Insect Reproduction

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

general plan of male reproductive system
- testis follicles (1-100)
- testes can be separate or bound together
- seminal vesicle for storage
- accessory gland
- 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

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

germarium
zone of spermatogonia [divide mitotically]

SPERMATOZOIA

acrosome
acrosomal rod
nucleus
axoneme
mitochondrial derivatives

assembly of spermatozoa

bridges between cells clear
relict centriole
do not look like sperm

differentiation begins

zone of spermatocytes

mitochondria coalesce into one paired structure - the mitochondrial derivatives
nebenkern

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

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>FUNCTION</th>
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<tbody>
<tr>
<td>Facilitation</td>
<td>Transportation</td>
</tr>
<tr>
<td>Provisioning</td>
<td>Nutrients</td>
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<tr>
<td>Sperm competition</td>
<td>Remove/flush previous sperm</td>
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<tr>
<td>-</td>
<td>Protect eupryenes from toxin</td>
</tr>
<tr>
<td>Filler</td>
<td>Delay remating</td>
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<tr>
<td>Cryptic female choice</td>
<td>Evaluate male quality</td>
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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

Accessory gland functions

Factors that reflect competition among sperm from different males
- speed
- toxins for other sperm
- mating plugs
- turn off female receptivity

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

<table>
<thead>
<tr>
<th></th>
<th>Successful matings</th>
<th>Rejected matings</th>
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</thead>
<tbody>
<tr>
<td>No SexP</td>
<td>154</td>
<td>671</td>
</tr>
<tr>
<td>Normal</td>
<td>9</td>
<td>724</td>
</tr>
</tbody>
</table>

18.7%

Compare fitness of females mated to each type of male

<table>
<thead>
<tr>
<th></th>
<th>Lifetime egg production</th>
</tr>
</thead>
<tbody>
<tr>
<td>No SP</td>
<td>73</td>
</tr>
<tr>
<td>Normal</td>
<td>55</td>
</tr>
</tbody>
</table>

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

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

Mariana Wolfner

2009. J. Heredity 100, 399-410
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 ovarirole number

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

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

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 females 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

fireflies
- species specific signals
- requires good but not remarkable vision

airborne | substrate vibrations
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

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

Males reared on artificial diet without PA

- 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
Dragonflies in tandem

- Guarding female to ensure use of his sperm

Back to Utetheisa for cryptic female choice

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

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