Crustaceans

-shelled creatures; "the insects of the sea"

~67,000 species

e.g.: 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

e.g. 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

e.g. 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;

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

e.g. 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)

e.g. barnacles common in intertidal areas

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

e.g. Copepods

small, slender, clearly segmented body

large pair of antennae used for movement

feathery legs to filter food

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

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

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

Animals: Arthropoda - Crustacea; Ziser Lecture Notes, 2012.10
eg. Krill (Euphasids)
small shrimp-like animals extremely abundant in marine plankton
often occur in swarms up to 30,000 individuals/m³
a major part of the diet of whales, seals, penguins and cephalopods among others
e.g. whales eat 2-3 tons of krill per meal
e.g. 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

e.g. 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)

C. while the vast majority of crustaceans are aquatic, some groups are semiaquatic or terrestrial
e.g. land crabs  burrow above tide line into the water table
can survive days out of water
e.g. 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 (=rollly 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

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"

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
  swimming
  reproduction
  respiration
lots of variation in appendages between groups
e.g in decapods (crayfish, crabs, lobsters, etc):
  1st 2 pr → 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
Animals: Arthropoda - Crustacea; Ziser Lecture Notes, 2012

last (19) \( \rightarrow \) uropod = swim fin

most crustaceans can cast off legs or pinchers and regrow them

voluntary (striated) muscle tissue arranged in antagonist 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"

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 \( \rightarrow \) bluish pigment with Copper

others: hemoglobin \( \rightarrow \) 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; SO₄ & 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
    - 2 pr antennae
    - 3 prs appendages
    - 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 carnivorous vertebrates esp reptiles and some birds
    - few human infections
intermediate host is vertebrate prey of final host
larvae live in blood

e.g. probably the most bizarre 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

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

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

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

**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

e.g. 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 (= roly 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

e.g. 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

e.g. cleaner shrimp remove skin parasites from fish

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

can survive days out of water

e.g. 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

e.g. 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

e.g. 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/m³

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”
Animals: Arthropoda

Crustacea

- 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 branchiopoda 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 (=Cladocera)
- 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 paleontologists 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 food

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:

→ 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 carnivorous vertebrates esp reptiles and some birds

→ few human infections

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

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**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