I. REPRODUCTION

TWO GENERAL MODES:

1. ASEXUAL: produce offspring whose genes come from a single parent, without the fusing of an egg and sperm.

2. SEXUAL: produce offspring by the fusion of haploid gametes to form a diploid zygote.

II. ASEXUAL REPRODUCTION

PARTHENOGENESIS

- found in some fish, amphibians and lizards (none in birds and mammals)

  e.g., *Cnemidopherus* lizards

  - populations of all females, reproduce clonally by parthenogenesis

  - however, requires sperm from another species to initiate parthenogenesis

III. SEXUAL REPRODUCTION

A. SEQUENTIAL HERMAPHRODITISM: individual reverses sex at one stage in life

  e.g., in marine fish, the wrasse

  - All individuals start as females

  - Largest individual in the group, changes into a male and defends the harem of females

  - If male dies, largest female changes into a male and defends the harem

B. MATING: male produces sperm, female produces egg; combine to form zygote

  - Fish

    a. Cartilaginous Fish (Chondrichthyes)

      - all species have internal fertilization: males have claspers, which are modified pelvic fins (called myxopterygia)

      - more primitive lineages lay eggs (oviparous) housed in hard egg cases for protection

      - more derived lineages retain egg and give birth to live young (ovoviviparous) (this is the most common among sharks)

    b. Bony Fishes: Osteichthyes

      - most are egg layers and have external fertilization

        e.g., spawning in salmon

      - spend most of their life at sea, but return to birthplace (freshwater streams) for mating

      - use olfaction (smell) cues to find way back to birthplace

      - external fertilization: females lay eggs (ca. 3500), and males spawn them (ca. 400,000,000,000 sperm!)

      - individuals die at the breeding grounds

      - young grow without parental care, then return to sea
III. SEXUAL REPRODUCTION

B. MATING: male produces sperm, female produces egg; combine to form zygote

1. Fish:
   b. bony fishes
      - some have internal fertilization
        males have modified anal pins: gonopodium
        e.g., guppies, mollies and other Poeceliid
      - most are live bearers

III. SEXUAL REPRODUCTION
B. MATING

2. Amphibians
   a. Anurans: Frogs
      - external fertilization
      - amplexus
      - eggs fertilized as females deposit them

   Exceptions: Tailed Frog: Ascaphus truei

III. SEXUAL REPRODUCTION
B. MATING

2. Amphibians
c. Caecilians
- internal fertilization: males have intromittent organ called phallodeum
- most are egg-layers: gelatinous eggs
- some are live bearers: eggs are housed in uterus, embryo develops and hatches then feed on “uterine milk” secreted by oviducts

III. SEXUAL REPRODUCTION
B. MATING

3. Reptiles
All reptiles have internal fertilization – males have an intromittent organ for inseminating females
Squamates (lizards and snakes) have hemipenes
- when not in use: housed within tail
- everted by muscle and blood flow

Exception:
Turtles have single penis
Male tuataras do not have an intromittent organ – cloacal kiss

III. SEXUAL REPRODUCTION
B. MATING

4. Mammals
- All mammals have internal fertilization: males have penis
- All mammals, except the Monotremes, are live-bearers

5. Birds
- Most birds do not have intromittent organs: “cloacal kiss”
- Exception: some fowls have penis
- Also females have lost second uterus
IV. PARENTAL CARE
- GREAT VARIABILITY IN PARENTAL CARE AMONG SPECIES/POPULATIONS.

WHY?
FOCUS ON THE COSTS AND BENEFITS OF PARENTAL CARE

COSTS
- can also think of reduced ability to produce offspring in the future

BENEFITS

IV. PARENTAL CARE
Quick Summary of Various Vertebrate Groups:

FISH: very variable
- most provide little parental care
- some provide extensive parental care:
  e.g., Many fish: males guard nests
  Cichlids: mouth brooders, keep eggs or larvae in mouth until they change into adults

AMPHIBIANS:
- TYPICALLY MINIMAL PARENTAL CARE
- MANY SHOW ADVANCED PARENTAL CARE
  e.g., Caecilians (see previous slide)

Marsupial Frog *Gastrotheca ovifera*
Gastric Brooding Frog *Rehobatrachus spp.*

- as female lays her eggs, male fertilize them and guide them to her pouch (back)
- females swallow eggs or larvae
- all digestive function stops and young develop in mother’s stomach (6-7 weeks)
- emerge as fully formed frogs

REPTILES:
- TYPICALLY NO PARENTAL CARE (e.g., Turtles)
- BUT SOME SPECIES HAVE EVOLVED PARENTAL CARE
  e.g., crocodiles
  - females lay eggs in nests of debris, sand or mud
  - young “call” after hatching
  - parents help young break free from rest of egg and nest
  - young swim to parents and protect young
  - do not feed young, only protect

http://www.smithfieldhs.qld.edu.au/
IV. PARENTAL CARE
Quick Summary of Various Vertebrate Groups:

MAMMALS:
- PARENTAL CARE: MOSTLY BY FEMALE
- EMBRYO IS RETAINED IN UTERUS AND FED THROUGH PLACENTA
- MAMMARY GLANDS PRODUCE MILK FOR YOUNG

BIRDS:
- ALL PROVIDE SOME PARENTAL CARE
- LAY EGGS THAT ARE PROTECTED AND INCUBATED (OFTEN BOTH SEX)
- PROVISION AND PROTECT NESTLING AFTER HATCHING
- PROVISION AND PROTECT YOUNG AFTER LEAVING NEST

MAMMALS AND BIRDS INVEST MUCH MORE PER OFFSPRING; HENCE, THEIR YOUNG HAS HIGHER PROBABILITY OF SURVIVAL
- PRODUCE FEW, BUT HIGH QUALITY YOUNG

FISH, MANY REPTILES AND AMPHIBIANS PROVIDE LITTLE PARENTAL CARE; HENCE YOUNG HAVE LOWER PROBABILITY OF SURVIVAL
- PRODUCE MANY, SO SOME WILL SURVIVE

IV. PARENTAL CARE: MATERNAL CARE
MOST COMMON ACROSS SPECIES -- why?
A. FEMALES HAVE ALREADY INVESTED MORE THAN MALES (e.g., more expensive gametes) AND SO WOULD PAY A HIGHER FITNESS COST IF THEY DO NOT PROVIDE PARENTAL CARE. SPERM IS CHEAP, SO MALES CAN MORE READILY PAY THIS COST

BUT... WE SEE PATERNAL CARE IN MANY SPECIES THAT SHOULD FOLLOW THIS RULE.
- e.g., MALLEE FOWL OF AUSTRALIA
  - MALES BUILD MOUNDS (SCRAPING DIRT AND LITTER)
  - MULTIPLE FEMALES LAY EGGS THEN LEAVE
  - MALE PROVIDES PARENTAL CARE BY CHECKING TEMPERATURE AND CHANGING LITTER/COMPOST COMPOSITION ACCORDINGLY
  - YOUNG ARE PRECOCIAL AND LEAVE AFTER HATCHING
IV. PARENTAL CARE: MATERNAL CARE

D. COST-BENEFIT RATIO OF PARENTAL CARE GREATER FOR MALES THAN FEMALES

1. LESS BENEFITS FOR MALES:
   PROBABILITY THAT OFFSPRING IS RELATED TO MALE: UNCERTAIN AND DEPENDS ON SYSTEM

   e.g., in Bluegills by Neff
   - Males build nests/mounds and provide all parental care for eggs of multiple females
   - Involves fanning (oxygen), and defending eggs, then defending fry from predators
   - No parental care = no young survive
   - Cuckolder males do not build nests and try to sneak fert: 1) sneaker hiding in adjacent areas or 2) satellite males mimicking females
   - Males exposed to sneakers defended their eggs less than control males
   - But not for fry. Why? Fry release olfactory cues upon hatching that MAY allow males to identify their own young. Test?

E. HOW DO FEMALES RECOGNIZE THEIR OWN OFFSPRING, ESPECIALLY IN COLONIES?

   e.g., Free-tailed bats that nests in LARGE colonies
   - Females leave pup with other females’ pups and are “mobbed” upon return from foraging

1. Can females recognize their own?
   McCracken used genetics to determine parents and offspring then observed if feeding occurred in a non-random way

   | Table 1. Non-random nursing in 167 pairs of Urodela brasilienior mexicana.
<table>
<thead>
<tr>
<th>Expected (random)</th>
<th>Me</th>
<th>SOD</th>
<th>Loc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed</td>
<td>5</td>
<td>2</td>
<td>7</td>
</tr>
</tbody>
</table>

   P < 0.001 (2-tail).

2. How do they do this? vocalizations!

IV. PARENTAL CARE: PATERNAL CARE

e.g., MANY MOUTH-BROODING FISH
SEA HORSES AND PIPEFISH
MANY MONOGAMOUS BIRDS
FROGS

Darwin’s frog (Rhinoderma darwinii)
- Males swallow their larvae after hatching
- Larvae develop in their vocal sacs until larvae change into froglets.

Fish family Syngnathidae – seahorses and pipefish,
Rosenqvist’s work on broad-nosed pipefish
- Males have brood pouches where females deposit eggs, and male provide oxygen, nutrients, protection until they hatch
V. PREFERENTIAL INVESTMENT
A. BASED ON CONDITION OF OFFSPRING
- If parents have finite resources, they should allocate more parental care to young in better condition
  e.g., parental care in coots by Lyon et al.
  - young differ in amount of orange in their downy feathers
  - removed orange tips, reduced feeding and growth rate
  - orange due to carotenoids, which is an excellent signal of condition in birds

B. THROUGH SIBLICIDE
- More aggressive individuals actively kill siblings
  e.g., Hyenas
  - mothers leave young in burrows, where they often fight
  - young also fight during suckling, some pups die via sibling fights (2 mo)
  - aggression is even more pronounced in same-sex litters
  - is this adaptive?
  - is this tolerated by parents?

VI. Mating Systems
- Defined by number of mates in a given breeding season
- Defined by extent of pair bond between individuals

A. Monogamous: prolonged and exclusive pair bond between one male and one female.
  (About 90% of birds vs. 10% of mammals. Why?)
B. Polygyny: A single male pairs with more than one female.
C. Polyandry: A single female pairs with more than one male
D. Polygynandry: both males and females pair with more than one mate

Why do species differ?
How does sexual and natural selection influence mating system evolution?
VI. Mating Systems
A. Monogamy
-extended and exclusive pair bond
-this is contrary to Bateman’s Rule and Anisogamy.

Why?
1. mate assistance: increase survival of offspring with two parents

- females do not necessarily increase their mating success with more males

male number of mates females
reproductive success

Why? e.g., Lyons work on Snow buntings
- monogamous
- experiment: 11 monogamous
  13 widowed
- assayed number of chicks fledged
- control pairs reared more fledglings than widowed females

2. mate-guarding – males guard receptive females
to prevent other males from mating

Why do females solicit EPCs?
1. Insures fertilization
2. Good genes
3. Increased genetic variation – offspring will be more variable
4. Access to extra resources
5. Reduced risk of harassment

*EPCs: Extra pair copulations
-e.g., 30-40% of broods in white-crowned sparrows are from EPCs
50% or more in tree swallows
mates of vasectomized RW blackbird still have high rates of fertility

In bee-eaters by Sherman and Emlen
VI. Mating Systems

B. Polygynous

- male mates with multiple females
- consistent with sexual selection theory: Bateman's Rule and Anisogamy

1. Resource-defense polygyny

* e.g., Cichlid Lamprologus callipterus by Sato
- males defend and collect small shells where tiny females lay their eggs and stay with young till hatching

| Table 3. The percentages of shells used in four nest sites |
|-----------------|-----------------|-----------------|-----------------|
| Size | No. of nests | N. tanganense | P. davisoni |
|       |               | Overall | Maximum | Minimum | Overall | Maximum | Minimum |
| E    | 4             | 42.3%   | 50.0% (48) | 33.3% (39) | 16.0%   | 15.4% (213) | 0.0% (012) |
| F    | 17            | 98.0%   | 100.0% (275) | 80.0% (45) | 4.7%    | 12.6% (1197) | 1.4% (2709) |
| G    | 8             | 42.9%   | 100.0% (113) | 33.3% (120) | 8.0%    | 18.1% (1372) | 0.0% (0246) |
| H    | 11            | 62.5%   | 66.7% (23) | 33.3% (15) | 5.8%    | 23.3% (294) | 0.0% (0199) |

Numbers in parentheses represent numbers of shells used and total numbers of shells in a nest, respectively.

Table 3. Breeding success of monogamous and polygynous males

<table>
<thead>
<tr>
<th>Year</th>
<th>Harem size</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>Males</td>
<td>Active</td>
<td>Nest</td>
<td>Nest</td>
<td>Nest</td>
<td>Nest</td>
<td>Nest</td>
</tr>
<tr>
<td>1976</td>
<td>8</td>
<td>14</td>
<td>8</td>
<td>7</td>
<td>9</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

1. Resource-defense polygyny

* e.g., red-winged blackbird

- best for males and females to be polygynous

2. Female-defense polygyny

* e.g., spear-nosed bat by McCraken and Bradbury

- males defend females in roost sites (caves)

* single male can guard (and mate with) up to 50 females
VI. Mating Systems
B. Polygynous

3. Promiscuous
- typically lek: aggregation of males to attract females
- no paternal care, no resources defended
- typically, male placement in lek is a cue/signal females use to decide

many ungulates, bats and dugong (topi below)
many bird species
frogs and salamanders

What dictates the type of polygyny?

1. Are females distributed in defendable clusters?
   Yes – female defense polygyny
2. Are resources needed by females distributed in defendable clusters?
   Yes – resource defense polygyny
3. Are resources or females not defendable?
   No, males defend small territories – lek or promiscuous
VI. Mating Systems

C. Polyandry

- female mate with multiple males
  1. Defend territory
  2. Defend males

  e.g., wattled jacana by Emlen, Wrege and Webster
  - both sexes defend floating vegetation – nests
  - male home range: 1127 m²
  - female home range: 1 to 4 male territories
  - female > males (135 vs 91 g)
  - females mate with 1 to 4 males (in a population 75% shared a female)
  - males provide all parental care (for 3 months total)

MALES ARE LOSING OUT—PAYING COST TO POLYANDRY

VI. Mating Systems

D. Polygynandry

- both sexes multiple mates
  e.g., cassowaries (other ratites)
  tinamous
  dunnocks

VI. Mating Systems

D. The Dunnock by Davies and Lundberg

- within a single population: ranges from monogamy to polygyny to polyandry.
- food density low: females forage wide
- food density high: females forage smaller regions

A natural home ranges

E. The Dunnock by Davies and Lundberg

- experiment: provide clustered food sources (meal worms and oats to some females)
- females with supplemental food: reduce range by 40%, become monogamous
- no supplement, large range with more mates
- BUT females can control specific matings, so some females solicit matings from beta males – results in more parental care