Phylum Cnidaria

(=Jellyfish & Corals)

9,000 living species, 9,300 fossil species

include:
- jellyfish
- sea anemones
- corals
- sea fans
- sea whips

another very **ancient group** with lots of **fossil** representatives

simplest living animals with true tissues

longest fossil history of any animal

known fossils are even more ancient than sponges

going back at least 700 M years

(plenty of hard parts – corals)

in terms of evolutionary history they were the 1st animals to appear that had a definite shape

radial symmetry

all known animals at that time were sessile organisms; cnidaria (jellyfish) may have been the first animals to swim

most members of the phylum (eg. corals) are **sessile**

often beautiful and graceful "plant-like" or "flower-like" forms with one or more rows of large tentacles extending from body

like sponges, ancient scholars considered them some kind of plant

not considered animals until 1700's

but some (eg. jellyfish) swim weakly as part of the **zooplankton**

though sessile almost all are extremely effective **predators**

jellyfish are among the **longest** of animals
up to 9' diameter with 120' tentacles

some colonial forms can grow up to 150' long

as a colony, they rank as some of the longest – lived animals on earth

eg. a gold coral colony off the coast of Hawaii was recently (2009) dated at 2742 years old

eg. a black coral in the same area was dated at 4265 years old

all are **aquatic**

widespread in marine habitats

→ especially shallow waters, warmer oceans

a few found in freshwaters

all but 1 species of fw cnidarians are polyps

but there is one small fw jellyfish: *Craspedacusta*

many are **colonial**

→ groups of individuals usually living together and interconnected eg corals

eg. a single coral colony can contain millions of individuals

tissue level of organization

more complex than sponges but still very simple

do have true **tissues**

body wall is made of 2 layers of tissue

only a few very simple organs

Body Forms

many cnidarians are **polymorphic**

→ with 2 or more separate body forms

with an alternation between forms

→the same species has 2 distinct forms

polyp (=hydroid)

tubular body
usually sessile – though some can move
upward facing mouth surrounded by tentacles

medusa (=jellyfish)

umbrella shaped
mouth facing downward
often, thick jelly-like layer in body wall
→ jellyfish
motile: contractions of "bell"
free floating, pelagic planktonic

polyp ⇄	medusa
sessile	motile
asexual	sexual
benthic	pelagic

Cells & Tissues

two true tissue layers, not the 3 typical of animals

=diploblastic

epidermis & **gastrodermis**

2 well defined embryonic layers:
ectoderm
endoderm

become two adult tissues
epidermis

gastrodermis

between the two tissues is a jelly layer called **mesoglea**

→ very thick in "jellyfish"

nontissue layer of mesoglea in between

in a few species this mesoglea is replaced by 3rd true tissue:

mesoderm → connective tissue

Body Wall

epidermis – tissue layer that lines outer surface

mesoglea – jellylike middle layer; not tissue layer

gastrodermis – tissue layer that lines GVC

1. Epidermis

outer "skin" of the animal

consists of cells that cover and protect

also contain special stinging cells

some areas also have gland cells for attachment

contain nervous and sensory cells

most epidermal cells contain contractile fibers and act like muscle cells to produce movement

Cells of Epidermis:

a. epitheliomuscular cells
covers outside of body
tall T shaped, columnar cells
base elongated with myofibrils
muscular contractions

b. interstitial cells
undifferentiated cells
can form cnidocytes, nerve cells, sex cells, etc
but not epitheliomuscular cells

c. gland cells
around basal disc and mouth
secretes mucus and adhesives
those in basal disc can secrete gas bubble for floating

d. cnidocytes
stinging cells, more later

e. sensory cells
scattered but especially near mouth and tentacles
respond to chemical and tactile stimuli

f. nerve cells
most multipolar (3 or more processes)
form synapses with sensory cells and other nerve cells
connect to epitheliomuscular cells and cnidocytes

2. Mesoglea

not really a tissue layer, just a layer of jelly-like secretions

very thin layer in polyps; much thicker in medusa thus "jellyfish"

3. Gastrodermis

inner lining of the digestive sac

mademostly of cells that digest and absorb food

these cells also contain contractile fibers for movement

Cells of Gastrodermis:

a. nutritive muscular cells
tall T shaped, columnar cells
ciliated
base elongated with myofibrils
lines GVC
in some freshwater species cells contain green algal symbionts
in some marine species cells contain dinoflagellate algal symbionts

b. Interstitial cells
scattered
transform into other cells as needed, see above

c. gland cells
in hypostome and scattered throughout
some secrete digestive enzymes
mucous glands around mouth

Movement

typically polyp is sessile and often secretes a cup like

cavity in which it lives

muscle layers in body wall contract against **hydrostatic skeleton**

some polyps of noncolonial forms are motile

eg. fw hydras are not permanently attached
→ can glide on pedal disc
→ inchworm movements using tentacles
→ gas bubbles and float to surface

medusae are more mobile

have **hydrostatic skeleton**

nerve net controls contractions of bell for swimming

Feeding and Digestion

all are carnivores

most species have one or more rings of **tentacles** surrounding mouth

armed with **cnidocytes** (=stinging cells) for capturing prey

Stinging Cells (cnidocytes)

one of the most characteristic features of the phylum used for feeding and defense

inside each cell is harpoon-like **nematocyst**

→ highly coiled tubular thread
→contained within a capsule like organelle
→ triggerlike cnidocil (tactile trigger)

when triggered can fire in a fraction of a second

discharge due to:

high osmotic pressure within (140 atm; 10x's sea level)
when stimulated to discharge water rushes in
forces thread out with great force – turns inside-out as it extends at 2m/sec
causes barb to flick out like tiny switchblades to impale prey

each cell operates independently

can differentiate between animate and inanimate objects

→ doesn't just fire at anything

cnidoblast must grow new nematocyst after firing

over 20 different kinds

some wrap around prey or are sticky

some with tiny barbs that impale prey & inject poison

most are not harmful to humans

eg. most sea anemones stings are harmless

but a few are very painful

eg. Portuguese Man-O-War and some corals

a few can be fatal

eg. cubomedusae (box jellies)

digestive system is a **mouth** that opens into a saclike cavity

= **gastrovascular cavity** lined with gastrodermis

single opening = **mouth**

incomplete digestive tract → mouth only

digestion mostly extracellular, but some intracellular

most are **predatory**

use cnidocytes to capture and paralyze prey
use tentacles to move prey toward mouth
engulf prey with mouth

inside GVC gland cells secrete digestive enzymes

nutritive muscular cells take in particles by pseudopodia

intracellular digestion completes the process

indigestible material is expelled through mouth

No respiratory or excretory system

Coordination and Control

no head, no cephalization, no CNS

very simple nervous system, no brain

= **nerve net**

mostly for coordinating contractions in body

diffuse network of nerve fibers connect to:
sensory cells
cnidocytes
epitheliomuscular cells
nutritive muscular cells

some simple sense organs:
statocysts → balance
ocelli → light

polyp
simple sensory cells scattered in epidermis

medusae
clusters of sense organs = **rhopalium**

at margins of bell
often between lappets
contains
ocelli → detect light
statocysts → balance organs
sensory pits → chemoreceptors

Life Spans

little is know of lifespans of cnidaria

but one sea anemone kept in an aquarium lived for 80 years until the tank was accidentally drained

some jellyfish can live up to 10 years

Reproduction

both sexual and asexual reproduction

asexual:
asexual reproduction usually by **budding**

if buds remain connected = colonial

fission
sea anemones only
pedal laceration

sexual:
most are dioecious

gonads are epidermal in hydrozoa
gonads are gastrodermal in other groups

most shed gametes into water, often **mass spawnings**

but one species of box jellyfish actually have a "wedding dance"

begins as male takes hold of female tentacle and pulls her around in the water

he then draws her close, male and female become entwined, so that their manubria touch

male deposits a spermatophore on one of her tentacles and releases her

the female ingests the spermatophore which then fertilizes her eggs

embryo in marine species is usually a **planula**

in many members of the group there is an **alternation of generations** between

polyp which reproduces **asexually** and the

medusae which reproduces **sexually**

some Cnidaria can switch genders

males require less food and energy and can more easily survive harsh conditions

when conditions improve more will turn into females to insure their success in producing offspring

Classification

Class: Hydrozoa

most are marine, a few are freshwater
individuals usually small and inconspicuous
polyp is dominant stage, some completely lack medusa
medusa when present has velum around margin
no septae in GVC, no pharynx (=throat), no cells in mesoglea
most are colonial - small plant-like appearance
most have polymorphism with alternation of generations

Class: Scyphozoa (true jellyfish)

most of the larger jellyfish belong to this group
medusae without velum, cells in mesoglea
all are marine
solitary polyp stage reduced or completely absent
thick jelly layer (=mesoglea)

Class: Cubomedusa (box jellyfish, sea wasps)

cubical jellyfish with extremely potent toxins - some lethal

Class: Anthozoa (Corals and Sea Anemones)

="flower animals"
all are marine
polyp only; no medusa stage
many cells in mesoglea
polyp with septae and pharynx
some are solitary = sea anemones, usually larger
most are colonial = corals, polyps usually small
most secrete skeleton of calcium carbonate or protein

A. Class Hydrozoa

most are marine, a few are freshwater

some are colonial

most have **polymorphism** with **alternation of generations**

polyp is dominant stage

some, eg *Hydra*, lack medusa stage

colonial species often have more than two body forms in same organism

different forms act like separate organs and are specialized for feeding, stinging, reproduction

eg. *Hydra* (hydra)
freshwater species
very common in ponds and creeks
feeds on small crustaceans
seems to "prefer" Daphnia
no medusa stage
→ polyp reproduces both asexually and sexually
asexual:
budding as outpockets of body wall
continuous GVC
eventually detach
sexual:
dioecious ovaries or testes are temporary organs on side of polyp
usually appear in autumn (low temp, low O_2)

eggs usually mature 1 at a time
eggs fertilized by sperm, then shed
cyst forms around embryo – overwinters
no larval stage
young hydras hatch from cyst in spring

eg. *Obelia*
common in nearshore marine habitats

more representative of class

have both **polyp** and **medusa** stage

colonial hydrozoan → interconnected hydroid colony

attaches to substrate by rootlike hydrorhiza

branching body = **hydrocaulus**

living tissue = **coenosarc**

chitinous protective covering = **perisarc**

attached to hydrocaulus are individual polyps

two types of **polyps**:

1. **hydranths = feeding polyps**
tubular or vaselike
mouth surrounded by tentacles
capture and ingest prey: worms, crustaceans, larvae
provide nutrition for whole colony
→ digested broth passes thru common GVC of whole colony
cilia of nutritive muscular cells move it

2. **gonangia = reproductive polyps**
no tentacles
medusa bud off sides

medusae

produced by gonangia
small; 2-3mm
velum surrounds inside of bell margin
mouth at end of manubrium
radial canals extend from GVC to margins of bell and ring canal
GVC also extends into tentacles from ring canal

eg. *Craspedacusta*

the only freshwater medusa
hydroid colony is microscopic in size; <2mm
medusa .5 – 1" in diameter

eg. *Physalia* (Portuguese Man-O-War)

colonial hydroid form
irridescent purple color
common on gulf coast
can produce painful sting even if dead
but with several different kinds of polyps:
- float = swimming bell filled with gas
- gastrozoid polyps = each with single long tentacle
- dactylozoids = fishing tentacles
- gonophores = sacs of ovaries or testes

a symbiotic fish, *Nomeus*, swims among the tentacles

B. Class Scyphozoa (true Jellyfish)

most of the larger jellyfish belong to this group
a few up to 2 m in diameter

contains one of the longest animals; lion's mane jellyfish → over 120'

all are marine

with few or many tentacles around margin of bell

medusa stage is dominant

solitary polyp stage reduced or absent

thick jelly layer (=mesoglea)
may contain amoeboid cells and fibers

medusa has no velum

Movement

jellyfish are the most motile members of the phylum

more complicated muscle layers:

muscles arranged in radiating and circular bands

contractions of these muscles allow the organism to propel itself to some degree

still, jellyfish are considered part of the **zooplankton** (the largest members) since they are not strong enough swimmers to go against the current

watching some jellyfish swim looks like they're not going anywhere

but contractions of bell creates water currents that draw food through tentacles and toward mouth
→ its not 'trying to go anywhere'

in a few species the medusa is sessile and spends its life laying upsidedown on the sediment

Feeding

mouth hangs down under umbrella on the end of a throat-like **manubrium**

GVC extends into radiating canals or pouches

all jellyfish are **carnivorous**

they eat mostly zooplankton, smaller fish and other jellyfish

larger ones may eat shrimp and other crustaceans

jellyfish are eaten by spadefish, sunfish and loggerhead turtules

only a few dozen of the 500 or so species of jellyfish are dangerous to humans

Nervous system & senses

since jellyfish are motile their sense organs are better developed than other members in the phylum

jellyfish in this class have a greater variety of sense organs than other jellyfish

scalloped margins of bell with indentations bearing **lappets** and **rhopalia**

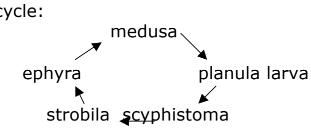
with **ocelli**, **statocysts** and **sensory pits**

reproduction & life cycle:

medusa stage is the sexual stage

polyp is asexual stage
buds off small medusa

jellyfish life cycle:



many jellyfish live less than a year

but a few arctic species live up to 10 years

eg. *Aurelia* (moon jelly)

common off Texas coast

7-10 cm diameter; some up to 2 feet
scalloped margin with indentations bearing lappets and rhopalium with ocelli, statocysts and sensory pits
mouth on manubrium drawn out into 4 frilly **oral arms**
feeds on small planktonic organisms

male releases sperm threads into water

female collects and eats them to fertilize eggs

eg. Cannonball jellyfish

eg. Lion's mane jellyfish

one of largest
can be 8' in diameter
tentacles can extend to 200'

C. Class Cubozoa (box Jellyfish, sea wasps)

poorly known group

once considered as a group of scyphozoa

medusa is dominant form, polyp is inconspicuous

most are relatively small; <1"

tentacles are at each corner of cubical bell

eg. sea wasp (Chironex fleckeri)

ranges from Indian ocean to coral sea

the most poisonous sea creatures known

since 1884, it has killed more people along the northern Australian coast than have sharks in the area

D. Class Anthozoa (Corals and Sea Anemones)

="flower animals"

all are marine

→range from deep to shallow water

some are solitary = sea anemones, usually larger

most are colonial = corals, polyps usually small

polyp only; no medusa stage

GVC large

muscular infolding of mouth = **pharynx**

GVC partitioned by **septa** (=mesenteries)

mesenteries can be complete or incomplete

free edge of incomplete septae form **septal filaments** with nematocysts

in some, lower septal filament prolonged into **acontia**

also with nematocysts

→ can be extruded thru mouth or

pores in body wall to help catch prey

3 major groups in class:
1. sea anemones and stony corals
2. sea fans, sea pansies, sea pens, soft corals
3. tube anemones and thorny corals

eg. anemones

especially common in tropical waters

much larger than their coral relatives; some 3' dia

mostly sessile, but some can glide on **pedal disc**

although anemone's move in slow motion, some group living species actually battle each other for territory using specialized tentacles for battle

reproduce by fragmentation; they leave pieces behind as they move

eg. hard corals ("stony corals")

colonial polyps

produce rock-like calcareous cups (=theca)

secreted by lower half of polyp

=**exoskeleton** for support and protection

form extensive reef structures in warm shallow waters

reef structure consists of compressed & welded together:
calcium carbonate coral skeletons
encrusting coralline algae

foraminiferan shells
bivalves
sea urchin plates

continually destroyed by:
sponges, worms & clams bore into reef
waves reduce it to white sand
crown of thorns starfish (*Acanthaster*) feeds on polyps and decimates populations
highly resilient communities → regenerate quickly

eg. soft corals (octocorallia)

secrete a flexible **endoskeleton** of spicules or keratin-like protein

eg. sea pens, sea pansies, sea fans, whip corals, pipe corals sea whips & sea pens

eg. tube anemones

secrete tubes

Ecological Interactions of Cnidaria

1. most are aggressive **predators**

eg. a single lions mane jellyfish was found with >200 fish within its tentacles

eg many jellyfish species congregate into large swarms of up to 1000's of individuals

can devastate prey in an area

can clog fish nets

swarms often triggered by eutrophication

climate change has caused many swarming species to expand their range

2. Some are **prey** for a variety of specialized predators

eg. parrot fish, butterfly fish, tangs eat coral polyps

eg. sea turtles like jellyfish

unfortunately many are suffocated by eating plastic bags floating in the ocean

eg. a number of sea slugs (nudibranchs) eat them but store unfired nematyocysts in their skin and use them for defense

3. numerous **symbioses** within this phylum:

eg. The "upside-down jellyfish" is not a predator

it harbors symbiotic algae in its tissues and spends its time in shallow water laying upside-down 'sunning' its algae

in deeper waters it moves up to the surface during the day for photosynthesis

eg. many anthozoa live as commensals on shelled animals

eg. attach to shells of hermit crabs

eg. decorator crabs

eg. almost every sea anemone is a host to a variety of fish and other reef animals (shrimp, crab, fish)

over 50 species of fish associated with anemones (also some shrimp)

eg. clown fish

fish symbionts are stung on first contact (on tail or nonvital body part)

→ then body mucous or slime is chemically altered so the fish is not affected by further stings

must continually refresh mucus layer

eg. most **corals** are mutualistic with dinoflagellate algae (**zooxanthellae**)

base of food chain in coral reef communities

eg. most coral species produce large amounts of slime which harbors a diverse community of bacteria and other microbes.

this community acts in lieu of an immune system to protect the animals which is lacking in most invertebrates, including corals

eg. some corals call for help when being smothered by seaweeds

corals compete for light with seaweeds

a new (2012) study found that when a staghorn coral species in Fiji is being smothered by mats of seaweed it signals gobies to come eat the seaweed

gobies don't touch the seaweed unless signalled by the coral

in return gobies get shelter from the coral

5. Coral Reefs

"cold water corals"

some live below 0ºC
no light
no zooxanthellae for extra nutrients
almost 700 species

"tropical coral reefs"

Tropical Coral Reefs

corals are familiar to most people as main components of **coral reefs**

Coral Reef Diversity

coral reef communities are the most luxuriant, complex and diverse of all aquatic communities

while they are dominated by coral species practically all animal phyla are represented

an abundance of sponges, clams, snails, octopi, squid, worms, fish, eels, sea stars, sea urchins, shrimp, crab, etc

also seaweeds, algae, bacteria, protists, etc

each species of life has developed ways to cooperate and compete within a myriad of nooks and crannies

reef ecosystems are characterized by **high diversity**

→ lots of competition especially for space & food

eg. algae, sponges and corals are constantly growing over and killing each other

eg. most reef fish are very localized with specific feeding preferences

eg. reef fish even differ between day and night

coral reefs cover 0.1% of earth's surface area

all kinds of reefs cover 1.5 M sq miles (=568,600 km^2)

(the most productive *shallow water reefs*, ie. reefs in <30m of water, cover ~0.75 M sq. miles (=284,300 km^2) = area ~ size of Italy)

coral reefs contain about 200,000 known species (~15% of all species)

tropical rainforests
6% of earth's surface; **14 M sq mi**, support ~**50%** of all species

coral reefs
0.1% of earth's surface; **1.5 M sq mi**, support **~15%** of all species

→Diversity per unit area: coral reefs are 400-500 times more diverse than rain forests

eg. 32 of the 34 animal phyla are found on coral reefs compared to only 9 of the 34 found in the rainforests

eg. >1/4th of all marine fish species are associated with coral reefs

Reefs are unique ecosystems:

1. reefs are the largest biological structures on the earth

2. their structure is created by biological activity
→ they create their own ecosystem

massive deposits of calcium carbonate
→ esp by corals

→ also coralline algae, mollusks, and a few other groups

3. coral reef communities have survived for 1000's or 10,000's of years

relatives of corals appeared over 500 MY ago
→ mainly solitary individuals

modern colonial reef building forms appeared and diversified in the last 25 M years

eg. one reef (Eniwetok) is ~ 4000' thick (1283 m) and estimated to be over 60 M years old

oldest reefs are in the pacific; youngest in the atlantic (10-15,000 years old)

the extensive vertical growth of reefs is the result of changes in sea level &/or subsistence of the seabed

→ virtually all modern reefs have grown upward due to recent sea-level rise beginning ~18,000 BP (rate of 3-15 M (10-40')/1000yrs)

→ some of the thickness may also be due to subsistence (especially at atolls and some barrier reefs)

Where are Coral Reefs

individual corals are found in all oceans from the poles to the equator

but coral reefs are only found in warm, clear equatorial waters

→ waters >68º F (20º C)

tropical reefs are most common in the western Pacific and Indian Oceans

many are **brightly colored**

numerous symbioses occur between reef organisms

yet most reefs grow in areas of ocean with fewest nutrients

→clear clean water = nutrient poor water

Reef Requirements & Structure

to become established a reef has some essential requirements:

1. hard substrate

initial growth requires a **hard surface** (firm base) on which to start construction

reef forming organisms are mainly **sessile, benthic animals**

= animals that live in or on a substrate (don't swim in open ocean)

2. warm tropical temperature

reef communities are also restricted by water **temperature**

→ most occur only in tropical and subtropical seas (±30º latitude)

where average water temperature ~23º - 25º C

none are found below 18º C

few on W coast of N America or Africa due to upwelling of cold water

3. shallow

most reefs grow depths of 75 ft (25 M) or less

limit is 50-70 M

they are therefore restricted to coastal areas or seamounts

most reef building corals contain **symbiotic photosynthetic algae** that require sunlight

→ form basis of reef food chain

not too deep (to 60M)
→ light is quickly filtered out
→ depth of active reef is restricted by light penetration

the growth and health of the coral community is

directly dependent on the amount of light reaching the reef

4. salinity near 33_{ppt}

normal salinity of sea water
→ can't withstand lower salt concentrations

eg. don't see any near E coast of S America because of outflow of Amazon River

5. clear

reef organisms require **clear waters** to allow their photosynthesis

→ low amounts of dissolved materials and few nutrients
→ not at mouth's of large rivers

if the water is shallow, but murky (turbid) sunlight will not get through for photosynthesis

also, too much sediment will smother the polyps

another reason why they are not usually found near outlets to large rivers

6. Prefer areas with Strong Wave Action

wave action oxygenates waters, brings in nutrients, and reduces sedimentation

Established Reefs

once established, **reefs create their own environment**:

coral colonies form the main framework of a reef

→ may be over 100 species of corals alone

the coral colonies are able to extract **calcium carbonate** from sea water to form the reef structure

→ they use sugar produced by the algae that live inside their tissues to do this

→ without the algae the corals cannot grow

most reef building corals contain **symbiotic photosynthetic algae** (=zooxanthellae)

present in enormous populations
provides a vital energy source for the reef organisms
base of reef food chain

this symbiosis is beneficial to both organisms:

corals	algae
provide CO_2	provide O_2
N, P	remove wastes
	make organic nutrients

some corals also have symbiotic nitrogen fixing cyanobacteria

→numerous crevasses and holes provide excellent hiding places

→ create numerous habitats

→any exposed surface created when organisms die, is quickly attacked by boring organisms especially sponges. worms and clams

→as organisms live and die get build up of coral skeletons, encrusting algae, shells, etc

→waves also break up and destroy old reef material

→fine materials settles into crevasses and holes
→ fills spaces
→ cements reef together

coral reefs show very **rapid recycling of nutrients** (similar to rainforests)

→ virtually all the nutrients the algae create are cycled to corals and the rest of the food web

→ prevents nutrients from sinking out of productive sun lit zone and lost

→produce several times more organic material/area than phytoplankton communities

reef communities show **numerous symbioses and interactions**

eg. zooxanthellae, sponge symbionts, crabs, molluscs, cleaner fish, etc

a common characteristic of many reef organisms is **mass spawning events**

most corals are **hermaphrodites**

take 7-10 years to reach sexual maturity corals don't have complex nervous systems or sense organs yet many coordinate their release of sperm and eggs within the same few evenings each year, sometimes timed to within minutes of each other

each year, at late-spring full moon, 100's of coral species simultaneously spawn

→ synchronized by a light sensitive pigment in the coral animals

Kinds of Reefs

Two general types of reefs:

1. Fringing Reefs or Barrier Reefs

most common type
surround islands and border continents
grow in shallow waters and border the coast closely or may be separated by a shallow stretch of water
project seaward directly from shore
subdivided into several zones:
reef crest – part of reef the waves break over
forereef – medium energy
buttress (spur & groove) – rows of coral with sandy canyons or passages between rows

eg. Great Barrier Reef is longest in world ~1000 miles

2. Atolls

at summits of submerged volcanoes (seamounts)
usually circular or oval with a central lagoon

Reef Zonation

Both reef types show similarities in profile (vertical zonation)

these differences due mainly to differences in wave energy and water depth

a. Reef Face

seaward side
inclined from gentle to steep slopes
often with terraces creating more zonation

10-20M: (30-60') high energy – help to dissipate wave energy
grooves drain off sand
masses of large dome shaped and columnar corals, large fish

20-30M: (65-100') little wave energy
only 25% of surface light reaches here
more delicately branched corals

30-40M: (100-130') gentler slope
very reduced light
sediments accumulate here
corals become patchy

>50M: (>165') slope drops off sharply

b. Reef Crest

highest point of reef front
exposed at low tide, covered by waves at high tide
elkhorn coral and shelf coral

c. Reef Flat (back reef)

sheltered, lagoon side
highly variable
short to several 100 meters
lowest energy, coral sand

delicate corals, eg. staghorn
becomes shallower and supports sea grasses

Reef communities are characterized by a coordinated reproductive frenzy at specific times of the year often late spring: "spawning"

→ one species after another will discharge reddish clouds of eggs and milky white sperm into the water

→ described as an underwater 'snowstorm'

Economic Impacts of Coral Reefs:

reef communities have significant impacts on human economies and activities:
fisheries
tourism
coastal protection
pharmaceuticals

1. Fisheries

eg. worldwide, coral reefs provide 1/4th of the annual commercial fish catch and feed over 1 Bil people in asia alone.

eg. US reefs support millions of jobs and a $200 M annual fishery

on global basis
1/2 sq mile of reef:
→ can sustainably yield 15 tonnes of fish and other seafood/yr
→ $8.6 M in revenue/yr

2. Tourism

eg. reefs of the florida keys generate $1.2 Bil/yr in tourist dollars

3. Biochemicals

scientists have extracted over 20,000 new biochemicals from marine life, mainly from coral reef organisms over past 20 yrs(04) since the greatest marine diversity is in coral reefs, they offer the greatest possibilities for potential uses

scientists first began looking at softbodied sessile organisms of coral reefs because they thrived under highly competitive conditions with no apparent claws, teeth, etc for defense

→ must use chemical weapons

by some estimates, coral reefs provide over $30 Billion in benefits (direct and indirect) , worldwide per year

destroying 1/2 sq mi of reef costs $137,000-$1.2 M in loss of fisheries, tourism and shoreline protection over a 25 year period.

Threats to Reefs:

Coral Reefs are among the most endangered ecosystems in the world

recent ('03) assessments of world's reefs show they are globally threatened

→ there are no "pristine" reefs left:
all reefs are impacted by human activities
only reefs in remote areas are generally healthy

→ 30% of reefs are damaged
up to 30% have been lost in last 50 years(06)
another 16% are severely damaged

→ 60% may be completely dead by 2030

generally, coral reefs are very resilient
→ have existed for 1000's to 100,000's of years

but today are being degraded in a matter of decades

the greatest threats to reefs are from human activities

eg. ~1/2 of world's population live in coastal regions

eg. in SE Asia, 70% of population is in coastal areas

Coral Bleaching

one of earliest signs of stress is **coral bleaching**

→ when water gets too warm algae "flee" their

coral hosts

therefore lose their color

triggered by disease, pollution, elevated temperatures, salinity changes, increased UV radiation, etc

bleaching is a normal response to short term stresses

while bleached, corals stop growing
→ leaves reef vulnerable to erosion

after one bout the reef can recover,
→but frequent episodes may kill the coral polyps

what is significant about bleaching today is its frequency, severity and extent

Coral Reefs are associated with 109 countries, those in 93 countries show significant damage

reefs at highest risk:

Japan	Singapore	Taiwan
Sri Lanka	India	Indonesia
Asia		

eg. Phillipines
only 5% of reefs are pristine
30% are dead
39% are still healthy

all are areas with dense coastal populations and

heavy coastal development

Human Causes of Coral Reef Decline:

while natural events, eg diseases and hurricanes can cause extensive damage to specific reefs

humans are having a global impact on reefs

human causes of reef decline:

1. **sedimentation**
2. **eutrophication**
3. **shipping and oil spills**
4. **exploiting for food (overfishing)**
5. **collecting**
6. **mining**
7. **tourism**
8. **Climate Change**
9. **Ozone Depletion**

1. Sedimentation

by far the greatest impact
increase in suspended silt, clay, dirt
mainly due to **deforestation** esp. mangroves
due to logging, farming, mining, dredging
doesn't have to occur near coast to have and impact
sediment blankets coral reef
initial plume blocks sunlight→reduces photosynthesis
smothers polyps
as they produce mucus to remove it, depletes their energy reserves; makes them more susceptible to disease
impedes larval settling

2. Eutrophication

food and nutrients usually limit the growth of most organisms
eg. N & P → plants, algae; organics → bacteria, heterotrophs
reef ecosystems are especially susceptible since they are found in nutrient poor waters
too much food can upset the balance between organisms in the community:
some grow much faster than others and can become toxic
sometimes a new predator gains upper hand
eg. crown of thorns starfish → can clean out entire reefs when its predators are eliminated

some algal infestations caused by eutrophication cause algae to release sugars that fertilize the symbiotic bacteria making them pathogenic and killing their coral hosts

3. Shipping and Oil Spills

eg. oil tankers pollute and kill reefs
eg. 1st gulf war oil release (10M BBL's)
caused extensive damage to reefs in arabian sea
eg. in Mid East a phosphate tanker ran aground on a reef, releasing phosphates into the water
killing 500 mi^2 of reef

4. Exploiting for Food (overfishing)

reef fish are prone to overfishing because many are slow growing, long lived fish (K-selected; low natural fertility)
when depleted they are slow to repopulate

historical record shows that over the last several 1000 years, large fish and animals have been hardest hit of reef community

blast fishing
use explosives to kill or stun fish

eg ~1/6th of reefs in Phillipines have been damaged this way since 1945

cyanide fishing
some use cyanide and poisons to fish
→ kills other organisms as well

child labor
in Phillipines 40 ships carry 300 children to reef each day
children pound reef with rocks to scare fish into nets
can destroy up to 1 km^2 of reef/day
children killed by needlefish, sharks, barracuda, poisonous snakes, etc

as fish become more scarce, fishermen earn extra income collecting turtles, clams, etc

5. Collecting

1.5 Million kg's (15 tonnes; 3M lbs) of coral & shells/year are harvested
mainly for "shell shops" around the world
~1/3rd from the Phillipines
most is exported
most goes to US gift shops and aquarium shops

live corals were collected and sold in Florida until 1989 when it was outlawed
but some is still traded on black market

shells etc collected by malacologists: prefer killing live specimens rather than dead shells from beach

exotic fish collected from reefs feed a $4 Billion/yr aquarium industry

6. Use as Building Material

in Sri Lanka and parts of India entire sections of reef have been removed to make cement
→ there is no other source of rock nearby

7. Tourism (Ecotourism)

walking on reef and touching it kills polyps and kicks up sediment
many break off souvenirs of live reef
beauty of reef stimulates beach front developments

eg. On S Pacific Island of Palau
they mined an area of reef to build a new airport runway
→ to accommodate an increasing number of tourists coming to see the reef

eg. in Grand Caymans a 525' cruise ship dropped a 5 ton anchor and
dragged its chain across 150M of reef
creating a 3M wide path 150M long
uprooted 8M diameter blocks of coral
destroyed an area 1/2 the size of a football field

Indirect Human Effects:

8. Climate Change

global temperatures are increasing 1/2 – 1 degree every decade
this rate is 100x's faster than natural rate at end of last glaciation
most of this accelerated warming is due to human activities
global warming will
alter weather patterns
alter ocean circulation
warm ocean surface waters
cause significant sea level rise up to 6 cm/decade
→ but reefs can grow up to 10 cm/decade
cause acidification (lowering of pH) of ocean waters
→ diversity decreases
→ individuals are less healthy
→ dissolves coral skeletons; reefs don't grow
→ reduces reproductive success of coral eggs and larvae

9. Ozone Depletion

will continue into next century
→ ozone levels decrease .5-5% over the tropics

→ this causes a 1-10% increase in UV radiation

shallow marine communities are particularly susceptible to damage from this additional radiation

Economic Importance of Cnidaria (excluding coral reef ecosystems):

1. in orient a few jellyfish are eaten

    eg. people in China and Japan eat the mushroom jellyfish; fresh or pickled

2. stinging cells of some cnidaria are lethal to humans

    eg. box jelly or sea wasp (*Chironex fleckeri*)

    from Indian ocean to coral sea - esp around coast of Australia

    can have up to 60 tentacles as long as 15 feet.

    most poisonous sea creature known

    stings can kill a human in 5 minutes

    each has enough toxin to kill 50 humans

    since 1884 at least 5,567 deaths have been attributed to these creatures.

3. Pharmaceuticals

    eg. anti-inflammatories, painkillers for arthritis, antimicrobials

    eg. cardiac stimulant from sea anemone

    eg. toxins from soft corals, *Palython* used as antitumor medication

    eg. treatment for multiple sclerosis from coral venom is in clinical trials

    eg. in development (2009) is a process developed to harvest stinging cells, remove their venom and then use them to inject painkillers or insulin into the skin

4. a green fluorescent protein extracted from jellyfish (also found in fireflies) and used to build tiny fuel cells which could be useful in powering nannodevices used to diagnose and treat diseases in the body

5. space travelers: in 1991 2500 moon jellies flew aboard the Columbia space shuttle

    to study how their balance organs develop under weightlessness