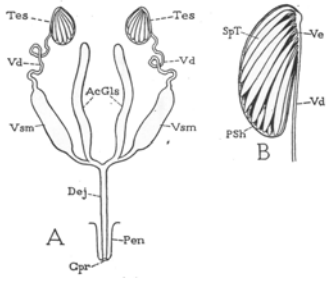
Insect Reproduction

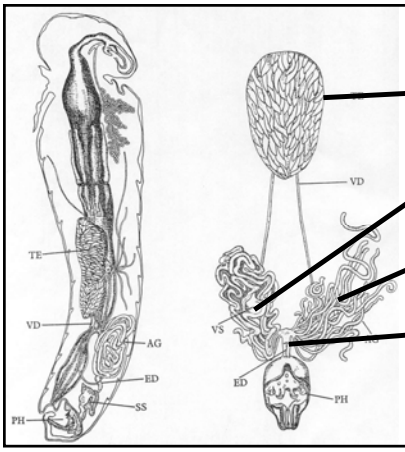
function of male reproductive system

- make spermatozoa • testes
- storage • seminal vesicles
- send them off with proteins with many functions • accessory glands
- deliver the whole package to the females • external genitalia

general plan of male reproductive system

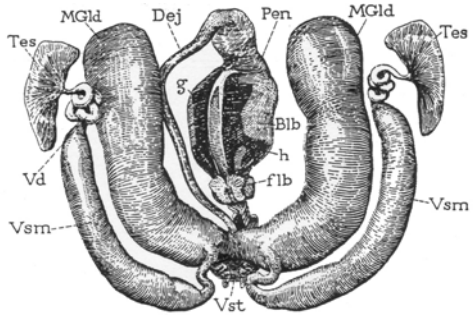
- testis follicles (1-100)
- testes can be separate of bound together
- seminal vesicle for storage
- accessory gland
- ejaculatory duct





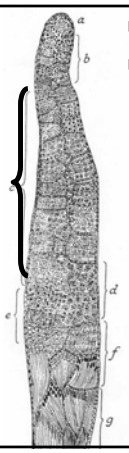
- testes
- seminal vesicle
- accessory glands
- ejaculatory duct

honey bee tract (Find the Parts)



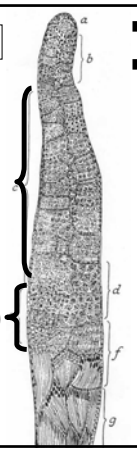
SPERMATOGENESIS

- cells in cysts (packets) go through series of mitosis
- each cyst contains 64-256 spermatocytes



- germarium
- zone of spermatogonia [divide mitotically]

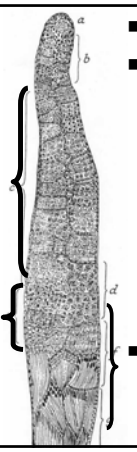
SPERMATOGENESIS



- germarium
- zone of spermatogonia [divide mitotically]

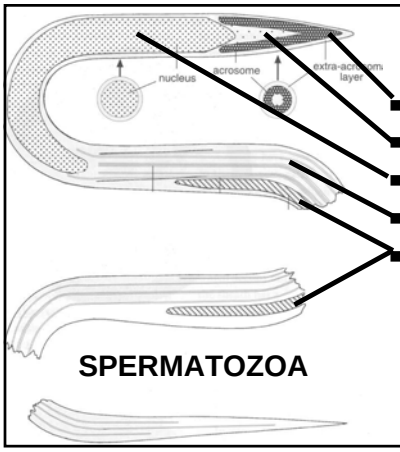
- zone of spermatocytes
- zone of maturation (meiosis, 2 rounds)
- 4x256 spermatids

SPERMATOGENESIS



- germarium
- zone of spermatogonia [divide mitotically]

- zone of spermatocytes
- zone of maturation
- **zone of transformation to spermatozoa**

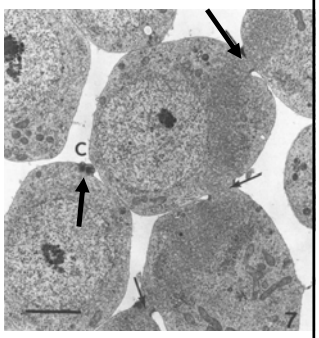


- acrosome
- acrosomal rod
- nucleus
- axoneme
- mitochondrial derivatives

SPERMATOZOA

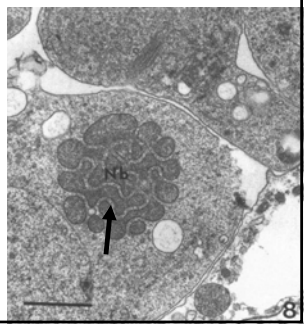
assembly of spermatozoa

- bridges between cells clear
- relict centriole
- do not look like sperm



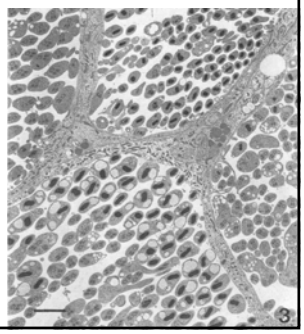
zone of spermatocytes

- mitochondria coalesce into one paired structure - the mitochondrial derivatives
- nebenkern

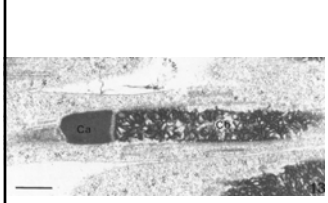


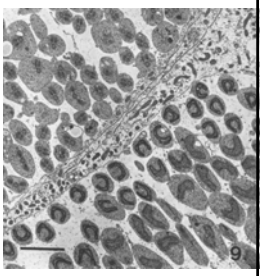
differentiation begins

- cells within cysts are synchronous
- nuclei are condensing

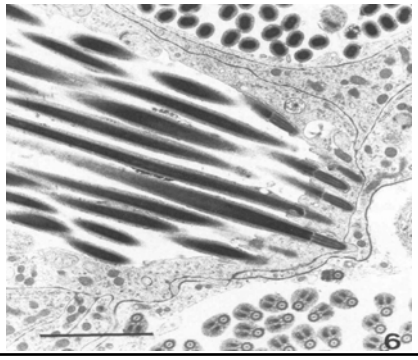


nuclei condensation

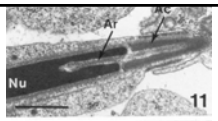


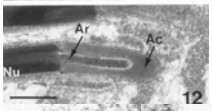


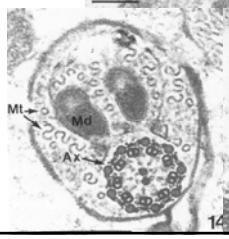
- nuclei condensed
- tails look like bunny rabbits



- acrosomal rod forms
- microtubular scaffolds support condensation of organelles



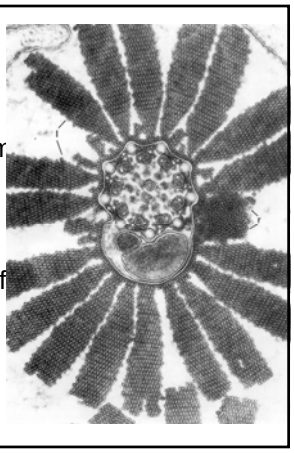




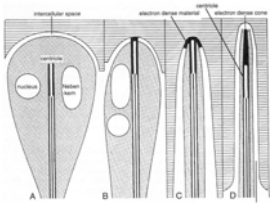
Many insects have dimorphic sperm

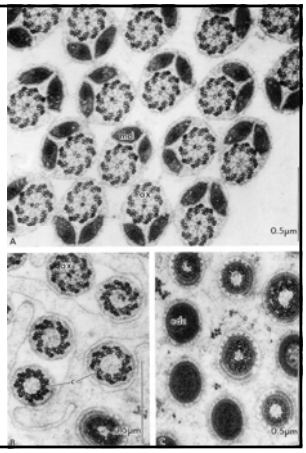
- eupyrene - the usual
- apyrene - without nuclei!

- mature eupyrene sperm of higher Lepidoptera have “lacinate appendages”
- blade like extensions of the glycocalyx



apyrene sperm





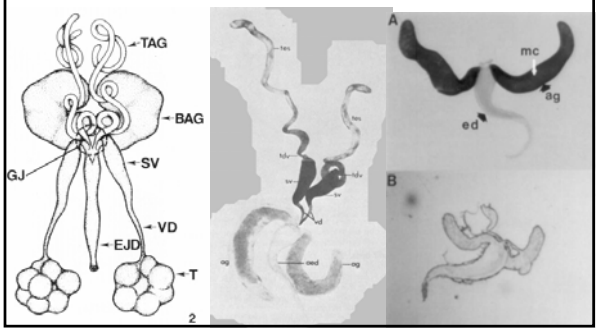
Bombyx mori

- mutant with only ‘real’ sperm
- mutant with only apyrene sperm
- neither fertilizes successfully alone
- if female mates with one of each type - fertilization!

Point: many functions have been proposed

CATEGORY	FUNCTION
Facilitation	Transportation
Provisioning	Nutrients
Sperm competition	Remove/flush previous sperm
“	Protect eupryenes from toxin
Filler	Delay remating
Cryptic female choice	Evaluate male quality

Accessory glands in *Tenebrio* and *Drosophila*



discovery of diversity in accessory gland products

- histology (looking at tissues and cells)
- identification by studying mutants (Drosophila)
- genomics and proteomics – identification by looking a gene expression, gene products

acessory gland functions

Factors that reflect competition among sperm from different males

- speed
- toxins for other sperm
- mating plugs
- turn off female receptivity

acessory gland functions

Factors that contribute to success of female and offspring

-nourishment

-antibiotics

-stimulation of female reproductive processes

-defensive chemicals

Look at “sex peptide”, Acp70

- Ends female receptivity
- Stimulates egg laying

Compare normal and mutant male flies without ACP70A

- How successful were the males?
- Mutant males had higher success in mating than normal males

	Successful matings	Rejected matings	
No SexP	154	671	18.7%
Normal	9	724	1.2%

Compare fitness of females mated to each type of male

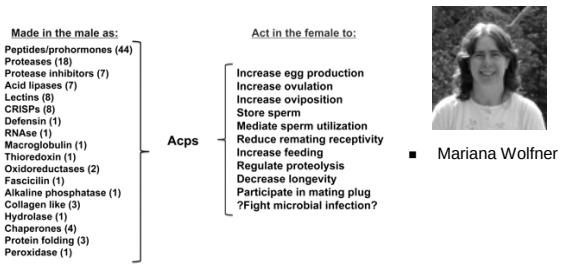
	Lifetime egg production
No SP	73
Normal	55

Normal males actually have lower success in mating and fitness of their mate reduced due to Acp 70

How can this be?

- Males produce compounds that enable sperm to compete with other sperm
- Toxic effect on females, shortens their lives
- Selection pressures on females and males not aligned
- Normal males have higher percentage of their sperm fertilizing eggs

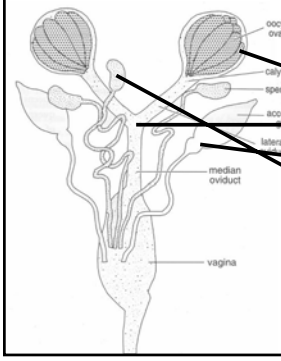
Battle and Ballet: Molecular Interactions between the Sexes in Drosophila



- Mariana Wolfner

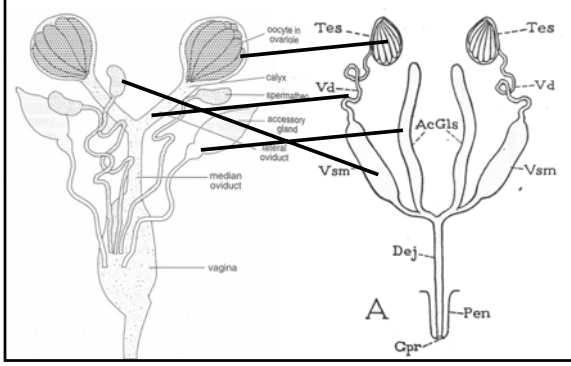
2009. J. Heredity 100, 399-410

Female Reproductive Systems

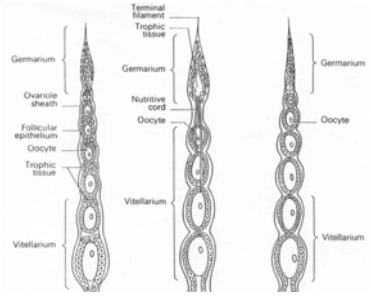


- ovaries, ovarioles
- oviducts
- accessory glands
- spermatheca (sperm storage)

basic plan of M and F similar



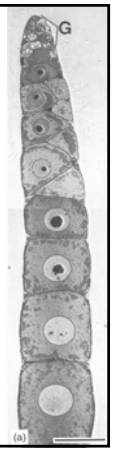
Morphology of Oogenesis



- panoistic teletrophic polytrophic

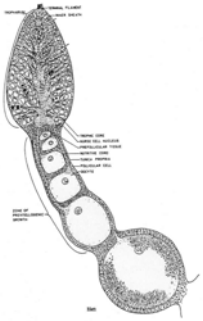
Panoistic

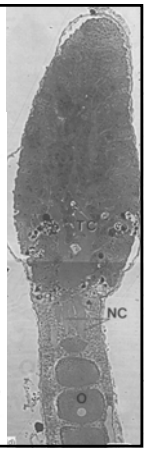
- every egg for him or herself
- 'primitive orders' including Orthoptera, Isoptera



telotrophic

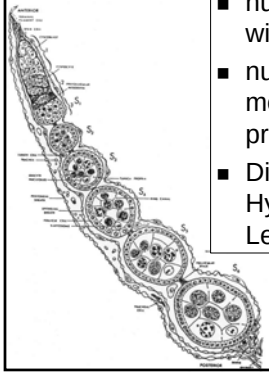
- trophic (nurse) cells confined to germarium
- Hemiptera, Neuroptera, many Coleoptera

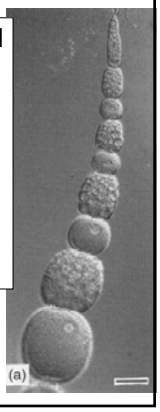




polytrophic

- nurse cells travel with oocyte
- nurse cells allow more rapid egg production
- Diptera, Hymenoptera, Lepidoptera



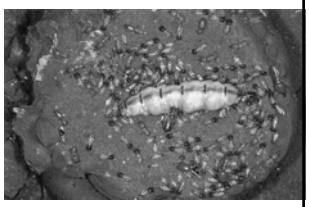


functions of female reproductive tract

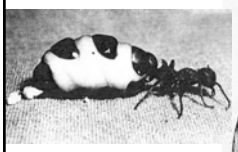
- make eggs
- receive sperm
- store sperm
- lay eggs at appropriate time and place with appropriate protection

variation in ovariole number

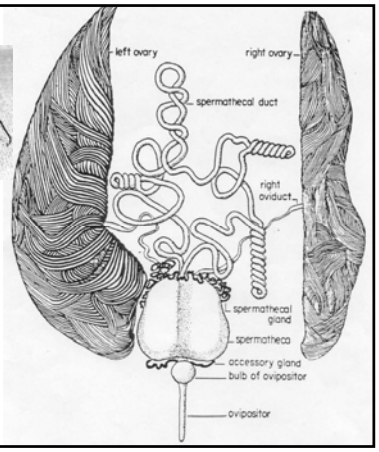
- typically 4-10
- as few as 2
- some social insect queens are the champions



- *Hypotermes obscuripes* – 2400/day
- *Eciton* army ant - 2400-2600/day

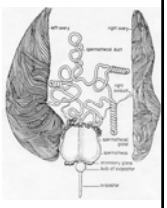


extreme ovaries in an army ant queen



Spermatheca and accessory glands

- after mating, sperm must move to spermatheca
- muscular contractions by female oviduct, sperm power
- often has a spermathecal gland attached



Insect Reproduction

- Reproductive systems
- Mate location and attraction - long range
- Mate choice - short range
- Post mating manipulations

males and females must

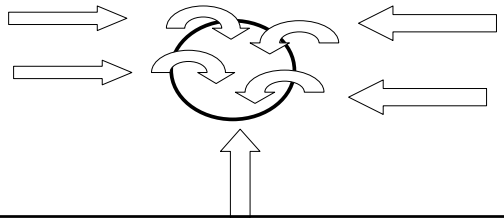
- find each other
- evaluate each other
- make a choice (yes or no) (and sometimes maybe)

selection of behaviors, morphologies etc. that affect mating success is called

sexual selection

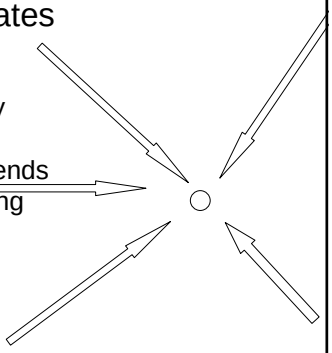
Finding mates

- both sexes come to the same site



Vs. finding mates

- mate attraction by adults - one sex, usually female, sends out signal attracting males to her



same site

- oviposition site
- feeding site
- landmark
- emergence site

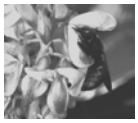
oviposition site

- where the female lays eggs
- perfect - she will need a mate



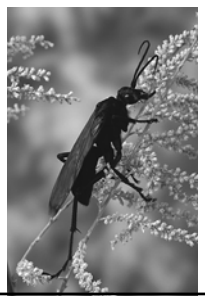
feeding sites

- large mammals for tsetse
- flowers for pollinators


landmarks

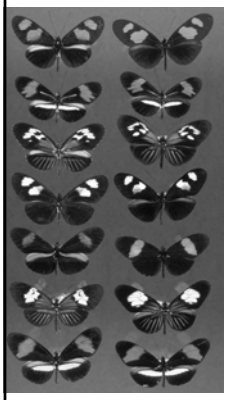
- spider wasp




- *Pogonomyrmex* ('Pogo') seed-harvesting ants
- have large mating aggregations at landmarks

emergence sites

- commonly, males emerge first and wait for female to emerge

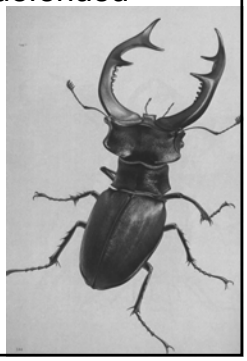


emergence sites - pupal matings

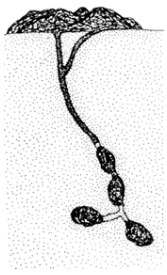
good sites must be defended

- male-male competition
- leads to large size
- striking morphologies

sexually selected traits



Dung beetles



mate attraction

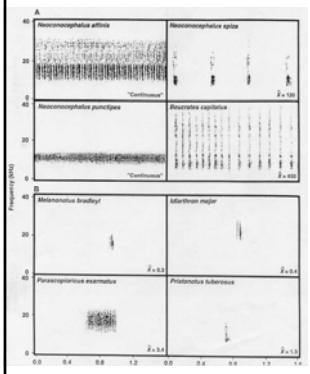
- sound
- sight
- smell

sounds

- crickets, katydids, grasshoppers
- males call
- what is the danger to the calling male?

katydids and bats

- in tropics, some bats glean insects from foliage in the forest
- bats go to feeding roost and dine
- these bats do not forage in clearings
- katydids on foliage in forest will have bat predation, clearing katydids won't

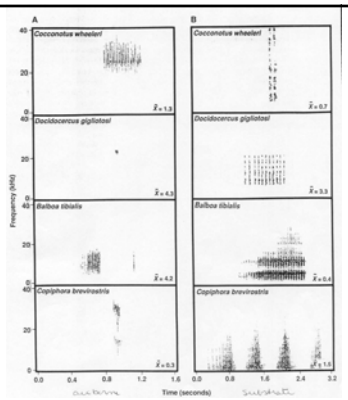


clearing katydid songs

jungle katydid songs

what can jungle 'dids' do?

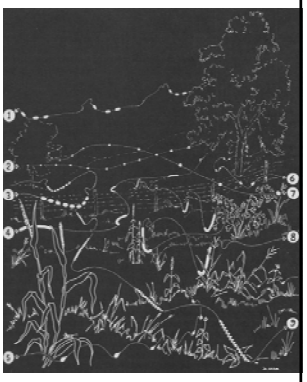
- use another channel of communication that bats cannot hear



airborne | substrate vibrations

fireflies

- species specific signals
- requires good but not remarkable vision



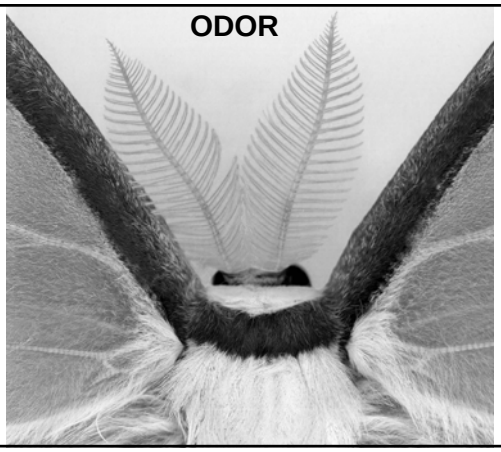
more perils of signaling to the world

- *Photuris* females respond to flash pattern of their males when they are virgins
- Once mated they are hungry
- *Photuris* females then respond to flash pattern of *Photinus macdermotti* males
- catchem and eatum

visual signals

- jumping spiders are very visual

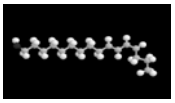
ODOR



In the 1870's, JH Fabre discovered the power of insect pheromones

80 years later..... the female sex attractant was isolated and characterized from the silk moth, *Bombyx mori*

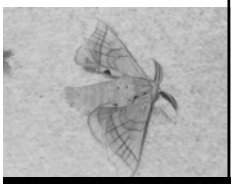
- 500,000 females used to obtain 6.4 mg of pheromone
- bombykol, a hydrocarbon chain



male moths have legendary antennae

- silkworm males have 40,000 sensory hairs on each antenna
- one molecule triggers one hair
- 200 hits triggers behavioral response - moving upwind towards source

ASIDE: MOTHS USE ODOR, BUTTERFLIES USE VISUAL CUES



Now, they have found each other ...
the evaluation phase uses signals over short distances

these can use any or all of the senses

making choices between potential mates

- females usually the choosy sex based on greater investment in gametes
- what should the choice be based on?
- real fitness of the opposite sex in being able to survive to pass genes to next generation (sexual+natural selection)
- What signals real fitness?

how can 'fitness' by signaled?

- a ritualistic signal such as a dance (most energy, right species?)
- body size of male - large size indicates success in growth, male-male competition
- resources offered to female (energy, protection, or time)

dance fly (Empididae)

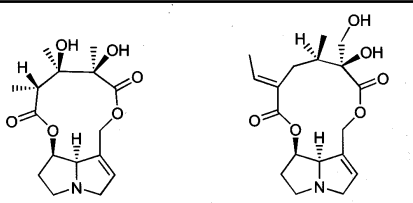
- catches a meal and eats part of it
- dances in swarm while holding remains
- female chooses
- eats gift while they copulate

Male pheromones

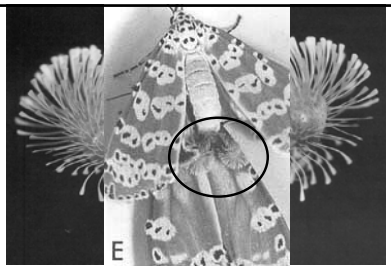
- *Utetheisa ornatrix*
- Arctiid moth
- females are attracted to males by the pheromone and use it in their assessment

Crotalaria

- host plant for *Utetheisa ornatrix*
- contains pyrrolizidine alkaloids (PA) - toxic protectant



- used in eggs
- blood
- seminal fluid
- male pheromone



Male hair pencils, or coremata, are extruded from the abdomen and the pheromone is released

Males reared on artificial diet <u>without PA</u>

- they are healthy
- they fly to females
- their hair pencils do not contain PA

BUT it isn't over with the obvious mate choice

.....sperm competition and cryptic female choice

Sperm competition

- Removal
- Last in first out
- Sperm size
- Toxic chemicals

damselflies

- male can removed sperm from previous mating

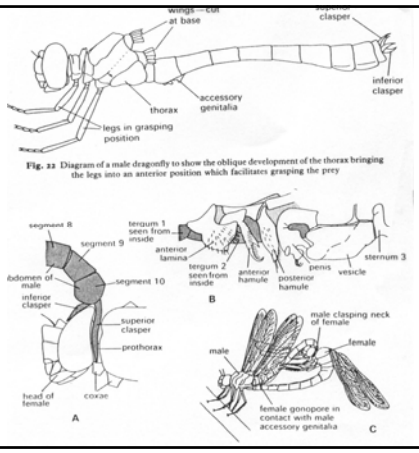


Fig. 22 Diagram of a male dragonfly to show the oblique development of the thorax bringing the legs into an anterior position which facilitates grasping the prey

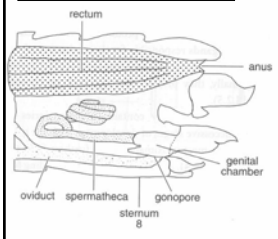
Dragonflies in tandem

- Guarding female to ensure use of his sperm

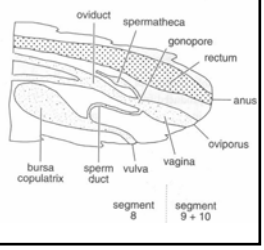
Back to Utetheisa for <u>cryptic female choice</u>

- some female groups have different anatomical arrangements
- these can be important in sperm management

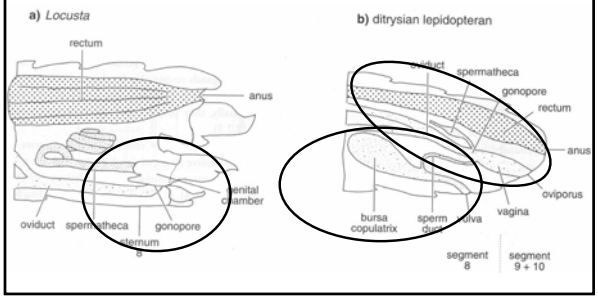
GRASSHOPPER



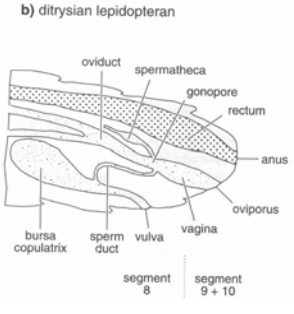
LEPIDOPTERA



- Grasshopper - eggs and sperm handled in same space
- Lepidoptera - eggs through ovipore, mating into bursa copulatrix



anatomy allows sperm sorting



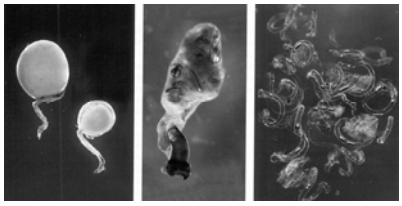
Lepidoptera arrangement allows for female choice

- Utetheisa female mates multiple times (up to 13)
- only one male is the father
- it is the largest male
- why and how?

Why choose largest males?

- large males have been successful and chances are some of this tendency can be passed on to offspring

Spermatophores contain nutrients, PA, sperm



How does she assess male size?

- spermatophore size?
- sperm volume?
- PA content?
- some or all of the above?

How can she sort out the sperm from two males?

- she must be able to set sperm from one mating aside until she can compare the first male to the second
- she must be able to discard the sperm of the smaller male

Keeps PA, nutrients from all, dumps sperm from all but largest