Why Study The Oceans?
(Why Should We Care?)

I Oceans Occupy Most of the Earth’s Surface

II Much of the World's Population Lives in Coastal Areas

III Marine Resources

IV Waste Disposal - 50 million tons/yr

V Transportation

VI Military

VII Tourism/Recreation/Aesthetics

VIII Oceans Influence Climate

IX Record of Earth History

X A New Frontier
I Earth Is A Water Planet

- 71% of Surface Covered by Oceans
- Average Depth 4 km
- Oceans Contain 97% of all Water

II Much Of The World’s Population Lives In Coastal Areas

- only 2% of Earth’s surface
- occupied by 50% of world’s population
  (estimated 75% by 2050)
So, what’s the big deal?

• Vulnerable Populations
  - Storms
  - Earthquake-generated Tsunamis
  - Rising Sea Level

• Impact the Ocean Environment
  - Pollution
  - Habitat alteration

• Rely on Oceans for Food
Tsunamis
The US is Not Immune
• Large Events in AK and HA
• Huge Ancient Events in WA
• Potential East Coast Disaster

Rising Sea Level
• 1 billion people at risk
• Some island nations at risk of loosing their homeland
Impacts On Ocean Environments
Reefs At Risk

- 27% of coral reefs are severely damaged
- one-half of all coastal wetlands have been destroyed
III Marine Resources

Seafood

- Important protein source for 1 billion people in developing nations
- Unfortunately, catches are declining

Destructive or Wasteful Fishing Techniques
- Fish Traps
- Blast Fishing

Aquaculture – a solution?
III Marine Resources

Energy Resources
- Hydrocarbons
- Tidal Power
- Wave Power?

Minerals From The Sea Floor
- Manganese Crusts and Nodules
- Sulfides Minerals From Deep-Sea Vents

Building Materials
- Limestone for cement
- Sand to replenish beaches and barrier islands
III Marine Resources

Medical Applications

• Antimalarial drugs from sponges
• Anticancer drugs from corals
• Acyclovir (anti Herpes drug) from a Caribbean sponge
• Bone grafts from coral
• Glucosamine from shrimp and crabs
III Marine Resources

Water

• Icebergs?

• Desalination plants (reverse osmosis or flash distillation)

“Bioneering”

• Humpback Whale Fin
  (Turbine Blade Based on Whale Fin)
IV Waste Disposal – 50 million tons/yr

- Industrial Wastes
- Hydrocarbons
- Agricultural Run Off
- Sewage
- Plastic Products

- Contributes to coastal “dead zones”
V Transportation

• Today – Main method of transporting cargo

• In Past – Main method of travel

VI Military Significance

• Hide submarines

• Control shipping and transportation
VII Tourism

• Provides revenues

• Can be done in an environmentally-responsible manner

• May impact infrastructure

• May impact marine resources
VIII Oceans Have A Major Effect On Climate
e.g. Gulf Stream

e.g. El Nino

IX Ocean Sediments Provide A Record Of The Earth’s History

• Climate Signal In Chemistry of Skeletons

• Record of Plate Tectonics

X The Oceans Still Represent A New Frontier

• Surfaces of Moon and Venus are better known than our own sea floor

• Many new organisms are waiting to be discovered
History Of Marine Studies

I Early Times (1500-0 B.C.) - Chiefly Utilization of Resources
   Some Impressive Feats of Navigation

II The Middle Ages (A.D. 900-1200) - Little Science,
   Improvements in Navigation

III Voyages of Discovery and Conquest
   (15th and 16th Centuries)

IV Beginnings of Ocean Science (Largely 19th Century)

V World War II and Postwar - Science Benefits

VI Modern Times (1950s - ) - Big Science, Remote Sensing
I Early Times (1500-0 B.C.) - Chiefly Utilization of Resources, Some Impressive Feats of Navigation

- Phoenicians (1500-500 B.C.) – Mediterranean, around Africa, to England
- Arabs (1500-500 B.C.) - Indian Ocean
- Polynesians (1500-500 B.C.) – Pacific ***
- Greeks (~350 B.C.) – Mediterranean and Atlantic
Milestones in Early Marine Science

- Chinese 400 B.C. – magnetic compass***

- Aristotle (384-322 B.C.) - Catalog of marine organisms

- Alexander the Great (356-323 B.C.) used diving bell to study marine life ***

- Library at Alexandria (~300 B.C. - A.D. 415) - repository for sailing charts and information (among other topics) Eventually burnt by angry mob

- Eratosthenes - ~200 B.C. - Librarian at Alexandria, calculated true circumference of Earth (~40,000 km) developed system of latitude and longitude lines***
• Posidonius (135-50 B.C.) - Depth soundings to 1800m

• Pliny the Elder (A.D. 23-79) - Related tides to lunar phase

• Ptolemy (A.D. 51-127) - Atlas w/ Lat & Long, degrees, minutes, seconds, 8,000 localities. (BUT - Incorrectly recalculated circumference of Earth at 29,000km) ***
II The Middle Ages (A.D. 900-1200) –
Little Science, Improvements in Navigation

• Vikings (A.D. 700-1000) - Reached N. America! ***

• Arabs (1000s) - Trade w/ India

• Chinese (1200s) - Trade w/ Persia

• 13th Century - Magnetic compass (Chinese to Arabs to Europeans by 1300s) ***

• 1416 - Prince Henry of Portugal, School for Navigators

• Importance of latitude and longitude - how determined?
• Earth rotates west to east (counter clockwise when viewed from north pole – that’s why the sun rises in the East and sets in the West).

• Latitude lines (parallels) run east-west, circumference changes, have a natural reference point – the equator.

• Longitude lines (meridians) run north-south, circumference doesn’t change, no natural reference point.

Latitude is determined by declination of the sun or north star (polaris).

We are at 42° N lat.

Therefore north star appears halfway above the horizon.
How to Determine Longitude? More difficult.

Note:

• Prime meridian (0° longitude) is arbitrarily located at Greenwich, England

• Earth completes a rotation on its axis once every 24 hours.

• Earth’s surface divided into 24 time zones, each cover 15° (360° divided by 24 zones). Each zone is approx. 1670 km wide at equator.

• At equator, Earth’s circumference is ~40k km (therefore, rotating at 1,670 km/hr at equator).
Longitude is determined by comparing local noon to Greenwich noon.

Requires highly accurate chronometer (in 1500s, the Spanish offered 100,000 crowns, in 1700s, the British offered L20,000)

We are 7 time zones west of Greenwich.

Therefore, $7 \times 15^\circ = 105^\circ$ west of Greenwich (actually at $111^\circ W$).
III Voyages of Discovery and Conquest
(15th and 16th Centuries)

• Chinese (early 1400s) - Major expeditions to explore Pacific and Indian Oceans (advanced ship building - including watertight compartments, central rudder, new sail design, very large ships)

• Bartholomeu Dias (1450-1500) - Sailed around Africa (1487)

• Christopher Columbus (1451-1506) - Landed in Americas (1492) (recall Ptolemy’s calculations!)
III Voyages of Discovery and Conquest
(15th and 16th Centuries)

• Vasco de Gama (1469-1524) - Sailed around Africa and to India

• Amerigo Vespucci (1454-1512) - Explored S. America

• Magellan (1480-1521) - First circumnavigation of globe, measured circumference of earth (1519-1521) confirmed Eratosthene’s calculation. ***

• Francis Drake (1540-96) – Circumnavigation, pirate
IV Beginnings of Ocean Science
(Largely 19th Century)

• James Harrison - Accurate chronometer (1761) ***

• James Cook (1728-79) - 3 Voyages of circumnavigation (1768-1779), took soundings and recorded current and temp. information, understood causes of scurvy, charts used by allies in WWII! ***

• First use of submarine in naval engagement – “Turtle” (1776) ***

• Alexander von Humboldt (1769-1859) - Cruise to S. America (1799-1804)

• U.S. Coast and Geodetic Survey (1807), U.S. Naval Hydrographic Office (1830)

• Charles Darwin (1809-82) - Voyage of the Beagle (1831-36) ***
IV Beginnings of Ocean Science – cont. (Largely 19th Century)

• Edward Forbes (1815-54) - Biotic zonation

• Johannes Muller (1801-58) - Marine plankton

• Wyville Thomson (1830-8) - Book, The Depths of the Sea (1873)

• The Challenger Expedition (1872-76) – first expedition dedicated solely to oceanography, depth soundings to 8,000+m, 4,700 new species! ***

• Albatross, USA (1882) - First dedicated RV (research vessel)

• Fridtjof Nansen (1861-1930) - The Fram Expedition (1893-96)
V World War II and Postwar
(Science Benefits)

• Radar, sonar, depth recorders ***

VI Modern Times (1950s- ) – Big Science

• Rise of oceanographic institutions

• IGY - International Geophysical Year (1957-58)

• Charles William Beebe (1877-1952) – designed bathysphere, reached 923 m (3,000’) off Bermuda in 1934, his descriptions of marine life were not believed! ***

• Auguste Piccard (1884-1962) - designed bathyscaphe Trieste, reached 10,915 m (36,000’) in Marianas Trench in 1960 ***
VI Modern Times - Big Science (cont.)

• Glomar Challenger/DSDP - Deep Sea Drilling Program (1960s)

• NOAA - National Oceanic and Atmospheric Administration (1970)

• Indian Ocean Expedition (1963-64)

• IDOE - International Decade of Ocean Exploration (1970s)

• Manned and remotely-operated submersibles

• Satellites and remote sensing ***

• Joides Resolution - Drilling Ship (1985 - ) ***

• Global climate change programs
Satellites - Remote Sensing

- Sea surface temperatures
- Wave heights
- Storms
- Current patterns
- Ocean productivity
Ocean Technology
How to Investigate the Oceans?

I Difficulties

II Direct Means of Sampling

III Indirect Means of Sampling

IV Types of Oceanographic Data

V Geophysical Techniques

VI Satellites/Remote Imaging
I Difficulties of Exploring the Oceans

• Breathing!

• Oceans are Deep (4 km avg)
  - Pressure effects
  - Difficult to reach seafloor

• May be Cold

• Absorption of Electromagnetic Radiation

• Sea Water is Corrosive

• Sea Surface is Dynamic
Effects of Pressure – Crushing

• 1 Atmosphere = 10m seawater =
  1.03 kg/cm²

• 4 km (average depth) = 400 atm =
  412kg/cm² (5,845#/square inch)

• 11 km (trench) = 1,100 atm =
  1,133kg/cm² (16,077#/square inch)
Effects of Pressure (cont.)

• Crush rigid objects

• Can tear soft tissues (e.g. eardrums, sinuses)

• Compresses gases in lungs

  Possible embolism or pneumothorax upon surfacing

Life Saving Tip # 1 – Always exhale during ascent when breathing compressed gas

• Increase gas partial pressures

  Nitrogen narcosis (w/ depth) – “the martini rule”

  Oxygen toxicity (w/ depth) – can cause convulsions

  The bends (w/ depth and time) – upon surfacing, usually caused by nitrogen bubbles
Dealing With Pressure (cont.)

The Bends

- Limit depth/time (e.g. 25 mins at 100’, 200 mins at 30’)
- Take decompression stops
- Saturate (and decompress later)

Narcosis/Oxygen Toxicity

- Don’t go deep
- Breath something other than air

  Nitrox – Oxygen-enriched air (for moderate depths only)
  Heliox – Mainly Helium, small amounts $O_2$ (for deep dives)

- Use 1 atmosphere suits, submersibles, ROVs
II Direct Sampling of the Oceans: Going There - Diving Technology

- SCUBA – Self-contained, underwater breathing apparatus (Jacques Cousteau) – usually open circuit
- Closed-circuit, mixed-gas rebreathers
- Surface-supply diving (hard hat and band mask)
- Diving bells
- Saturation habitats
- 1 atmosphere “Jim” suits
- Research submersibles
III Indirect Means of Sampling the Oceans

Remotely-Operated Vehicle (ROV) –

e.g. Ropos (Canadian)

Research Vessels -
e.g. RV Thomas Thompson
IV Types of Oceanographic Data

• Community composition
  – Benthos
  – Nekton
  – Plankton
• Ocean sediment
• Currents
• Water chemistry
• Bathymetry (depth)
• Subsurface geology
• Waves
• Water temperature
• Productivity
Collecting Oceanographic Data May Involve

- SCUBA Diving
- Submersibles
- ROVs
- Research Vessels (RVs)
- Satellites
Sampling Plankton

• Plankton nets
• Plankton traps

Sampling Ocean Sediment

• Diver-Collected Sediment Core
• Collecting Sediment with Submersible Arm
• Clamshell Sampler
• Piston Corer
• Diver-Operated Drill
• Joides Resolution Deep-Sea Drilling Ship
• Dredge Samples
Water Chemistry

CTD Probe

- Conductivity (Salinity)
- Temperature
- Dissolved Oxygen

Niskin Array for Water Sampling
Measuring Ocean Currents

- Drifters
- Drogues
- Sofar Buoys
- Acoustic (Doppler) Arrays
V Geophysical Techniques

• Gravity – reveals subsea mountains

• Magnetics – reveals seafloor spreading (and submarines)

• Sonar – sound pulse, depth & bottom topography

• Seismology – energy pulse, subsurface layers
Depth

• Line Soundings

• Echo Sounder or Fathometer
  - Single-Pulse Echo Sounder
  - Side-Scan Sonar
  - Multibeam Echosounder
VI Satellite Oceanography

Active Sensors – radar, laser

• Sea Surface Roughness
• Sea Surface Elevation
• Submarine Topography (Indirectly!)

Passive Sensors (receive reflected electromagnetic radiation)

• Hurricane Tracking
• Turbidity (sediment in water)
• Chlorophyl / Productivity
• Temperature
GEOLOGY OF THE WORLD’S OCEANS

Plate Tectonics

I Development of Theory

II Mechanism

III Plate Boundary Types

IV Tectonics of Americas

V North American Tectonic Belts

VI Wilson Cycle/Supercontinent Cycle

VII Phanerozoic Tectonics
I Development of Theory

Principal Figures

• Alfred Wegener - “Continental Drift”, Pangea ****

• Harry Hess - Sea Floor Topography

• Fred Vine & Drummond Matthews – Magnetic Reversals

• J Tuzo Wilson - Ridge Transforms

• D P McKenzie & R L Parker – “Plate Tectonics”
I Development of Theory (cont.)

Evidence for Plate Tectonics Available to Alfred Wegener

• Fossil distributions (e.g. *Glossopteris*)

• Paleoclimate indicators (e.g. tillites and coals)

• Fit of continental outlines

• Match of mountain ranges and ore bodies
I Development of Theory (cont.)
Modern Evidence for Plate Tectonics

• Patterns of seismicity
  - General distribution of earthquakes
  - Shallow vs deep foci

• Patterns of volcanism (e.g. ring of fire)
  - Distribution
  - Composition (explosive or not)

• Age patterns of seafloor

• Seafloor topography

• Geomagnetism
  - Magnetic anomalies
  - Polar wandering
II Mechanism

- Seismology – Provides evidence
- Structure of Earth Crust, Mantle, Core
- Mantle Convection
- Push or Pull?
- Lithospheric Plates

Mechanism
Ridge Push and Trench Pull
III Plate Boundary Types

• Divergent
  - Mid Ocean Ridges
  - Ocean Rift (Sea of Cortez, Red Sea)
  - Continental Rift (East Africa, Great Basin)

• Convergent (Subduction “factory” makes continental crust)
  - Ocean to Ocean (Aleutians, Japan, Indonesia, Lesser Antilles)
  - Ocean to Continent (NW US Cascades, Cent America, S America Andes)
  - Continent to Continent (Alps, Himalayas)

• Strike-slip (San Andreas, Mid Ocean Ridge offsets)

• Hot Spots – e.g. Hawaiian Islands and Snake River Plain/Yellowstone are not plate boundaries
IV Tectonics of Americas

- Plates
- Microplates

V North American Tectonic Belts

- Craton
- Platform
- Mobile Belts - Leading and Trailing Edges
- Terranes
VI Wilson Cycle/Supercontinent Cycle

• Sedimentation on Trailing Edge (Passive Margin)

• Convergence and Deformation (Active Margin)

• New Material “Welded” to Continent
VII Phanerozoic Tectonics

How to determine plate positions? (Remember that there is no seafloor older than ~200Ma)

• Paleoclimate indicators

• Paleomagnetism
  - Magnetic anomalies
  - Polar wandering

• Seafloor age patterns

• Biogeography
VII Phanerozoic Tectonics

Patterns over time

- Rifting of Pre-Phanerozoic Supercontinent (Rodinia)
- Paleozoic Assembly of Pangea
- Mesozoic and Cenozoic Rifting of Pangea