Reproduction in Fishes

I. Lifetime spawning frequency

II. Spawning cycles

III. Modes of spawning

IV. Sex change and mating systems

I. Lifetime spawning frequency

Semelparity — spawn once

Iteroparity — spawn multiple times

Why?

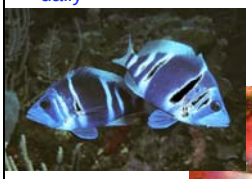
semelparous

iteroparous

II. Spawning cycles

- semelparous — annual (or multiples thereof)
- iteroparous — annual, lunar, daily; & cycles within cycles

daily



monthly

yearly

III. Modes of reproduction

- **oviparity** — egg laying
- **ovoviviparity** — livebearing, no maternal nourishment
- **viviparity** — livebearing with maternal nourishment

Tradeoff: number vs. size of eggs/offspring

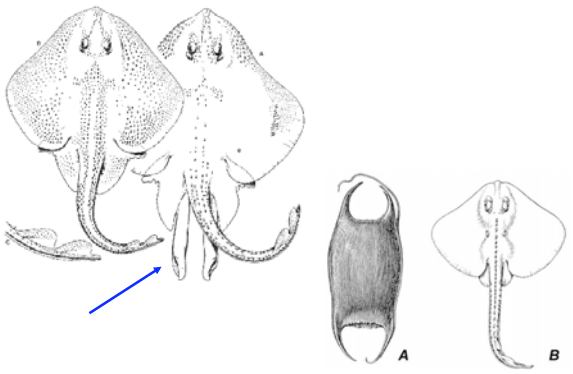
Number of offspring (eggs or young) and degree of parental care

Species	Relative Egg/ Offspring Size	Mean # of Eggs/ Offspring	Degree of Parental Care
Mola mola	very small	28,000,000	none, free floating pelagic eggs
cod	very small	9,000,000	
haddock	very small	2,000,000	
sturgeon	medium	200,000	eggs buried, no other care
salmon	medium	5,000	
sculpin	medium	140	high
stickleback	medium	60	
medaka	medium	30	
sand shark	very large	1-2	extreme: uterus w/ cannibalism

Oviparity

- **external fertilization** — gametes shed into water
  - most common mode
  - ancestral condition
  - simple
  - small, but numerous eggs
- **internal fertilization** — eggs fertilized internally, but later released into water
  - uncommon
  - many elasmobranchs
  - often very large eggs in cases

Internal Fertilization in Oviparous species



Ovoviviparity

- **internal fertilization** — eggs fertilized internally & hatch internally, but no direct maternal nourishment

advantage

- young are generally larger and more advanced

disadvantages

- low dispersal of offspring
- few offspring produced
- if mother dies while pregnant, offspring die, too

examples:
- most sharks and rays
- coelacanth
- rockfishes

Viviparity

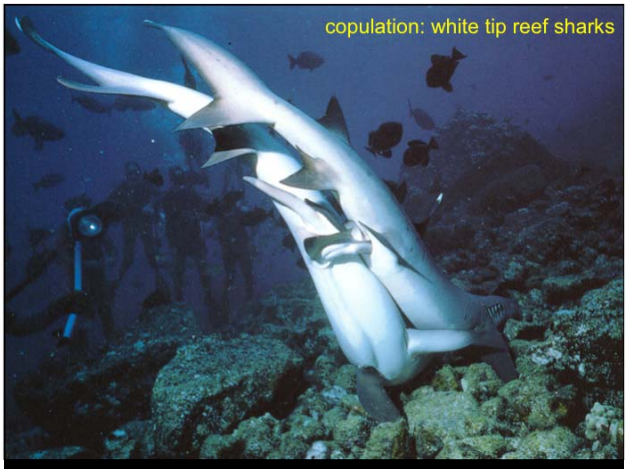
- **internal fertilization** & **direct maternal nourishment**
  - ovarian fluids
  - placenta (some sharks)

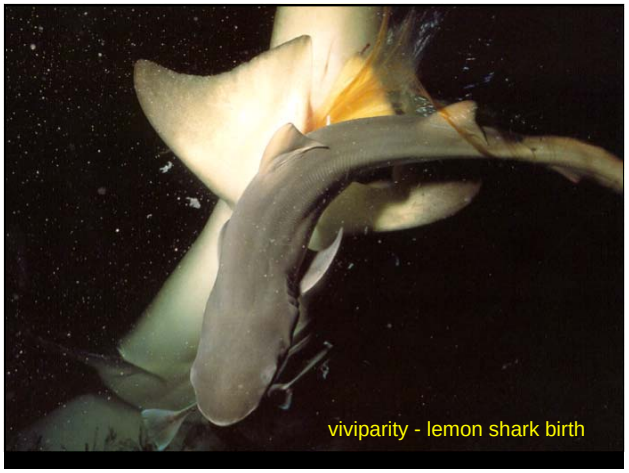
advantage

- young are very large and advanced

disadvantages

- same as for ovoviviparity
- energetic cost to mother

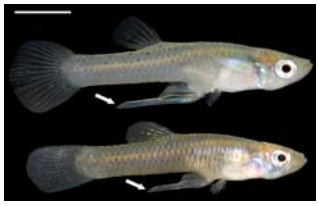


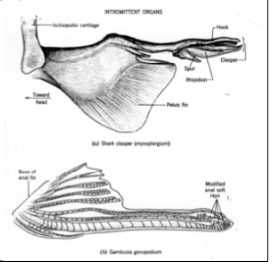


Internal Fertilization: males have an *intromittent organ*

1. modifications of pelvic or anal fins:
   - claspers: elasmobranchs, chimeras
   - gonopodia: guppies, mollies

2. genital papilla: non-bony tube
   - rockfishes, surfperches, cottids





Viviparity

examples:

- requiem sharks (family Carcharhinidae) & hammerheads
- guppies & other freshwater livebearers
- marine surfperches

viviparity - shiner surfperch birth

Return to Oviparity:

Modes of Oviparity

1) broadcast spawning
2) demersal, non-guarding
3) demersal, guarding
4) brooders

1) Broadcast Spawning
   - most marine fishes
   - eggs & sperm shed into water column & drift away
   - larval & juvenile/adult habitat completely different (bipartite life cycle)

1) Broadcast Spawning

- **advantages**
  - zero energy expenditure after gametes released
  - best chance of long distance dispersal
- **disadvantages**
  - very low survival of offspring
  - caused by:
    - * lack of parental protection
    - * small larval size
    - * inability to find or return to appropriate adult habitat

1) Broadcast Spawning: Timing & Location

- maximize transport of eggs & larvae away from the reef
  - spawn during outgoing tide
  - downcurrent side of reef
  - upward spawning rush to place gametes high in water column
- two hypotheses:
  - minimize exposure to predators
  - maximize dispersal ("spread the risk")

2) Demersal Non-Guarding

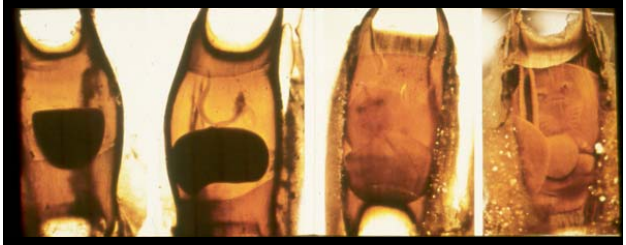
- hiders and non-hiders
- eggs usually placed or glued on bottom
- common in freshwater fishes (minnows), but not in marine fishes

advantages
- zero energy expenditure after gametes released
- eggs may be better protected
- greater control over where offspring end up

disadvantages
- still quite low survival of offspring
- high risk of loosing entire batch of eggs
- lower dispersal
- nest sites can become limited

Grunion spawning

Skate egg cases



Swell shark egg case

3) Demersal Guarding

- common among reef fishes (e.g., gobies, damselfish, triggerfish)
- males usually guard

3) Demersal Guarding

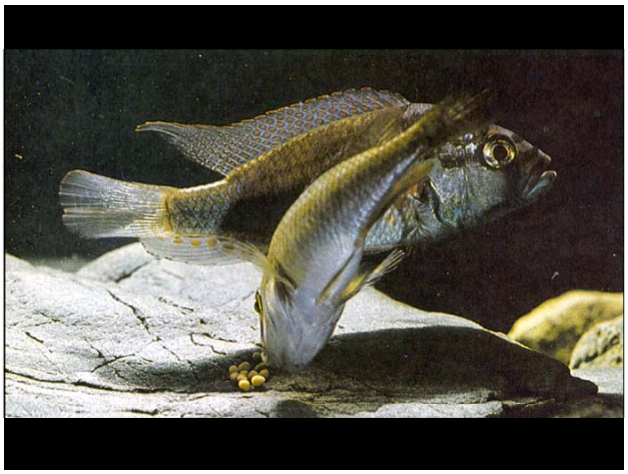
advantages
- increased survival due to parental protection
- increased survival due to parental care (cleaning and oxygenation)

disadvantages
- high cost to parent(s): energy and time
- increased risk of mortality in parent(s)
- nest sites may become limited

4) Brooding

- young brooded in:
  - **mouths** (males of cardinalfishes, jawfishes, catfishes; female cichlids)
  - **on body** (some male pipefishes)
  - **pouches** (male seahorses & some pipefishes)
- offspring usually (but not always — e.g., cardinalfishes) well developed when released

Haplochromis spawning



Haplochromis mouthbrooding female

seahorse oviposition
& male giving “birth”

4) Brooding

advantages

- increased survival due to parental protection
- increased survival due to parental care
- (cleaning and oxygenation)
- no need to find or maintain a nest

disadvantages

- high cost to parent(s): energy and time
- if parent dies, so do offspring
- low dispersal

IV. Sex change

- among vertebrates, found only in fishes

Sexual Strategies

- **gonochorism** — separate sexes, no sex change
  - advantage: allows sexual specialization
  - disadvantage: may not maximize fitness
- **hermaphroditism**
  - simultaneous
  - sequential
    - ***protogynous*** = female then male
    - ***protandrous*** = male then female

Why are fish able to change sex?

- simple gonads and reproductive tracts
- sex chromosomes are similar or identical

Why do fish change sex?

- to maximize *fitness* by maximizing lifetime *reproductive output*

Why do fish change sex?

Size advantage model - predicts sex change if your current reproductive value (**RV**) is less than what it would be if you were the opposite sex

RV = (expected fecundity at a given size)
×
(probability of surviving to that size)

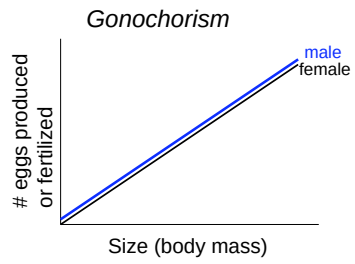
Why would RV differ between the sexes?

1) **relative cost of gametes**
   - sperm are cheap, eggs expensive
   - therefore, females usually limited by ability to produce eggs or hold them or embryos in the body
     (69 human offspring; Russian woman, 1700's)
   - males usually limited by access to females
     (850+ children: Emperor of Morocco 1600-1700's)

2) mating system...
   - monogamy - one partner
   - polygamy - multiple partners
     - polygyny - many females, one male
     - polyandry - many males, one female

RV changes with body size and mating system:

1) female — increases linearly with size
2) **male** — depends on mating system
   - competition for mates or sperm competition



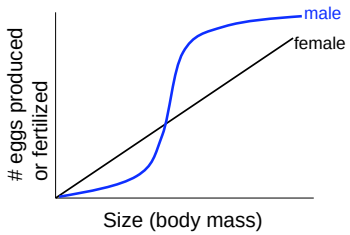
RV changes with body size and mating system:

1) female — increases linearly with size

2) **male** — depends on mating system

- competition for spawning sites or limited access to females

Protogyny



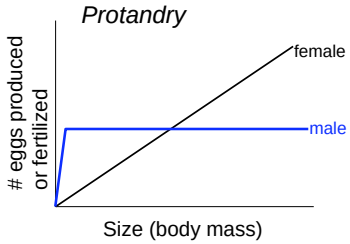
Protogyny -- California sheephead

RV changes with body size and mating system:

1) female — increases linearly with size

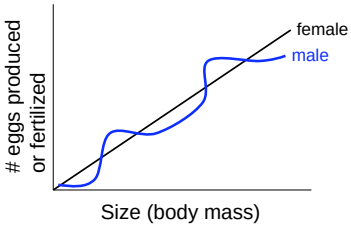
2) **male** — depends on mating system
   - no defensible resources
   - limited # of sperm needed
   - no direct competition between males
   - can occur if matings are random or there is stable monogamy

Protandry



Protandry -- anemonefish

Reversible Sex Change
or
Simultaneous Hermaphroditism



Reversible sex change is very rare
(a handful of gobies)

Why?

- energetically expensive?
- lost mating opportunities?

Simultaneous hermaphroditism seems like best strategy

- Why is it so rare?

Cheating

Simultaneous hermaphroditism is common in two groups of fishes:

- deep sea fishes
- small serranids

barracudina

barracudina

Deep sea fishes

- population densities very low
- must be able to act as either sex when you encounter a conspecific
- selection so strong that cheating species went extinct?

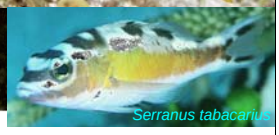
lancetfish

Small serranids (*Hypoplectrus, Serranus)*

- **egg trading** allows cheaters to be detected and punished
- **cheaters abandoned**
- abandoned cheaters **lose mating opportunities** while searching for new mate

Hypoplectrus indigo

Serranus tigrinis



Serranus tabacarius