



# Rationale Behind Biological Inspiration in Robot Design

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# Objectives

- Explain motivation for bio-inspiration in robot design
  - What ideas can nature offer engineers?
  - Can bio-inspired designs outperform traditional technology?
  - How is the source for bio-inspiration chosen?



# Mobile Robots

# Robot Concepts: Traditional sources

Automating/programming existing engineered devices

- Automobiles



Off-road truck



ATRV Robot

- Aircraft



F/A-22 Raptor



Predator UAV

- Tanks



M1A2 Battle Tank



Andros Wolverine

- Submarines



USS Virginia



Odyssey AUV



# Why not traditional mobile robots?

## Advantages

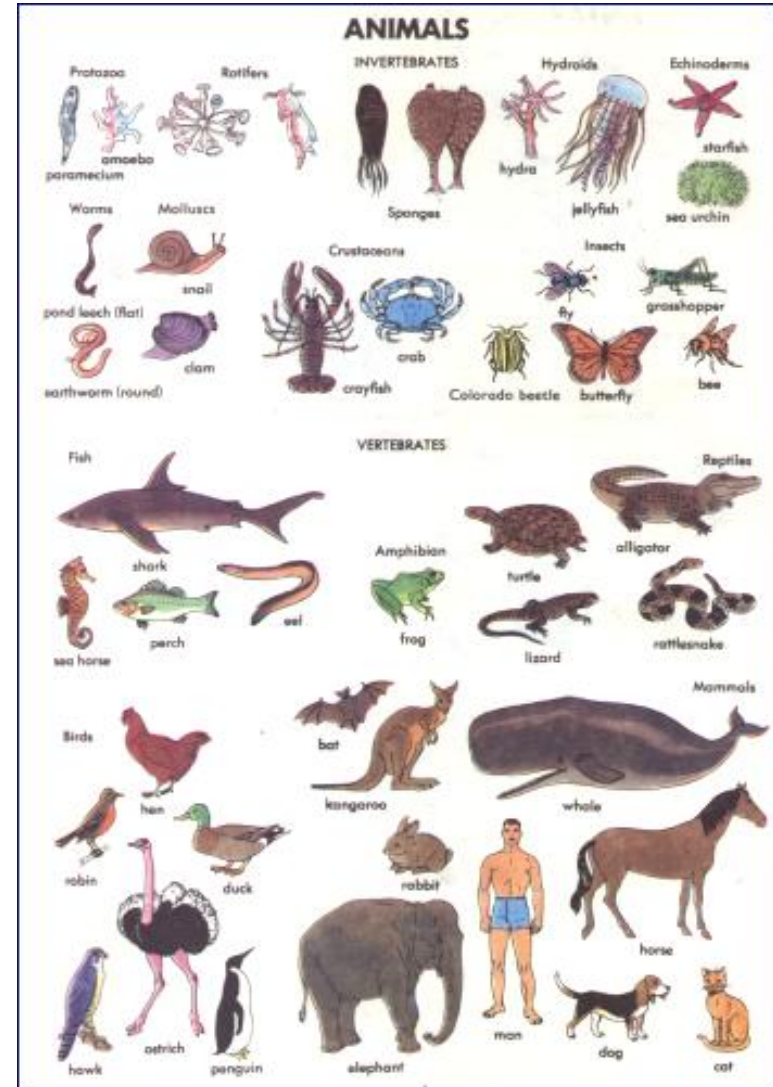
- Speed
- Strength
- Durability
- Reliability
- Repeatability

## Disadvantages

- Poor maneuverability
- Complex systems
- Many components
- Designed for single type of locomotion
- Limited by terrain and obstacle height
- Best suited for highly specified tasks

# Design Concepts: Alternative sources

- Entire animal kingdom
  - Vertebrates
    - Mammals
    - Birds
    - Fish
    - Reptiles
    - Amphibians
  - Invertebrates
    - Crustaceans
    - Insects
    - Spiders
- Biological locomotion
  - Biomechanics
- Biological structures
  - Materials and geometry
- Biological control
  - Sensors and processing





# Why look to nature?

Nature's creatures are capable of a variety of tasks

- On land
  - Walking
  - Running
  - Jumping
  - Climbing
- In the air
  - Flying
  - Gliding
  - Hovering
  - Diving
- In the water
  - Swimming
  - Diving
  - Leaping from water
  - Neutral buoyancy
- Anywhere
  - Lifting/carrying
  - Pulling/pushing
  - Grasping

# Nature's Designs

Some animals have been optimized for speed

- Running → Cheetah (72 mph)
- Swimming → Sailfish (68 mph)
- Bird flying → Swift (106 mph)
- Insect flying → Dragonfly (36 mph)
- Bird diving → Peregrine falcon (100-200 mph)





# Nature's Designs

Some animals have been optimized for other tasks

- Lifting → Elephants (1 ton)  
Rhinoceros beetle (850 x body weight)
- Long jump → Kangaroos (30 ft)  
Flea (200 x body length)
- High jump → Puma (18 ft)  
Flea (150 x body height)
- Gliding → Flying squirrel (650 ft)





# Capabilities of Nature

Nature's creatures exhibit one or more of the following qualities:

- Stability
- High maneuverability
- Ability to traverse highly irregular terrain relative to body size
- Ability to function in varied environments
  - Locomotion in a combination of land, water, and air
  - Locomotion in varied terrain – rocks, sand, swamp, etc.
- One system capable of several types of motion
  - Land: walking/running/jumping/climbing
  - Air: flying/gliding/hovering
- Ability to carry objects many times their own weight
- Self healing

# Capabilities of Nature

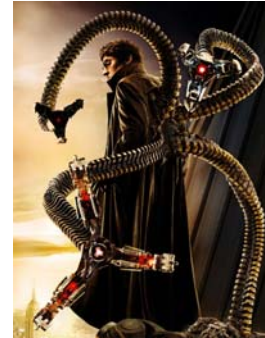
Nature's creatures are capable of unique tasks

- Geckos can walk upside down
- Hummingbirds can hover, fly straight up, down, or backwards
- A 70 lb octopus can fit through a hole the size of a silver dollar



# Bio-inspired Design Concepts

- Design concepts from nature can be implemented in a number of imaginative ways
- Some bio-inspired robots have shown up in today's movies
  - Spider robot (*Minority Report*)
  - Octopus arms (*Spiderman 2*)



- Squid robot (*Matrix*)



- Elephant robot (*Star Wars*)





# Locomotion Comparison: Wheel/Treads vs Legs

## Traditional

- Wheels



- Tank treads



## Biological

- Legs





# Locomotion Comparison: Wheel/Treads vs Body Undulation

## Traditional

- Wheels



- Tank treads



## Biological

- Body Undulation





# Locomotion Comparison: Propeller Vs Body Undulation

## Traditional

- Propeller



## Biological

- Body undulation





# Locomotion Comparison: Rotating Blades vs Flapping Wings

## Traditional

- Rotating blades
  - Propeller
  - Turbine engine
  - Helicopter rotor



## Biological

- Flapping Wings





# Summary

- Nature offers engineers new design concepts
  - Engineers take ideas from the engineered world
  - The natural world offers a large source for new ideas
- Nature uses unique forms of locomotion unseen in robotics



- Bio-inspired designs may outperform traditional robots
  - Traditional mobile robots are limited by natural terrain
  - Nature's creatures are well adapted to and thrive in the natural world
  - Nature's creatures are capable of unique tasks