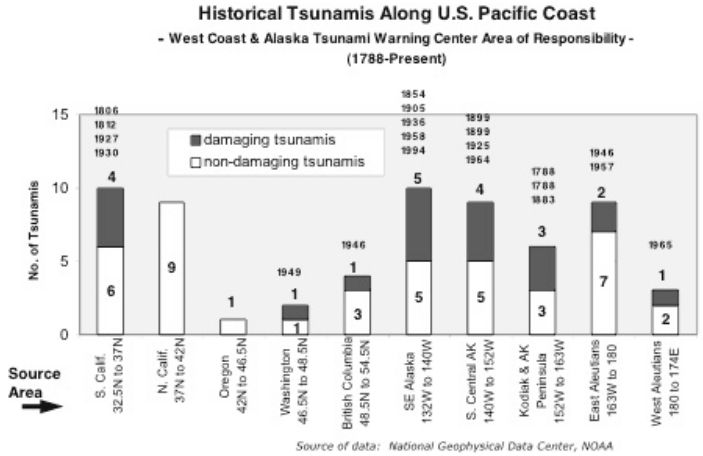
Even a tsunami that looks small can be dangerous!

Any time you feel a large earthquake, or see a disturbance in the ocean that might be a tsunami, head to high ground or inland.

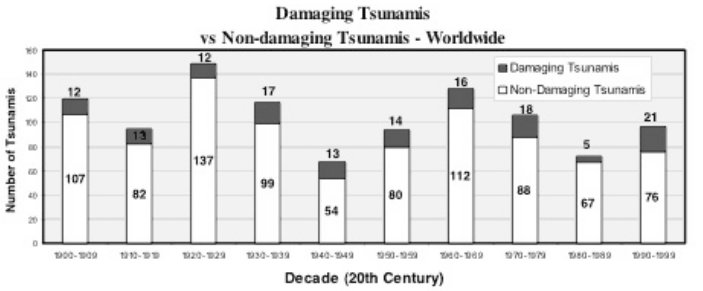
38


Atlantic ray path
60
45
30
15
0
-15
-30
-45
-60
-180
-150
-120
-90
-60
-30
0
30
60
90
120
40
36
32
28
24
20
16
12
8
4

39


Historical Tsunamis Along U.S. Pacific Coast
- West Coast & Alaska Tsunami Warning Center Area of Responsibility -
(1788-Present)
damaging tsunamis
non-damaging tsunamis
No. of Tsunamis
Source Area
S. Calif. 32.5N to 37N
N. Calif. 37N to 42N
Oregon 42N to 46.5N
Washington 46.5N to 48.5N
British Columbia 48.5N to 54.5N
SE Alaska 132W to 140W
S. Central AK 140W to 152W
Kodiak & AK Peninsula 152W to 163W
East Aleutians 163W to 180
West Aleutians 180 to 174E
1806 1812 1927 1930
1949
1946
1854 1905 1936 1958 1994
1899 1899 1925 1964
1788 1788 1883
1946 1957
1965
Source of data: National Geophysical Data Center, NOAA

40



Most Damaging Tsunamis Worldwide

Deaths	Year	Location Name
40000	1782	S. CHINA SEA
36500	1883	S. JAVA SEA
30000	1707	TOKAIDO-NANKAIDO, JAPAN
26360	1896	SANRIKU, JAPAN
25674	1868	N. CHILE
15030	1792	SW. KYUSHU ISLAND, JAPAN
13486	1771	RYUKYU TRENCH
8000	1976	MORO GULF, PHILIPPINES
5233	1703	TOKAIDO-KASHIMA, JAPAN
5000	1605	NANKAIDO, JAPAN
5000	1611	SANRIKU, JAPAN
3800	1746	LIMA, PERU
3620	1899	BANDA SEA, INDONESIA
3000	1692	JAMAICA
3000	1854	NANKAIDO, JAPAN
3000	1933	SANRIKU, JAPAN*
2243	1674	BANDA SEA, INDONESIA
2182	1998	PAPUA NEW GUINEA
2144	1923	TOKAIDO, JAPAN
2000	1570	CHILE
1997	1946	NANKAIDO, JAPAN
1700	1766	SANRIKU, JAPAN
119	1964	ALASKA, USA

Note: Statistics quoted before 20th Century are approximate

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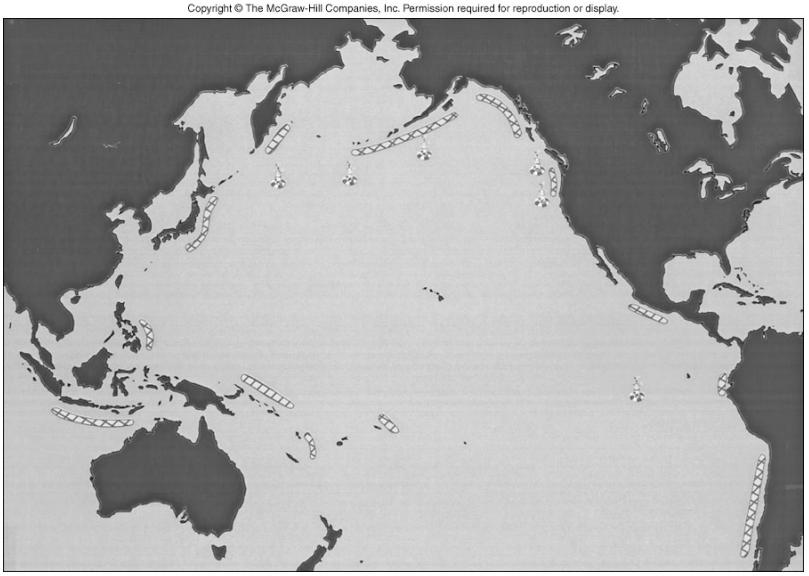
Tsunami Warning Network



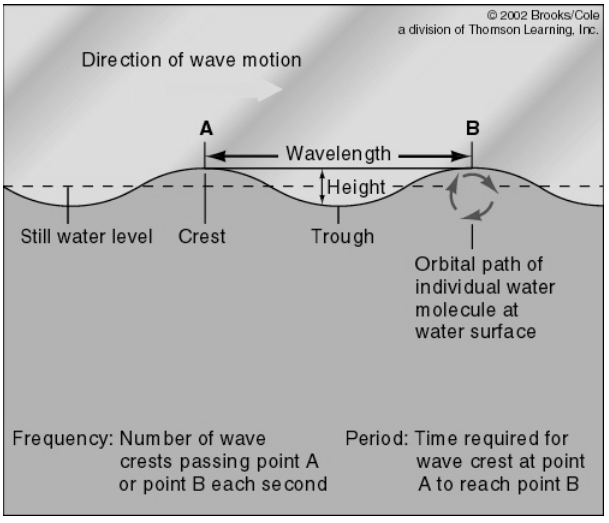
42

Key Ideas

- **Waves transmit energy, not water mass, across the ocean's surface.**
- **The behavior of a wave depends on the relation between the wave's size and the depth of water through which it is moving.**
- **Wind waves form when energy is transferred from wind to water.**
- **Waves can change direction by refraction and diffraction, can interfere with one another, and reflect from solid objects.**

43

Summary



Parts of an ocean wave

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