Arthropods - Chelicerates

an ancient group with good fossil record

include horse shoe crabs, sea spiders, scorpions, spiders, ticks, mites, sea scorpions

most living species are fairly small

but some fossil sea scorpions (eurypterids) were 5-6'long; a few up to 9'

most members of the group are **terrestrial**

→1st group of animals to successfully make transition to land

→ oldest known fossils of terrestrial animals are chelicerate arthropods from 420 M years ago (Silurian)

Transition to land

required major adaptations:

a. Ability to resist drying

already had waxy cuticle
→ impermeable to water

b. improved excretory system

for salt and water balance

conserve water by getting rid of N wastes as urea or uric acid rather than as ammonia (most aquatic animals)

c. respiratory system

to extract oxygen directly from air instead of water

need moist thin surface protected inside body

→ several experiments:
book lungs
tracheae

some can open and close spiracles

d. modification of appendages

for life on land (gravity)

strong muscles and strong support

e. change in sensory systems

change from chemical senses (~**taste**; more reliable in water) to **vision**, vibrations of air & soil not water (=**sound**), and airborne chemical senses (~**smell**)

f. Internal fertilization

gametes must remain moist

leads to anatomical changes for copulation

more elaborate courtship rituals

g. eggs must be protected from drying

egg must contain enough nutrients for early development

or animal must bear live young

h. ability to withstand extreme

temperatures

or become inactive during temperature extremes

eg. diapause

Distinctive Characteristics of Chelicerates:

1. head is fused to thorax = **cephalothorax**
2. named after their main feeding appendage

→ **chelicerae** (pincer-like or fang like) used to grab or pierce or tear prey

most also have second feeding appendage = **pedipalp**

4. only arthropod group **without antennae**
5. most have **4 pairs of walking legs**

Body Plan

body consists of a **cephalothorax** and **abdomen**

cephalothorax

no distinct head

head is fused with thorax to form a **cephalothorax**

cephalothorax contains:

feeding appendages; including chelicerae and pedipalps

usually 4 pairs of walking legs

chelicerates lack antennae

Feeding & Digestion

chelicerae are either pincher like or fang like

pedipalps are usually larger and may also have "pinchers"

in some the pedipalps resemble the walking legs

Respiratory System

aquatic species have **book gills**

terrestrial species use **book lungs** or **tracheae**

book lungs consist of parallel air pockets extending into haemocoel

→ book lungs resemble book gills of *Limulus* but are internal

Senses

1. **Vision**

aquatic species have **simple** and **compound eyes**

terrestrial species generally have several pairs of simple eyes or **ocelli**

2. **mechanoreceptors**

→ sensory hairs and bristles used for "touch"

some also can detect sounds; used for "hearing"

Circulation

open circulatory system as in all arthropods

body cavity a **haemocoel**

in some, blood contains the blood pigment **hemocyanin** to transport oxygen

Excretion

excretory organ of most Chelicerates are **malpighian tubules**

also have **coxal glands** at base of some legs

= modified nephridia open at coxa of 1st and 3rd walking leg

Reproduction

dioecious

some with elaborate mating rituals

some with considerable parental care

Classification of Chelicerates

Class Merostomata (4 species)

ancient. formerly diverse. group of aquatic chelicerates

today consist of 3 genera and 4 species of horse shoe crabs

Class Pycnogonida (~1000 species)

sea spiders

Class Arachnida (>100,000 species)

spiders & scorpions, mites, ticks, etc

Class Merostomata

Eurypterids (Water Scorpions)

extinct group

→ lived from Cambrian to the Permian (especially Silurian & Devonian)

largest of all fossil arthropods

→some up to 6' long

body plan is a blend between horseshoe crabs and scorpions

cephalothorax with **simple** and **compound eyes**, **chelicerae** & **pedipalps**

largest chelicerae of the subphylum

pedipalps resemble the 4 pr of walking legs

4 pr of walking legs

all but the last pair of walking legs had "pinchers"

last pair of legs have paddlelike structures for swimming

segmented abdomen

spikelike telson

sluggish bottom dwellers

marine, brackish and probably freshwaters

feeding:

they were the "killing machines" of the oceans

probably mostly ate trilobites

one paleontologist: " I'd much rather be in a pool with a 6' shark than a 6' eurypterid"

Eurypterids may have been the first animals to move onto land

Horseshoe Crabs

[not "true" crabs which are crustaceans]

also an ancient group; but still survives today

→ almost unchanged for 300 million years

can grow up to 2 feet in total length and weigh up to 6 lbs

females usually larger than males

generally found on sandy bottoms in deeper water

can swim upside down above sediment

Body Form

large **cephalothorax**, **abdomen** & long **telson**

cephalothorax with **compound** and **simple eyes**

Feeding & Digestion

eats clams, snails and sandworms

mouth is in center of legs

→ chews food with bases of legs = **gnathobases** have stiff spines

uses **chelicerae** to help get and break up food

Respiration

breaths by flat, leaflike **book gills** on underside of abdomen

the book gills can also be used for swimming

Reproduction & Development

spawn in early summer (May & June)

nights of full and new moons they arrive by 1000's on Atlantic beaches (100 years ago they arrived by the millions)

female always dragging 1 & sometimes 2 or 3 males up onto the beaches with her

female burrows into sand to lay several 1000 eggs at a time on beach

may lay 120,000 eggs per season

one or more males deposit sperm on the eggs then female covers them with sand

in 8-10 days, eggs hatch into larvae = "trilobite larva"

horseshoe crabs live up to 20 years

Ecological and Human Impacts

used by humans as cheap fertilizer for past 100 yrs, until 1970 when the last processing plant closed

pharmaceuticals are also extracted from them

today millions are taken to be used as bait for eels, conch and whelk

are the most important food source for loggerhead turtles

eggs are also a valuable food source for migrating shore birds

→overharvesting of horseshoe crabs has correlated with a decline in shorebird numbers

the dramatic decline in shorebirds caused New Jersey to ban the collecing of horseshoe crabs recently, now subject to $10,000 fine

a horseshoe crab reserve has been recently created in Delaware Bay where they are now permanently protected

today, the horseshoe crab population has stopped declining

a similar species is now almost extinct in Japan

Class Pycnogonida

(sea spiders)

1000 species

shallow coastal waters and deep oceans

common in all oceans, especially polar waters

also, often found on soft tissues of sponges, hydroids and soft corals, anemones, and clams

spider-like in appearance but with very small body and very long legs

most with 8 legs; but some with 10 or 12

many species have **chelicerae** and **pedipalps**

small head with 2 prs of eyes

mouth at tip of long **proboscis**

are **fluid feeders**

→ feed on cnidaria and soft bodied animals

gut branches and gonads extend throughout entire length of each leg

no resp or excretory systems

Class Arachnida

>100,000 species

most chelicerates belong in this class

include spiders, scorpions, mites, ticks, & "daddy long-legs"

body with **cephalothorax & abdomen**

cephalothorax with eyes, feeding appendages and 4 pairs of walking legs

abdomen may or may not be segmented

contains digestive, respiratory and reproductive systems

Feeding & Digestion

most are **predators** with fangs, claws, venom glands or stingers

fangs = modified chelicerae

claws = modified pedipalps

stinger = last abdominal segments

generally predigest soft tissues then suck in

predigested liquid with strong sucking **pharynx**

Respiration

trachea, book lungs or both

book lungs consist of parallel air pockets extending into **haemocoel**

oxygen diffuses from air into blood

Circulation

open circulatory system as in all arthropods

dorsal tubular heart that moves fluid around internal organs

hemocyanin is used to transport oxygen

Senses

most are predators

→ relatively simple eyes but very good vision

Excretion

main excretory organ in arachnids are **malpighian tubules**

=closed end tubules that branch off the hindgut or rectum and float in haemolymph

unique organs of arachnids and insects

also have **coxal glands** at the base of each leg

=modified nephridia

Classification of Arachnida

Order: Scorpionida (scorpions) (~2,000 sp)

Order: Thelyphonida (vinegarroons or whip scorpions) (~100 sp)
- -book lungs
- -coxal glands & malphiggian tubules for excretion

Order: Schizomida (short-tailed whip scorpions) (~230 sp)

Order: Palpigradi (microwhip scorpions) (3,000 sp)

Order: Amblypygida (whip spiders) (~150 sp)
- -no tail
- -short, wider, flat
- -whiplike pedipalps
- -common in South Africa

Order: Pseudoscorpioida (pseudoscorpions) (3,300 sp)
- -very small, no tail
- -poisonous,
- -widely distributed
- -tracheal system
- -coxal glands

Order: Solifugida (wind scorpions, sun spiders) (~1000 sp)
- -resemble spiders
- -not poisonous but bite may become infected from bacteria
- -in dry areas, most nocturnal
- -SW US

Order: Ricinulei (hooded tickspiders) (60 sp)

Order: Acarina (mites & ticks) (30,000 sp)
- -large order
- -single prosomal carapace, united epistosomal segments
- -pedipalps may be chelate or leg like
- -smaller ones have no respiratory organs, larger ones have trachea

Order: Opilionida (daddy-long-legs, harvestmen) (6,300 sp)

Order: Aranea (true spiders) (40,000 sp)

A. Scorpions

~2000 living species

most ancient of all arachnids

mainly in tropics and subtropics

but some temperate

especially deserts

secretive

active at night = **nocturnal**

usually stay in underground burrows in day

Texas has 18 species of scorpions
Austin has 2 species

Body Form

cephalothorax & **abdomen**

cephalothorax (=prosoma)

short

contains large median **eyes**

2-5 pairs of smaller lateral eyes

chelicerae and pedipalps

4 pair of walking legs

abdomen (=opisthosoma)

subdivided into a wider **mesosoma** of 7 segments

and a thinner tail-like **metasoma** of 5 segments

at tip of abdomen is recurved **stinger**

Feeding & Digestion

come out at night to prey on spiders and insects

detect prey by sensing vibrations in sand with hairs on **legs** and possibly **pectines**

large prey are subdued by injecting paralyzing venom from stinger at tip of tail

rarely sting humans → only if provoked

venom is a **neurotoxin** that causes paralysis

very painful but rarely fatal

in children the more poisonous species may cause
- convulsions
- vomiting

even death

a few are **deadly** to humans

~25 of the 1500 species (2%)

none in Texas

eg. *Centruroides*

found in Mexico

kills 100's – 1000's/yr in Mexico

effect of poison is very rapid
- immediate drowsiness
- excessive salivation
- sluggish tongue
- severe contractions of jaw muscles
- fever to 104 or 105
- may be hemorrhaging in stomach, lungs and intestines
- waves of convulsions
- cardiac irregularities
- breathing difficulties

death usually occurs in <3hrs

if patient lives this long will probably survive

Reproduction & Development

scorpions have an elaborate courtship ritual and show parental care like spiders

male and female
hold each other by pinchers (chelae)
touch chelicerae
and dance back and forth

male then stings female
→ to subdue her aggression
does not permanently harm her

male deposits **spermatophore** on ground
(a solid packet of sperm)

male maneuvers female until her genital pore is over the spermatophore

she flips open lid of spermatophore releasing sperm into her genital opening

in some species male then flees; in others he remains to be cannibalized
→ provides food to nurture young

development can take up to a year

scorpions are **viviparous**

→ embryos develop inside mom

development may take several months to a year

absorb nutrients from mom

born alive

at birth 1-100 babies are are born

after birth, babies climb onto mom's back

→ she carries them around for a week or so
before they set out on their own

B. <u>Spiders</u>

large group; 40,000 species

<u>Body Form</u>

two part body

cephalothorax and unsegmented **abdomen**

connected by small **pedicel**

cephalothorax

simple eyes, no compound eyes, can detect movement

in some may actually form image

yet some with very good vision

eg. jumping spider, *Portia*, has eyes with spatial acuity better than most mammals and birds (better than a cat or pigeon)

(but retinas have only a few 1000 receptors; humans have ~200 M/eye)

most have **chelicerae** modified into a "switch-blade" like **fang**

→ extends and injects venom from poison gland into prey

then retracts like pocket knife

some spiders also use **chelicerae** to:
carry prey
grasp objects
dig burrows

pedipalps help in manipulating food

also sensory

and to transfer sperm to female

4 pairs of **walking legs**

with **sensory setae**

→ tactile; cover legs and detect vibrations in web and in air

abdomen

unsegmented

with **spinnerets** and up to six **silk glands** for webmaking

<u>Feeding and Digestion</u>

all spiders are predators

fang-like chelicerae inject venom into prey

venom can be:

1. **neurotoxin**

   → affects nervous system and muscles to cause paralysis or death

2. **digestive enzymes**

   → digest proteins to kill and liquify prey

3. **pain inducing amines**

   → make prey unable to fight back

after biting prey, spider backs off while toxin kills or paralyzes it

many spiders wrap prey with **silk** to further immobilize it

after prey has been subdued:

spider may mash it with chelicerae and regurgitate digestive enzymes over it

or

if venom consisted of digestive enzymes injected into prey the spider sucks up liquified prey

eg. one African spider can liquefy a 2" fish or small snake in <3 hrs

spider then uses **pharynx** and "pumping **stomach**" to suck up liquefied prey

spiders have very low metabolism: most can live for long periods without eating

eg. tarantulas → several months

eg. Black Widow → 200 days

Spider Webs

virtually every aspect of spider biology depends on its ability to produce silk:

used to **wrap prey**

silk is also used in web as "**trip lines**"

males produce **sperm webs**

females weave **coccoons** and build nursery webs

juveniles use it to "**balloon**" to new habitats

spiders have six different kinds of **silk glands**

→each produces a different kind of silk:

sperm web
drag line
coccoon
various parts of web

silk is made of liquid proteins (**keratins**) that harden as it is secreted from glands

weight for weight spider silk is 20 x's stronger than steel

silk is extruded from **spinnerets**

→tension of pulling out silk changes its structure from a liquid to a solid string

after use it is eaten and amino acids are recycled into new silk

3 basic types of webs:

1. **sheet webs**

   most common

   leads to funnel shaped retreat in which spider awaits prey

   conspicuous on lawns after heavy dew

2. **cobwebs**

   loosely woven

   depend on sticky threads to snare prey

3. **orb webs**

   most well known

   most intricate geometry

   general pattern varies by species

spider plucks web to determine where prey is located in web

some other variations of web and silk use:

eg. Bola Spiders

produce single sticky strand

they throw at flying insects (eg moths) to catch them

eg. many spiders live in webs of other spiders

eat host's prey or host

Reproduction

when ready to reproduce, male stops feeding

constructs "**sperm web**"

deposits drop of **semen** on it

picks up and stores semen in tip of **pedipalp**

goes in search of a mate (**pheromones**)

copulation is usually preceded by elaborate courtship rituals

→ to ensure the female doesn't treat suitor as prey

if successful, male inserts pedipalp with sperm into female genital opening

female stores sperm in seminal receptacle

after mating male goes out in search of another female

female remains in web and deposits 100's or 1000's of eggs in egg web

often lots of maternal care

sexual cannibalism is also common among spiders

after mating female will pounce on male

fatherly meal improves hatching success for eggs

fishing spiders are so aggressive that some females pounce and eat the male suitor before the nuptuals then lay unfertilized eggs that don't develop

Examples of Spiders

the two most dangerous spiders in US are
Black Widow and
Brown Recluse.

both are common in Texas

both have a tendency to live in homes, outhouses and outbuildings

eg. Black Widow

has been found in all 50 states; common in central Texas

female is the most venomous

venom is a **neurotoxin**

→ venom is 15x's more toxic than that of a prairie rattlesnake

but so little that only ~1% of bites are fatal

native Americans of California rubbed arrows with mashed spiders for more effective hunting

causes synapses to release Ach causing:
muscular spasms
abdominal rigidity
cramps
sweating
salivation
high blood pressure
sometimes convulsions

eg. . Brown Recluse

South Central US, including Texas

venom contains **digestive enzymes**

→its venom contains enzymes that destroy blood cells

this induces WBC's to attack surrounding tissues

creates large crater-like wounds that may require months to heal

its bite can be fatal to children

eg. *Phoneurtria* sp. (Brazilian wandering spider)

also called banana spiders but NOT the same as the relatively harmless *Nephila*, also called banana spiders

most dangerous of all spiders

→ most toxic venom

species responsible for most spider bite deaths

Costa Rica and throughout South America east of the Andes

large spiders: 10-12 cm (4-5") leg span

very aggressive

→ will attack anything (including humans) who appear aggressive

wander the jungle floor at night

in day they hide inside termite mounds, under logs and rocks or in banana plants and bromeliads

in some bites very little venom is released; in others a large amount is injected

bite can cause:

intense pain

sweating

acute allergic reaction

uncomfortable penile enlargement - can lead to impotence (being studied as erectile dysfunction meds)

death (esp in children injected with large dose)

eg. camel 'spiders' (=wind scorpions)

mideastern species

have reputation as one of the nastiest arachnids but are relatively harmless

it is *said*: they are bigger than a human hand
extremely aggressive
will climb onto the belly of a camel and eat the camel alive

truth: they are as large as a 5 yr old child's hand
they can run up to 10 mph (fastest moving nonflying arthropod)
they don't eat camels or people

C. <u>Harvestmen</u> (Daddy Longlegs; Harvestmen)

~6,300 sp.

most conspicuous in late summer (harvest time)

easily distinguished from spiders

<u>Body Form</u>

cephalothorax & **abdomen**

broadly joined abdomen and cephalothorax rather than pedicel of spiders

cephalothorax

no antennae

simple eyes

no poison fangs

long thin legs

can be cast off to escape (=autotomy)

abdomen

unlike true spiders, abdomen is segmented

<u>Feeding & Digestion</u>

feed as **scavengers** on inverts and plants

not predators

cephalothorax has **stink glands** for protection

<u>Reproduction</u>

dioecious

internal fertilization

male has **penis**

lay eggs (oviparous)

<u>Evolutionary Relationships</u>

new research shows they are more closely related to scorpions than to spiders

D. Mites and Ticks

30,000 species described

→ most authorities believe unknown species outnumber known

(est: 500,000 - 1 M undescribed species)

most economically important group of Chelicerates

<u>Body Form</u>

cephalothorax and **abdomen** completely fused

no signs of segmentation

have projecting mouth region = **capitulum**

contains mouthparts:

chelicerae for piercing or tearing food

<u>Feeding & Digestion</u>

some are blood sucking parasites

<u>Reproduction</u>

some mites have a highly unusual reproductive strategy; eg. *Acarophenax*

these mites are parasites of beetles

after mating, the female broods the offspring inside her body

there may be up to 30 young, typically all are female except for one male

these offspring reach sexual maturity before they are even born

the lone male fertilizes all the females in the brood and dies before being "born"

the females are born pregnant with the next generation

the advantage to this bizzare life cycle is a very short generation time; 3-5 days

eg. mites

mites usually < 1mm

→ some mites are so small they can only be *identified* with electron microscope

many species are **freeliving**

feed on decaying vegetation;

some are **predators**

some are blood sucking **parasites** during all or part of their life cycles

some mites have become adapted to live as internal parasites in the lungs and air sacs of

snakes, birds and mammals

a. follicle mites (*Demodex*)

mutualists with humans

found in hairs of face especially around nose, and in ear wax

~ 1 in 5 people harbor them, proportion increases in older folks

usually symptomless

in a few may cause redness or irritation

in dogs different species of same genus cause mange

b. dust mites

feces of dust mites sometimes causes allergies

eg. chiggers (redbugs)

"there is probably no creature on earth that can cause more torment for its size than a redbug"

is actually a larvae: minute, reddish; 0.2x0.15"; barely visible to eye

feed on dermal tissue of many vertebrates including humans

the irritation is largely due to sensitization to in the saliva that it injects to liquify skin cells (<u>not</u> due to burrowing)

12-24 hrs after infection itching is at its worst

eg ticks

ticks are much larger than mites

all ticks are parasites during some part of their life cycle

feed on blood and lymph

most infest mammals

many attack birds

a few attack cold blooded vertebrates

some show host preference; others are nonselective

attracted by animal smells from a distance of up to 50'

→ tend to collect on game trails

some lay up to 12,000 eggs at a time

ticks surpass all other arthropods in the numbers and variety of diseases that they can carry

they are **vectors** for some of the world's main human diseases

second only to the mosquito in importance

transmit viral, fungal, & bacterial diseases

eg. deer tick → lyme disease

eg. wood tick →rocky mtn spotted fever

eg. tularemia (rabbit fever)

their bite can be serious

anticoagulants are sometimes toxic

may cause fever and inflammation

wounds made by ticks are very likely to become infected

especially if "head" is torn off

may even result in blood poisoning

most ticks will not let go even if touched or

prodded by chemicals or heat

best removed by gentle pulling

Human Impacts of Chelicerates:

most arachnids, though feared, are actually harmless to humans

1. spiders are directly beneficial as predators → each kill 1000's of insect crop pests

2. large infestations of some mites can damage food and ornamental plants by sucking their juices

2. Venomous species → a **few** are deadly

eg. black widow

eg. brown recluse

eg. scorpions, esp *Centruoides*

3. Arachnid Diseases and Parasites:

eg. ticks
- all ticks are vertebrate parasites
- esp of birds and mammals
- feed on blood and lymph
- some lay up to 12,000 eggs
- the bite can be serious
  - anticoagulants are sometimes toxic
  - may cause fever and inflammation

eg. mites

eg. dust mite
- feces in housedust causes dust allergies

eg. itch mite (scabies)
- excavate tortuous burrows in skin
- esp fingers, wrists, elbows, groin, back of knees
- mating occurs in burrows
- eggs hatch and larval mite excavates 2-3 mm/day

eg. chiggers
- "there is probably no creature on earth that can cause more torment for its size than a redbug"
- red bugs are mite larvae that are very small and can easily go through clothing and burrow in skin
- minute, reddish; 0.2x0.15"; barely visible to eye
- adults are not parasites
- chiggers don't actually burrow into skin but secrete saliva to dissolve skin cells for food
- the irritation is largely due to sensitization to saliva and its enzymes
- 12-24 hrs after infection itching is at its worst

eg. follicle mites
- cause mange in dogs
- in humans related species are commensals not parasites
- live in hair follicles esp eyebrows

4. more serious impact on humans is as disease **vectors**:

eg. mites and ticks:
- Rocky Mtn Spotted Fever
- Lyme Disease
- relapsing fever
- tularemia
- Cattle Diseases

5. Chinese herbal Medicine

Black scorpions are sold for $12/lb

<u>Future Applications</u>

6. scientists are experimenting with **venom genes** to use as biological control against insect pests

venom gene in virus → infect & kill insect pest

7. spider silk is being investigated for a variety of possible uses.

(very similar to insect silk, eg silkworms)

20x's stronger than steel

it does not trigger an immune response

can be easily produced at low temperatures and pressures compared to other similar polymers

is biodegradable