Crustaceans

=shelled creatures; **"the insects of the sea"**

~67,000 species

eg: lobsters, crayfish, shrimp, crabs, water fleas, copepods, barnacles, pill bugs, etc

vary in size from microscopic (<0.1 mm) to 12'

some crustaceans live for several decades; some molt throughout life

so continuous increase in size

eg. crayfish & freshwater shrimp

largest crustaceans in freshwaters

some up to 2' and weigh 9 lbs

a river shrimp, *Macrobrachium jamaicense*, was collected from Devils River, Tx: body was 10.5" long, 3' long including antennae, 3 lbs

eg largest (longest) is giant **Japanese crab**

→ up to 12' from end of claws to tail and a weight of 40 lbs (20 kg)

Lobsters may be the longest lived Crustaceans

one was collected that weighed 35 lbs

was estimated to be 50 yrs old;

body only was ~2' long, claw was an additional 20"

→ ~ 4' long total

some crustaceans are quite colorful; blue, red, orange, yellow

many are **bioluminescent**

A. crustaceans are mostly **aquatic**, the great majority are **marine**

inhabit most waters of the earth: ocean , arctic , freshwaters, high mountain creeks and lakes thermal springs, brine waters

1. many are **benthic**

eg. especially the larger crustaceans; shrimp and crabs

eg. also isopods, amphipods

e. Ostracoda (=seed shrimp)

common in freshwater and marine habitats

mainly benthic animals that inhabit all types of substrates in standing and running water

a few actively swim just above the substrate

generally use their antennae to move

enclosed in bivalve carapace that completely covers the entire animal

their shells are so strong that they fossilize well

important to paleontolotists in dating sediment

(65,000 fossil species vs 13,000 living species)

generally feed on bacteria, fungi, algae and detritus

viable eggs have been collected from dried ponds and revived after 20 years

some crustaceans construct tubes in sediment, wood and rock

eg. boring isopods can destroy wooden pilings in less than 2 yrs

some isopods can tunnel through limestone rock

some have been known to burrow through the insulation of undersea cables shorting them out

some crustaceans are **sessile** (=attached)

eg. barnacles common in intertidal areas

2. many small are at the base of aquatic food chains part of **zooplankton**

eg. Copepods

small, slender, clearly segmented body

large pair of antennae used for movement

feathery legs to filter food

found most abundantly in oceans but also common in freshwaters

may be the most abundant **animals** on the planet

feed in a variety of ways: scraping food from hard surfaces, filtering articles from the water, seizing and biting prey

extremely important food source for marine fish

majority of the diet of commercial fish is copepods

some are important vectors for diseases such as guinea worm

eg. Water Fleas (=Cladocerans)

cladocera are most abundant in permanent freshwater ponds & lakes, among marginal vegetation

→ important part of freshwater zooplankton

body is enclosed within a bivalve shell called a **carapace** that covers the thorax and the abdomen but not the head

large **eyes** – looks like a single eye but is actually 2 compound eyes that are fused together

very large **antennae** that are used for locomotion

inside the carapace are **5 or 6 pairs of feet** used to filter the water for food

female carries her eggs around in a brood pouch enclosed in carapace

eggs hatch and young swim free – direct development

eg. **Krill (Euphasids)**

small shrimp-like animals extremely abundant in marine plankton

often occur in swarms up to 30,000 individuals/m^3

a major part of the diet of whales, seals, penguins and cephalopods among others

eg. whales eat 2-3 tons of krill per meal

eg. freshwater zooplankton:

esp. water fleas, copepods, seed shrimp

B. certain specialized crustaceans are the dominant animals in highly saline or alkaline environments or in temporary waters such as **playas**

eg. fairy shrimp, tadpole shrimp, clam shrimp

generally inhabit temporary pools, ponds and playas

and are generally completely absent from permanent bodies of water

feed mainly on algae, bacteria, protists and microscopic animals

typically appear in the spring and disappear in late summer or autumn as habitat dries

to survive most produce very drought resistant eggs that can survive dried or frozen for years in lake beds

eg brine shrimp (*Artemia*)

only animals that flourish in the Great Salt Lake of Utah and other hypersaline environments

their eggs can persist in dry salty lakebeds

today they are cultured extensively as fish food or as novelties; "sea monkeys"

C. while the vast majority of crustaceans are aquatic, some groups are **semiaquatic** or **terrestrial**

eg. land crabs burrow above tide line into the water table

can survive days out of water

eg. pill bugs & sow bugs (isopods)

isopods are the only group of crustaceans with truly terrestrial representatives

have very delicate gill-like respiratory organs that must be kept moist

found in damp places under stones and logs

able to roll up for protection (=rolly pollys)

young develop in brood pouch

some salt water relatives are found along coasts and live in seaweed, along rocks and algae

some bore into wood causing destruction of pilings and warves

eg. beach fleas or sand hoppers (amphipods)

some are almost terrestrial; found crawling around on piers and jetties

Crustacean Body Form

the most ancient crustaceans resembled some kind of aquatic centipede; lots of segments, each with a pair of appendages

only one small group of these kinds of crustaceans remain today

in most crustaceans today, the body is usually divided into a **cephalothorax, abdomen** and **tail**

cephalothorax

often have **carapace** extending over the sides of the animal

in some groups carapace forms clamshell like valves that encloses the whole body

in others the carapace covers cephalothorax but not abdomen

abdomen

segmentation is most apparent in the **abdomen**

abdomen usually with pairs of jointed appendages on most segments

Movement

generally have many pairs of appendages

most appendages are **biramous**

they branch like a "wishbone"; one of the branches usually has a gill attached at its base

most primitive species had long segmented body with similar segments and similar appendages

over time, great variety of body types arose

appendages modified for a variety of uses:
- sensory
- feeding
- defense
- walking
- swimming
- reproduction
- respiration

lots of variation in appendages between groups

eg in decapods (crayfish, crabs, lobsters, etc):

1st 2 pair → antennae with chemoreceptors

next 5 pr (3-8) → feeding appendages; including mandible, maxilla and maxillipeds

next 5 (9-13) → walking legs including cheliped and gills

next 5 (14-18) → called swimmerets; used to carry eggs and as copulatory organ

last (19) → uropod = swim fin

most crustaceans can cast off legs or pinchers and regrow them

voluntary (striated) muscle tissue arranged in **antagonistic groups**

eg. flexors & extensors

similar to vertebrates

Feeding & Digestion

use jaw-like **mandibles** as main feeding structures

also **maxillae** and **maxillipeds**

great variation in feeding types:

many are **predators**

eg. **crabs** use large claws used to break open shells to feed

eg. **mantis shrimp**

is an ambush predator, extremely carnivorous and aggressive

called "split thumb" in Bermuda and West Indies

front end looks like praying mantis

has "jackknife claws"

live in solitary burrows

eyes are stalked and constantly watch for prey

some are **suspension feeders**

eg. barnacles sit upside down in shell and use legs to strain water for food

some are **scavengers**

eg. isopods, amphipods

crustaceans have a well developed digestive system:

cardiac stomach with **gastric mill** for grinding

gastric mill has hardened "teeth"

pyloric stomach for sorting

digestive gland secretes digestive enzymes

Respiration

in small crustacea: no special organs

→ exchange across body surface

in larger crustacea: respiration usually by feathery **gills**

on bases of walking legs

in some sides of **carapace** form **gill chambers** that enclose gills

have an appendage called a "**bailer**" that creates a water current across gills

Circulation

open circulatory system

most crustaceans have some kind of blood pigment to better distribute oxygen to tissues

most: **hemocyanin** → bluish pigment with Copper

others: **hemoglobin** → red pigment with Iron

some: no pigments

Sense Organs

sense organs are well developed in crustaceans

1. most have **compound eyes** and **simple eyes**
2. **chemoreceptors** (taste) on mouthparts,
3. crustaceans uniquely **have 2 pairs of antennae**
4. **tactile hairs** and **spines** spread over body
5. **statocysts** for orientation

at base of antennae

saclike; opens to surface by pore

take in sand grains which trigger hair cells to provide info on orientation

6. **hearing: communication by sound**

many crustaceans make underwater noises to communicate

eg. pistol crabs snap claws together producing sound like pulling a cork from a bottle

eg. one species of mantis shrimp makes a vigorous rasping noise by rubbing uropods against underside of telson

eg. Florida spiny crab produces sound like moist fingers rubbing against a window pane

some crabs have **striae** or **ridges** on inner side of chelae that they rub against tubercles on carapace

some crabs have **tympanic membranes** on their 1st leg segments to pick up these sound vibrations

sound is used for warning, to frighten enemies, mating rituals, etc

7. Light emitting organs & communication by light

many crustaceans have light emitting organs (=**photophores)** that use luciferase to produce light

many crustaceans give off rich blue sparks of light when disturbed

eg. some ostracods and a few copepods, even some freshwater decapods

krill have light organs with lens and reflector to focus and intensify the light beam

many pelagic crustacea flash brilliantly during mating swarms

Endocrine System

hormones help control:

molting

body coloration → **chromatophores**

heart rate

sexual development

blood sugar levels

Excretion

nitrogen wastes are excreted through skin (if no gills)

or through **gills** & **antennal glands** (or maxillary/green gland)

antennal glands also used to regulate water & salts

(K & Ca^{+} conserved; SO_4 & Mg excreted)

[no malpighian tubules]

Reproduction

most are separate sexed (**dioecious**)

but a few are hermaphrodites including barnacles

female can only mate after final molt

develops large "apron" for carrying eggs

copulation: male delivers sperm packet to receptacle using modified swimmerets

a few groups reproduce **parthenogenetically**

eg. brachiopods, ostracods, isopods and a few crayfish

males are rare or unknown

eggs are generally released into the water

some retain their eggs until they hatch in brood pouches

eg. Most crabs and shrimp

in some crustacea such as crayfish, development is direct with no larval stage

but most crustaceans produce a variety of distinctive larval forms as the animal develops

many marine crustaeans begin with a characteristic larval form

= **nauplius larva**

3 prs appendages { 2 pr antennae; 1 pr mandibles }

then zoea larva or some other larva distinctive for the specific group

Symbioses

a. numerous **commensal** relationships with other invertebrates

eg. many bivalves harbor commensal crabs within their shells

eg. crabs and shrimp also live inside sponges, worm tubes, etc

b. **mutualistic** interactions

eg. **cleaner shrimp** remove skin parasites from fish

c. a diverse variety of crustaceans have become **parasitic**

eg. Fish Lice

parasites on marine and freshwater fish

have flattened bodies, compound eyes and maxillae modified into suckers to attach to the sides of fish

mouth borne on a long tube or piercing organ used to obtain food; blood and body fluids of host

after feeding on host the parasite detaches and drifts downstream

many species can tolerate both fresh and salt waters

eg. Tongue Worms

so unlike other crustaceans that until recently they were classified in their own phylum, pentastomida

wormlike; 2-13 cm long; >70 sp, 4 fossil genera

4 clawlike appendages at anterior end

mouth with protuberance

no resp, circ or excretory organs

parasites in lungs of carnivourous vertebrates esp reptiles and some birds

few human infections

intermediate host is vertebrate prey of final host
larvae live in blood

eg. probably the most bizzare of all parasitic animals is ***Sacculina***

Sacculina is a highly modified barnacle that has become a parasite of crabs

female cypris larva attaches to a crab and injects a mass of eggs

these cells migrate to intestine of host and develop rootlike growths that permeate the hosts body

develops an extensive system of branches extending into every appendage

a saclike growth appears under the crabs abdomen where eggs and sperm form (*Sacculina* is a hermaphrodite)

the crabs metabolism is completely altered:

the cells of the parasite multiply and differentiate into a reproductive form which produce an egg mass in the female hosts apron

the host protects, ventilates and grooms the egg mass as if it were her own

if crab is a male:

body assumes shape of a female
reduced length of some segments
broadening of abdomen
testes reduced or converted to ovaries

→ both male and female resemble mature female bearing eggs: physically and behaviorally

Classification of Crustacea

6 Classes:

Class Remipedia (10 sp.)

Class Cephalocarida (9 sp.)

Class Branchipoda (10,000 sp.)
water fleas, fairy shrimp, brine shrimp)

Class Maxillipoda (10,000 sp.)
copepods, barnacles, fish lice and tongue worms

Class Ostracoda (13,000 sp.)
seed shrimp

Class Malacostraca (20,000 sp.)
sand fleas, shrimp, crabs, lobster, wood lice

[short descriptions of these major groups can be found on pp 24 & ff]

Ecological Role of Crustaceans

many examples have already been cited

crustaceans feed a vast number of other animals in the oceans and in freshwaters

small planktonic crustaceans such as copepods, ostracods and krill are essential links between producers and larger consumers in aquatic food webs

krill and copepods are extremely abundant in the worlds oceans

may be the animals with the greatest biomass on the planet

their numerous symbioses help to control populations of other animals

without crustaceans, animal populations in aquatic ecosystems would collapse

Economic Importance of Crustaceans

many are at the base of aquatic food chains
part of zooplankton

1. as food

eg. crab, lobster, crayfish, shrimp

more than 10 million tons of crustaceans are harvested for food each year (2007)

→ mostly shrimp, crab, lobsters and prawns

the heyday of lobster fishing was in the 1890's:

1892 yield was 24 M lbs of lobster; 25 pounders were common

80% of all crustaceans are harvested in Asia, mainly China

some crab are harvested by breaking off claws and throwing rest back

crayfish (crawfish) are commonly eaten in the southern US and in other countries

Louisiana produces 70-90% of all commercial crayfish, most of it from aquaculture

recent (2007) annual harvest of ~55,000 tons

Krill are now being harvested for human consumption around the Antarctic

can harvest 12 tons/hour

but they are difficult to process

2. bait

crayfish are commonly sold and used as bait either live or only the tail meat

sometimes causes problems with bioinvasions

3. pets

crayfish are kept as pets in freshwater aquaria

land crabs are often sold in pet stores

4. many crustaceans are serious pests

a. cause crop destruction

eg. rice crabs in China and India eat rice; burrows may drain rice fields destroying crops

eg. crayfish destroy young cotton plants

b. boring & fouling organisms

borers destroy warves & docks and wooden hulled boats

undermine sea walls and bore into stone

destroy underwater cables

adhere to ships reduce efficiency and increase hull decay

eg. barnacles

5. Many Crustaceans are **endo**- and **ectoparasites** on other organisms

eg. many kinds of copepods
eg. *Sacculina*

6. some act as **intermediate hosts** for human parasites

eg. Guinea worm
larva is in copepods; swallowed in contaminated water
grow in lymphatic system
up to 3' long
female produces blister like lesions on lower extremeties to lay eggs in water

eg. fish tapeworm
larva in Cyclops and Diaptomus
eaten by fish
humans eat uncooked fish

Short Descriptions of the Major Groups of Crustacea

Class Remipedia

very primitive characteristics

→ resembles a centipede in general body form but with biramous legs

very poorly known → all known species are from underwater caves

Class Cephalocarida

occur along the coasts of the United States, in the West Indies and Japan

2-3 mm long

live in bottom sediment from intertidal zone to 300 m

also thought to be very primitive

Class Malacostraca

largest crustacean class

extremely diverse

appendages on both thorax and abdomen

Isopoda

only group of crustaceans with truly terrestrial representatives: sow bugs, pill bugs

most species are either marine or terrestrial, only a few (5%) are freshwater species

mainly found crawling on the substrate or under rocks and submerged plants in small lakes and streams

a few cave adapted forms occur in subterranean waters

commonly dorsoventrally flattened, segmented, with a reduced cephalothorax

most are less than .5", the largest is over 12" long (*Bathynomus* – a deep water species)

seldom found in open water

isopods are mainly scavengers

dioecious with no larval stage

eg. pill bugs & sow bugs (isopods)

only truly terrestrial crustaceans

have very delicate gill-like respiratory organs that must be kept moist

found in damp places under stones and logs

able to roll up for protection (=rolly pollys)

young develop in brood pouch

some salt water relatives are found along coasts and live in seaweed, along rocks and algae

some bore into wood causing destruction of pilings and warves

Amphipods, Sand Fleas or Scuds (=Amphipoda)

a mainly marine group with some freshwater species

strongly compressed laterally, no carapace

abdomen not sharply separated from cephalothorax

compound eyes lie flat on the sides of the head rather than on stalks

generally much more active at night than during daytime

amphipods are voracious feeders

omnivorous scavengers

feed on all kinds of plant and animal matter

a few are parasites

like decapods, the females brood eggs and young in a ventral brood chamber

eg. beach fleas or sand hoppers (amphipods)

found in both freshwaters and marine habitats

some are almost terrestrial; found crawling around on piers and jetties

Decapoda

best studied group of crustacea

~10,000 species

most larger crustaceans; shrimp, crayfish & true crabs

vast majority are marine, some found in freshwaters

5 pairs of walking legs

mainly benthic: in and on the sediment

lots of specialized legs

crabs use large claws used to break open shells to feed

fiddler crab uses largest claw for social interactions

only uses small claw for scavenging food from sand

others are filter feeders, herbivores or scavengers

most crab and shrimp carry eggs or brood their young

eg. **cleaner shrimp** remove skin parasites from fish

eg. **land crabs** burrow above tide line into the water table

can survive days out of water

eg. **mantis shrimp**

is an ambush predator, extremely carnivorous and aggressive

called "split thumb" in Bermuda and West Indies

front end looks like praying mantis

has "jackknife claws"

live in solitary burrows

eyes are stalked and constantly watch for prey

eg. Lobster

Lobsters may be the longest lived Crustaceans

one was collected that weighed 35 lbs was estimated to be 50 yrs old; body only was 2' long, claw was an additional 20" → ~ 4' long total

the heyday of lobster fishing was in the 1890's:

1892 yield was 24 M lbs of lobster

25 pounders were common

eg. crayfish & freshwater shrimp

freshwater decapods

largest crustaceans in freshwaters

some up to 2' and weigh 9 lbs

a river shrimp, *Macrobrachium jamaicense*, was collected from Devils River, Tx: body was 10.5" long, 3' long including antennae, 3 lbs

Krill (Euphasids)

small shrimp-like animals extremely abundant in marine plankton

often occur in swarms up to 30,000 individuals/m^3

a major part of the diet of whales, seals, penguins and cephalopods among others

eg. whales eat 2-3 tons of krill per meal

Class Branchiopoda

"breath through their feet"

→ feathery gills at base of walking legs

the most characteristic crustaceans of freshwaters

most are exclusively freshwater forms

some in brines, only very few marine species

eg. fairy shrimp, tadpole shrimp, clam shrimp, water fleas

feed mainly on algae, bacteria, protists and microscopic animals

except for the water fleas, the branchipoda generally inhabit temporary pools, ponds and playas

and are generally completely absent from permanent bodies of water

typically appear in the spring and disappear in late summer or autumn as habitat dries

to survive most produce very drought resistant eggs that can survive dried or frozen for years in lake beds

the eggs of most hatch into nauplius larvae

Water Fleas (=Cladocerans)

cladocera are most abundant in permanent freshwaters

→ important part of freshwater zooplankton

cladocera are most abundant among vegetation at margins of ponds and lakes

body is not obviously segmented

body is enclosed within a bivalve shell called a **carapace** that covers the thorax and the abdomen but not the head

large **eyes** – looks like a single eye but is actually 2 compound eyes that are fused together

very large **antennae** that are used for locomotion

inside the carapace are **5 or 6 pairs of feet** used to filter the water for food

female carries her eggs around in a brood pouch enclosed in carapace

eggs hatch and young swim free – direct development

Fairy Shrimp (=Anostraca)

common but seldom seen unless pursued

stalked compound eyes

no carapace

some grow up to an inch

graceful movements, often transparent

use legs to swim upsidedown

eg brine shrimp (*Artemia*)

only animals that flourish in the Great Salt Lake of Utah and other hypersaline environments

their eggs can persist in dry salty lakebeds

today they are cultured extensively as fish food

Tadpole Shrimp

large shield-like carapace covering most of the body

look somewhat like tiny horseshoe crabs

at end of abdomen are two long filamentous extensions

Clam Shrimp

laterally compressed

enclosed within a carapace of 2 valves to resemble a small clam

Class Ostracoda (=seed shrimp)

resembles clams and clam shrimp but much smaller (usually <1mm)

common in freshwater and marine habitats

mainly benthic animals that inhabit all types of substrates in standing and running water

important interstitial fauna

a few actively swim just above the substrate

generally use their antennae to move

enclosed in bivalve carapace that completely covers the entire animal

their shells are so strong that they fossilize well

important to paleontolotists in dating sediment

(65,000 fossil species vs 13,000 living species)

nearly all traces of segmentation are gone

generally feed on bacteria, fungi, algae and detritus

difficult to study and identify → usually requires dissection

many species are parthenogenetic

viable eggs have been collected from dried ponds and revived after 20 years

Class Maxillipoda

Copepoda

small, lack carapace

slender, clearly segmented body

large pair of antennae used for movement

feathery legs to filter food

found most abundantly in oceans but also common in freshwaters

common as plankton, benthos, interstitial fauna

also many parasitic species

feed in a variety of ways: scraping food from hard surfaces, filtering articles from the water, seizing and biting prey

may be the most abundant animals on the planet

extremely important food source for marine fish

majority of the diet of commercial fish is copepods

some are important vectors for diseases such as guinea worm

Barnacles (=Cirripedia)

sessile: secrete shell of several calcium plates in which they live

considered a kind of mollusk until 1830

but once they were discovered to produce a nauplius larva it was clear they were a kind of crustacean

there are 2 main kinds of barnacles:

some with stalk = **goose barnacles**

some without = **acorn barnacles**

eggs hatch into motile, nauplius larvae then a cypris larva

after swimming a short time the larva secretes a strong polysaccharide cement from its antennae and attaches to the substrate

→ the strongest adhesive known

adults secrete chemicals that attract the larvae to settle near them to facilitate reproduction

the carapace develops into a mantle that secretes calcareous plates

legs develop in feathery **cirri** for filtering water

animal sits up-side-down in shell and extends legs to filter feed

almost all are hermaphrodites yet they cross fertilize with internal fertilization

a few species are dioecious with the dwarf males attached to the female

they don't feed and die after inseminating the female

barnacles are preyed on especially by starfish and snails

some in symbiosis with humpbacks and other whales

stick on skin; esp head, flippers and flukes

appear to cause little damage except for some species that seem to burrow into the skin but don't seem to cause serious inflammation

feed on scraps produced by whale feeding

some are **parasitic**

includes one of the most bizarre parasites of all, ***Sacculina***:

Sacculina is a highly modified barnacle that has become a parasite of crabs

female cypris larva attaches to a crab and injects a mass of eggs

these cells migrate to intestine of host and develop rootlike growths that permeate the hosts body

develops an extensive system of branches extending into every appendage

a saclike growth appears under the crabs abdomen where eggs and sperm form (*Sacculina* is a hermaphrodite)

the crabs metabolism is completely altered:

the cells of the parasite multiply and differentiate into a reproductive form which produce an egg mass in the female hosts apron

the host protects, ventilates and grooms the egg mass as if it were her own

if crab is a male:

body assumes shape of a female
reduced length of some segments
broadening of abdomen
testes reduced or converted to ovaries

→ both male and female resemble mature female bearing eggs: physically and behaviorally

barnacles are one of the most important "fouling" organisms on ocean going ships

→ reduce speed up to 50%
→ increase duration of voyage
→ increase fuel consumption
→ increase wear and tear on engine

all this translates into millions of dollars lost in ocean transport

in Chile a large 9" barnacle is an important food source that is used in soups and chowders

Fish Lice

parasites on marine and freshwater fish

have flattened bodies, compound eyes and maxillae modified into suckers to attach to the sides of fish

mouth borne on a long tube or piercing organ used to obtain food; blood and body fluids of host

after feeding on host the parasite detaches and drifts downstream

many species can tolerate both fresh and salt waters

Tongue Worms

so unlike other crustaceans that until recently they were classified in their own phylum, pentastomida

wormlike; 2-13 cm long; >70 sp, 4 fossil genera

4 clawlike appendages at anterior end

mouth with protuberance

body covered by chitinous cuticle, periodically molted

single digestive tract

no resp, circ or excretory organs

parasites in lungs of carnivourous vertebrates esp reptiles and some birds

few human infections

intermediate host is vertebrate prey of final host larvae live in blood