We have seen many impressive cases of evolution:

- Gigantic giraffe necks
- Transvestitism
- Elaborate male bird tails
- Barnacle penises and male atrophy
- Eusocial organisms that give up reproduction
- Hyena females with phalluses
- Etc.

*With evolution all things seem possible*
But we have also seen cases of constraints in evolution:

Mammals inner ear, needed second joint to arise for the original joint bones to be capable of reducing in size and becoming hearing organs (Q-I, A-M)

No vertebrates with more than 2 pairs of limbs

Almost no altruism in nature

*With evolution NOT all things are possible*
Other sorts of constraints:

Mollusca  While the organisms can be very complex (octopus, squid) the shell/skeleton is always simple

Insects  No insect has more than 3 body segments  
          (Arthropods in general are not limited)

Mammals  Mammals all (*mostly*) have 7 cervical vertebrae

What causes *evolutionary constraints*?
Evolutionary novelty needs two things:
- Mutants with the new variant arise
- The new variant is selected for

Lack of novelty (constraint) is therefore due to:
- New variants are not produced (Developmental constraint)
- New variants are not selectable
  Selective constraint
  Functional constraint
  Pleiotropic constraint
Ex: Patterns of digit loss in tetrapods correlate inversely with patterns of digit development

Order of digit development:

Lost last

Lost first

Evolutionary constraint: developmental
Evolutionary constraint: developmental

Ex: Patterns of digit loss in tetrapods correlate inversely with patterns of digit development.
Mollusca

While the organisms can be very complex (octopus, squid) the shell/skeleton is always very simple.

The shell grows only from the outer margin - this doesn't allow for multiple joints or internal elongation.
Selection at one level prevents adaptation at another.

Why don't females reproduce asexually?
  - Group selection > individual selection

Why isn't altruism widespread?
  - Individual selection > group selection

Why are there no "superdiseases" like in *Contagion*?
  - Group selection at level of hosts prevents prolonged individual selection (virulence) (I.E., Ebola vs HIV)
Why don’t whales have gills?
Gills are easy to evolve (they’re just finely divided blood supplied tissue)

Why are the biggest terrestrial insects and arthropods so small?
As the body becomes larger, the exoskeleton must become thicker. This limits the room inside for muscles
Evolutionary constraint: functional

Limit to the size of buildings/organisms with exoskeletons. Bigger buildings/organisms use endo-skeletons to allow space for humans/tissues inside.
Math argument for relative sizes of limbs and bodies.

Idealized organism: cubic body and cylindrical legs.

As the length of the body increases, the volume would increase as the cube of the length. Therefore the mass would also increase as the cube.

*In Jonathan Swift’s *Gulliver’s Travels* the Liliputians are 6 inches tall (1/12 in length). Gulliver is given food equal to 1728 (12³) Liliputians

The strength of the limbs are determined by their cross-sectional area, this increases with the square of the radius.

\[
M = L^3 \\
S = r^2
\]
Impossible on land, but in water gravity is less of a factor
- largest exoskeleton animals are aquatic
Math argument for relative sizes of limbs and bodies.

Idealized organism: cubic body and flat wings.

As the length of the body increases, the volume would increase as the cube of the length. Therefore the mass would also increase as the cube.

The lift of the wings is determined by their cross-sectional area, this increases with the width x wing length.

Evolutionary constraint: functional

\[ M = L^3 \]
\[ S = Lw \]
Evolutionary constraint: functional
Why do almost all mammals have 7 cervical vertebrae?  
Not a functional reason (swans have 22-25, ducks 16)
Pleiotropic constraint:

Why do almost all mammals have 7 cervical vertebrae?
Not a functional reason (swans have 22-25, ducks 16)

*Hox* genes are involved in axial patterning
*Hox* genes are also involved in regulating cell proliferation
Human children with embryonic cancers have a 125x increase risk of having cervical ribs
Human children born with cervical ribs have a 120x increased risk of having an early childhood cancer
Taxa with more cervical vertebrae have lower metabolic and cancer rates (birds, reptiles, amphibs, manatees, sloth)
Pleiotropy of *Hox* genes prevents the evolution of novel # of cervical vertebrae in taxa with cancer risk

Evolutionary constraints:

- Developmental constraint (digits)

- Selective constraint
  - Individual > group (hyenas)
  - Gene > individual (mice)
  - Groups > individual & gene (sex)

- Functional constraint (whale gills, max. size)

- Pleiotropic constraint (cervical vertebrae)