האיגוד הישראלי להנדסת מערכות

Israeli Society For Systems Engineering

Biomimetics

Applying nature's innovations to system design

John Gill, PhD, ESEP

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Biomimetics

- **The term Biomimetic refers to human-made processes, substances, devices, or systems that imitate nature.**
- **The art and science of designing and building biomimetic apparatus is called biomimetics.**
- **Biomimetics is of special interest to researchers in …**
  - **Nanotechnology**
  - **Robotics**
  - **Artificial Intel (AI)**
  - **Medical industry**
  - **Military**

Biomimetics is applying what we learn from nature to system design.

Biomimicry is when nature imitates itself.

Common examples of Biomimetics (1 of 2)

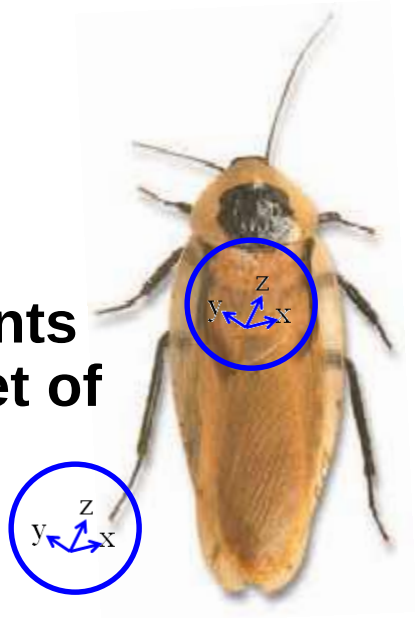
- Bats (Echolocation)
  - Why? Bats are essentially blind
    - Navigation in utter darkness, finding food and mates
  - How? Generate a high frequency “ping”, interpret the return
    - Locate surfaces, detect relative movement (Doppler) and distinguish identified targets
  - Why high frequency?
    - Better discrimination, lower probability of detection
    - Tuned to their environment;
      - Pressure, density and humidity at ground level
- Biomimetic equivalent; RADAR, SONAR
- Variations on a theme
  - Moths, Mosquitoes, Dolphins, Humans

Common examples of Biomimetics (2 of 2)

- Spiders and Ants (Hydraulics)
  - Why? Exoskeletons and muscles generally incompatible
    - Rapid movement and strength
    - Good system solution for small (natural) systems
  - How? Muscular "bulb" at joint compresses fluid, relaxing the bulb moves the limb in the opposite direction
    - Lightweight, high strength limbs move quickly
    - Excellent movement control
    - Remains rigid easily (no fatigue)
- Biomimetic equivalent; Earthmoving Equipment, Presses
- Variation on a theme
  - Grasshoppers, Lobster

Biomimetics and Biomechanics

- **Insects move quickly (but somewhat erratically!)**
- **Microfabrication is being applied to develop the nextgen sensors for biomechanical experiments.**
- **These sensors make multi-axis force measurements of the ground reaction forces produced by the feet of running insects (and the body centroid).**
- **Measurements used to develop a better understanding of the peculiar self-stabilizing dynamics used by sprawl-postured animals.**



Think “Modeling and Simulation” here…

Biomimetic application; robots which can mimic their structural dynamics and simple control strategies will be extremely well-suited to navigate difficult terrain at high speed

What's the big deal about bug eyes?

- Xenos peckii has about 50 separate lenses per eye and can see and process a very wide field of vision.
  - Each lens has limited field of view, fixed depth resolution
  - Lens arrangement delivers required coverage
  - Individual images upside down and discrete
    - Simple parallel processing algorithm
- Lightweight device ("Bug Eye") delivers 120 degrees of coverage and replaces heavy, gimbal-mounted equipment (complex!) which can only cover 20 degrees while fixed
- Application; motion detection and tracking

Humans have foveal optics.
What's the difference and why?

Some cool applications to consider…

- Studying pressure gradients across birds' wings to see what can be learned for aircraft
- Material sciences
  - Mimicking the arrangement of wood fiber to create blast resistant structure (concrete with nanotube reinforcement?)
  - Cochina; coral based, cementitious (Shock Resistant)
  - Deer antler – a fracture-resistant material
- Developing artificial intelligence and autonomous systems based on observing swarms of insects/birds, schooling fish
- Shark skin (ultra-low surface friction)
- Eagle vision, Shrews

Nature has solved more of our "problems" than we may ever know -without creating new problems in the process…

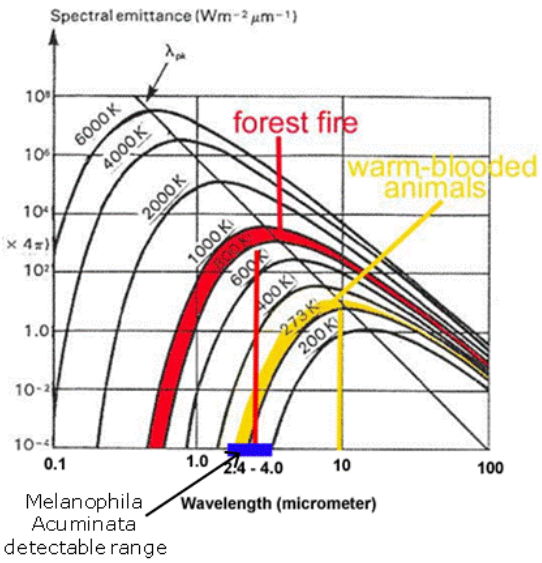
The Buprestid Beetle

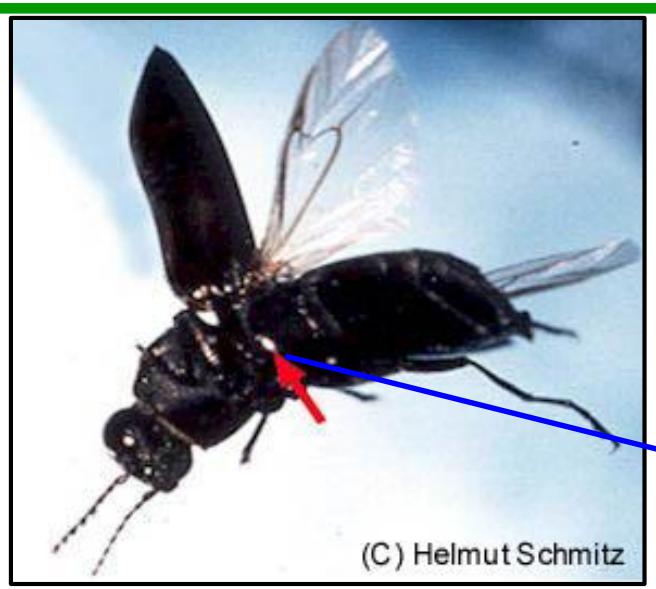
- **The “Jewel beetle” or “Metallic / short-horned wood borer”**
- **Found in wood/bark of trunks, logs, branches or plant roots**

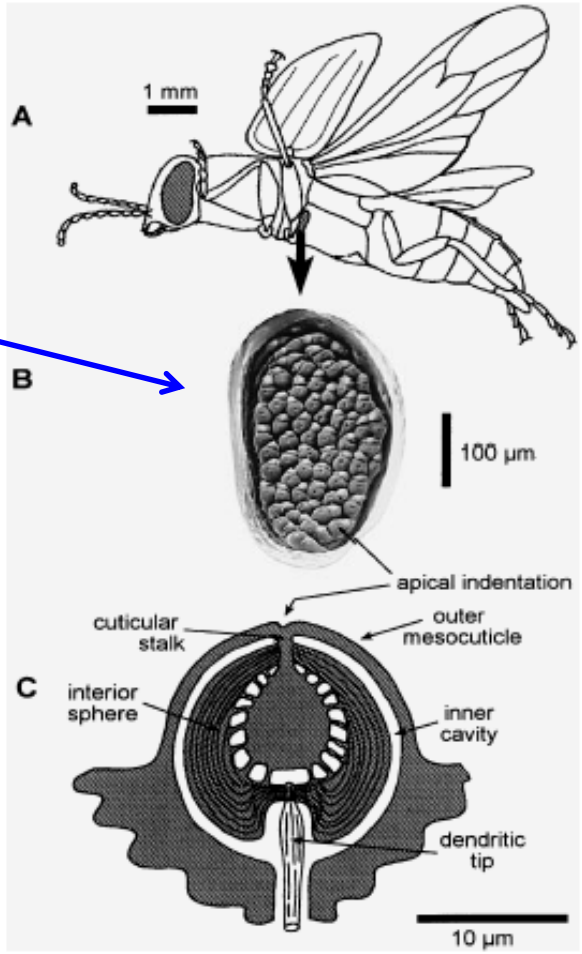
Why is that important to us?

- **Melanophila Acuminata;** Black Fire Beetle or Fire Bug
  - Like others, the Jewel Beetle must be able to find mates and plant larva where they will grow to maturity
  - Burning trees are prime environments
  - Sensory pits; this capability sets the Jewel Beetle apart from all other buprestids

Nature evolves to survive

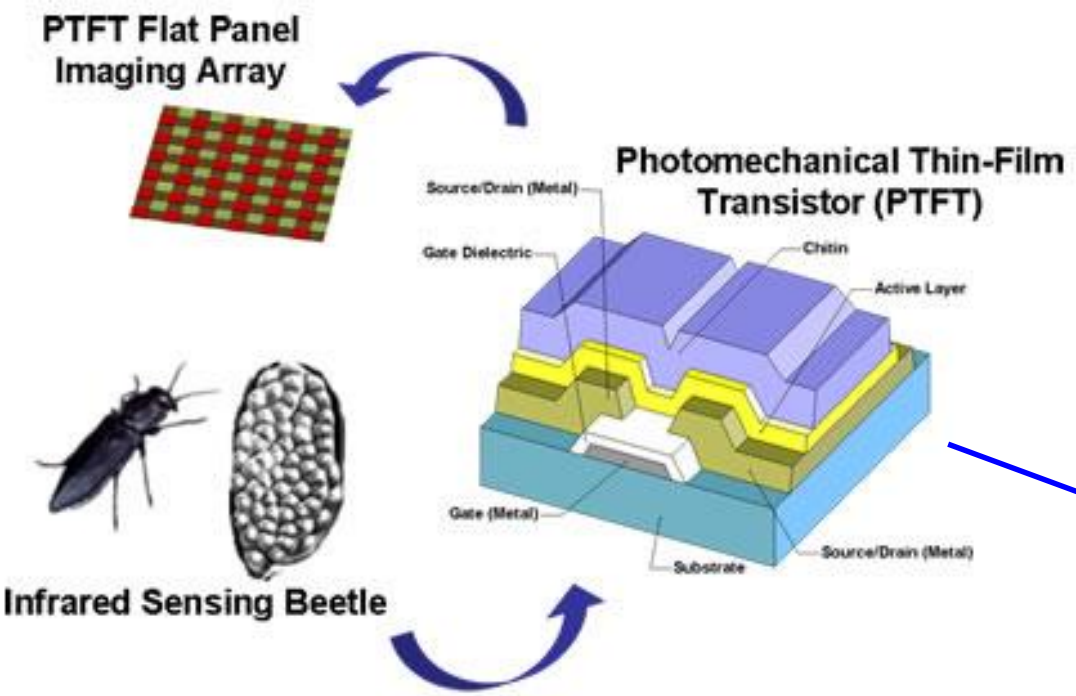


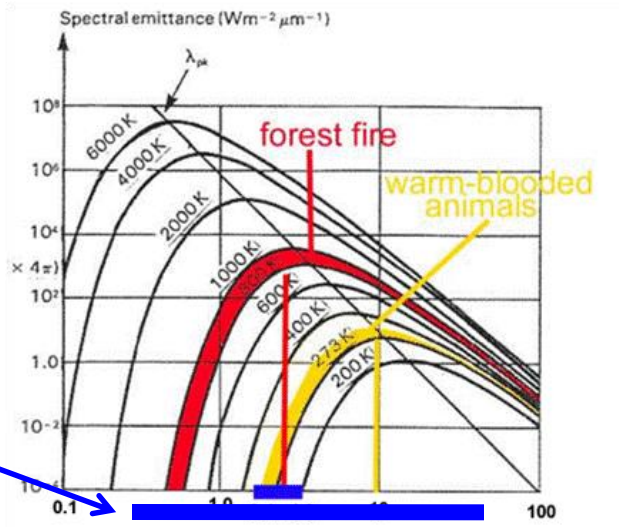




1. **The legs are lifted in flight exposing pit organs**
2. **IR pit organ: 62 domed IR sensilla (sensors)**
3. **Expansion of the sphere due to IR radiation absorption causes deformation of dendritic tip**

Biomimetic application





Adjustable sensitivity range

High sensitivity, broad range of coverage
or specifically tunable to detect unique emissions

Snakes… and Squirrels

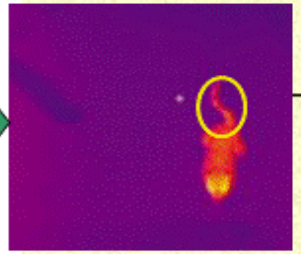
Threat Evaluation

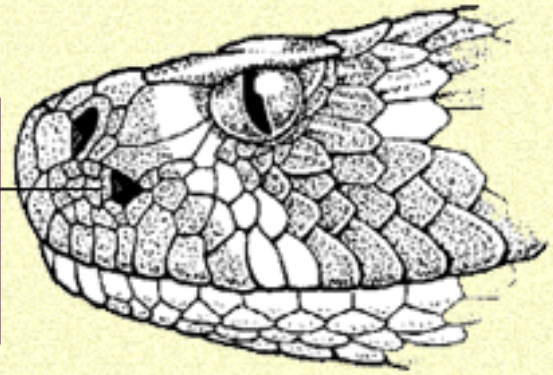
California Ground Squirrel

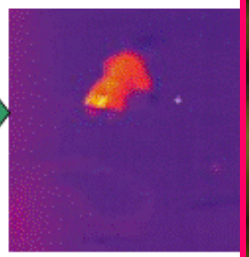
Rattlesnake

Gopher Snake

SQUIRCM in Action

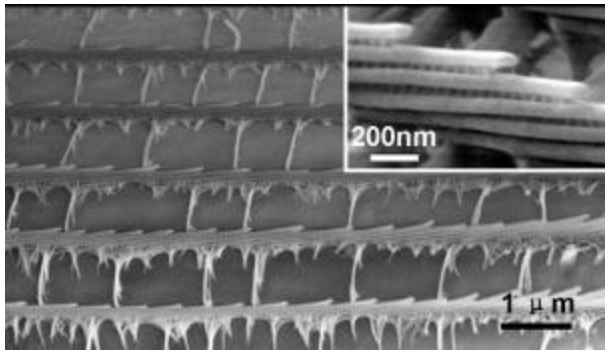






Butterfly wings…

Basic Construction



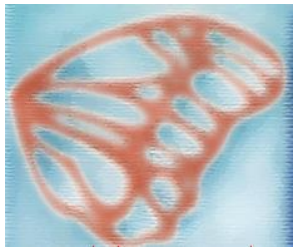
-Wing structure; alternating layers of thin films (chitin) and air. Color often not a result of pigment.

-IR; up to 96% absorption, heat evenly distributed.

- What we see; wing structure determines color by reflecting or canceling components of white light

Delivers Multiple Functions…

- Maintains wing structure and thermal management
- Colors and spots used to communicate between butterflies
- Mirror-like structure under scales allows for directed light reflection
- Other ways butterflies use IR
  - Detect wing patterns (Friend or Foe)
  - Find food (Healthy green plants owing to differential IR reflection)



Nature delivers elegant solutions
- every time

Biomimetics

Solutions developed through evolutionary processes can lead to revolutionary advances

Human innovation is the product of awareness and application engineering.
We must first be aware

We understand only a small percentage of our world

Questions?