



Lecture 2: Sensory Systems and Innate Behavior

HSSP Summer 2017

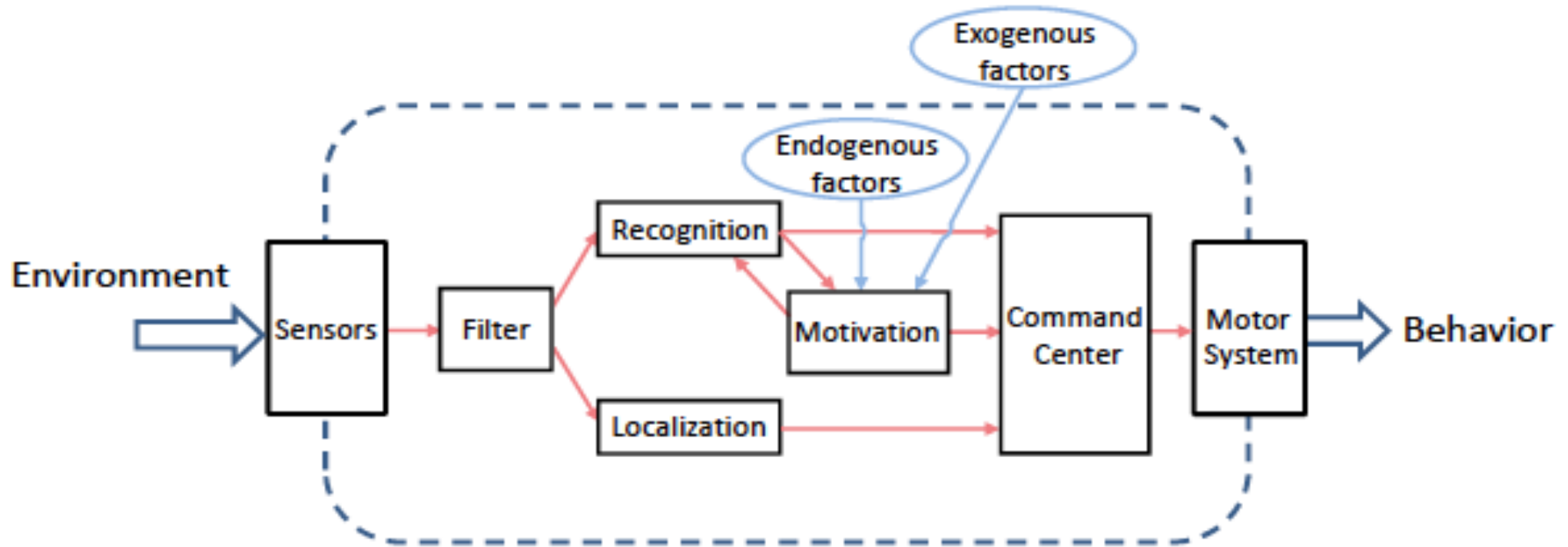
16 July 2017

Alexandra Ding

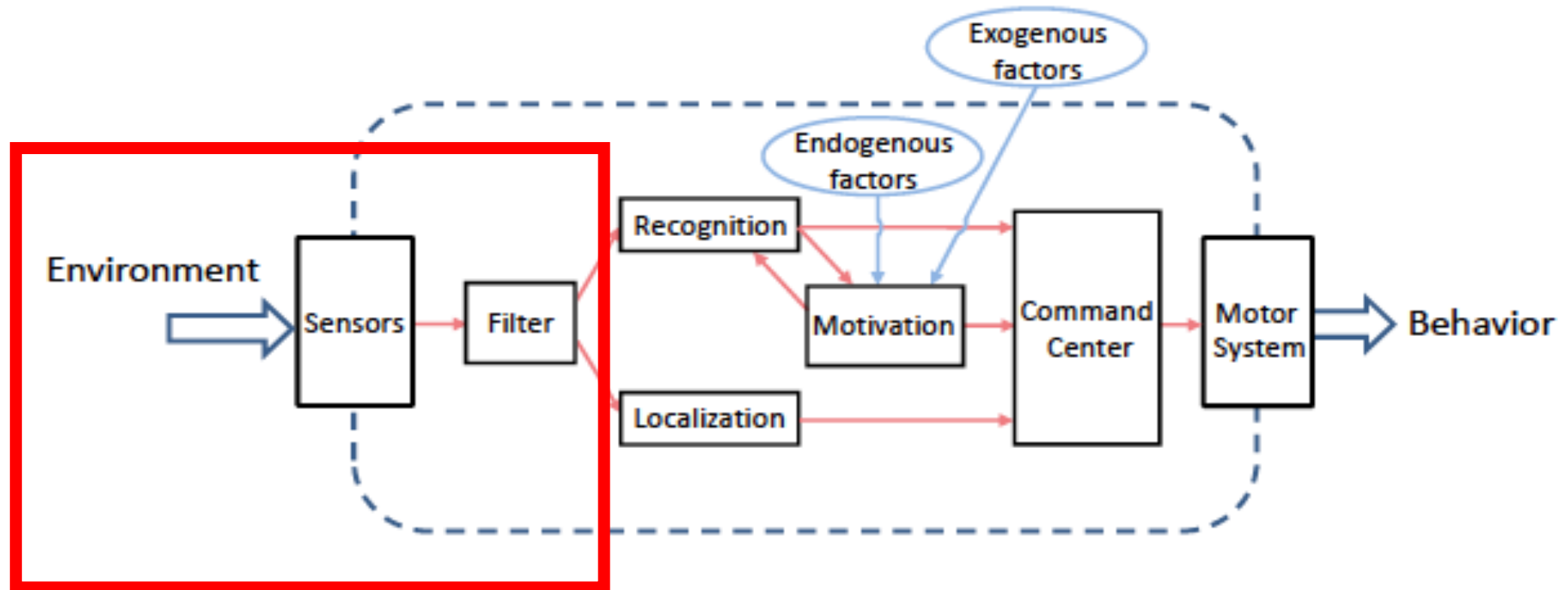
Neural Mechanisms of Behavior

Neurons → Neural Circuits → Behavior

Animal Behavior– conceptual schematic



Our focus today is on sensation and filtering



Today:

- Sensors
- Filtering
- Innate Behavior
 - Stickleback Fish
 - Herring Gull Chicks
 - Greylag Goose
 - Courtship Behavior
 - Imprinting

Sensors transmit signals from the environment to the nervous system

- **Sensation:** the conversion of a stimulus into a change in the membrane potential of sensory receptors
 - Measure a physical quantity and turn it into a signal the brain can use



How many senses can you think of?

- **Senses (Sensory Modalities):** different aspects of a stimulus that can be perceived



How many senses are there?

- Sight (Vision)
- Hearing (Audition)
- Taste (Gustation)
- Smell (Olfaction)
- Touch (Somatosensation)
- Temperature Sensing (Thermoception)
- Proprioception (Body Position)
- Pain (Nociception)
- Balance (Equilibrioception)
- Vibration (Mechanoreception)
- Chemoreception (various chemical stimuli)

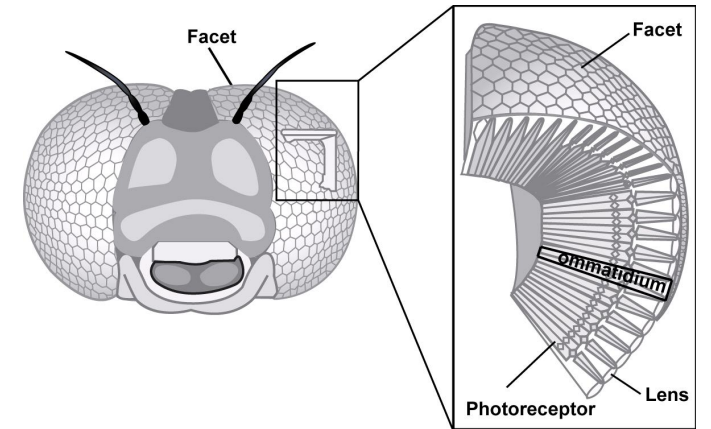
TO NAME A FEW

Even more senses (non-human)

- Echolocation
- Electroreception/Electrosensation
- Magnetosensation
- Infrared Sensation

Vision

- Single vs. Compound eyes
- Density of photoreceptors affects Resolution
- Color sensitivity of photoreceptors



Human vision
(R+G+B)

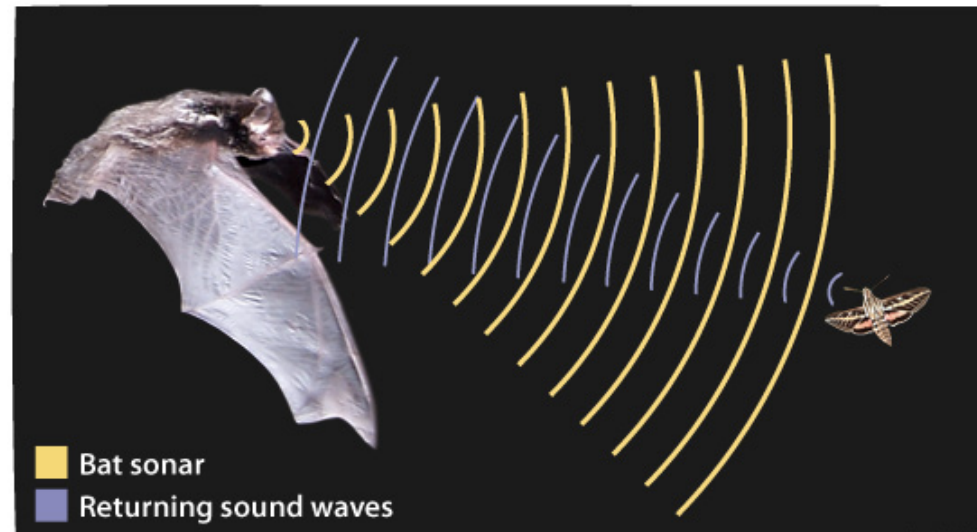
UV vision

Simulated bee
vision (UV+G+B)

Simulated bird vision
(UV+R+G+B)

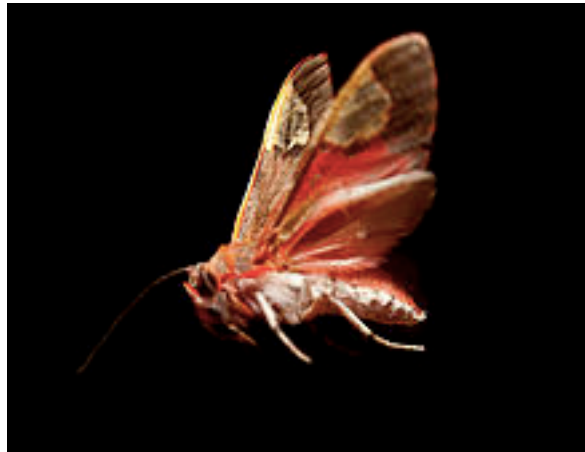
Echolocation

- Bats, dolphins, whales, shrews, birds
- Delay and amplitude of the echo signals the distance and size of the object
- Frequency of echo reveals the speed of the object (Doppler Shift)



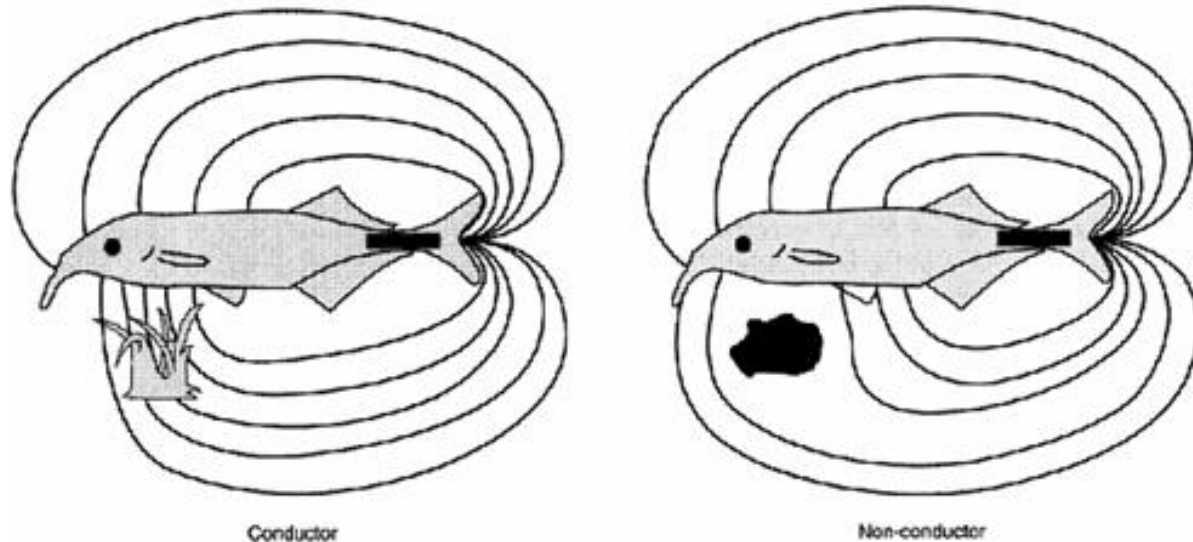
Echolocation: Moths jamming bats

- Bats use echolocation to detect prey (moths)
- But some species of moths have evolved echolocation jamming!
- Tiger Moth:



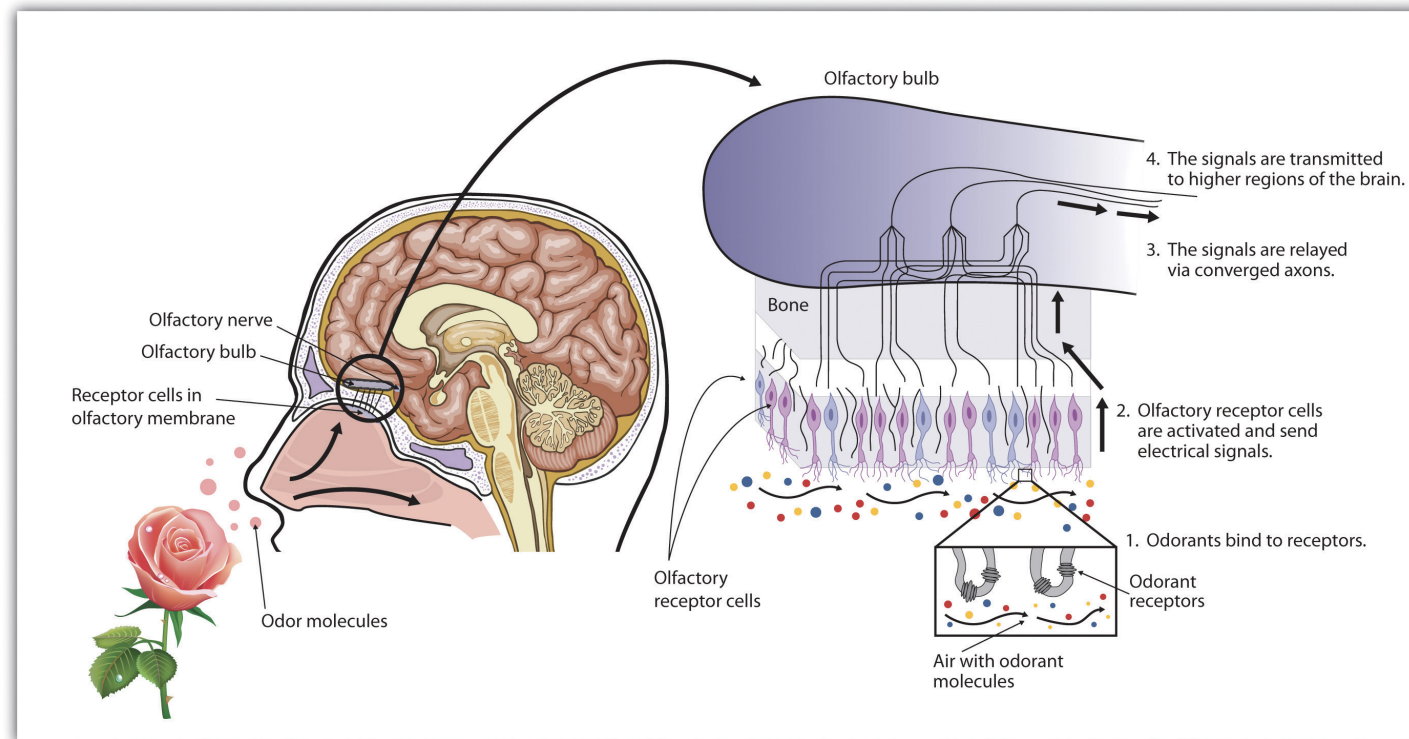
Electroreception vs. Electrosensation

- **Electroreception:** sensing small bioelectric waves generated by muscle contractions
- **Electrosensation (Active):** creating an electric field. Objects distort the field and thus can be detected.



Sensory Receptors

- Senses rely on receptors (but not all receptors are known)
- Sensory receptors detect stimuli *inside and/or outside* the body



Infrared sensation in the Pit Viper

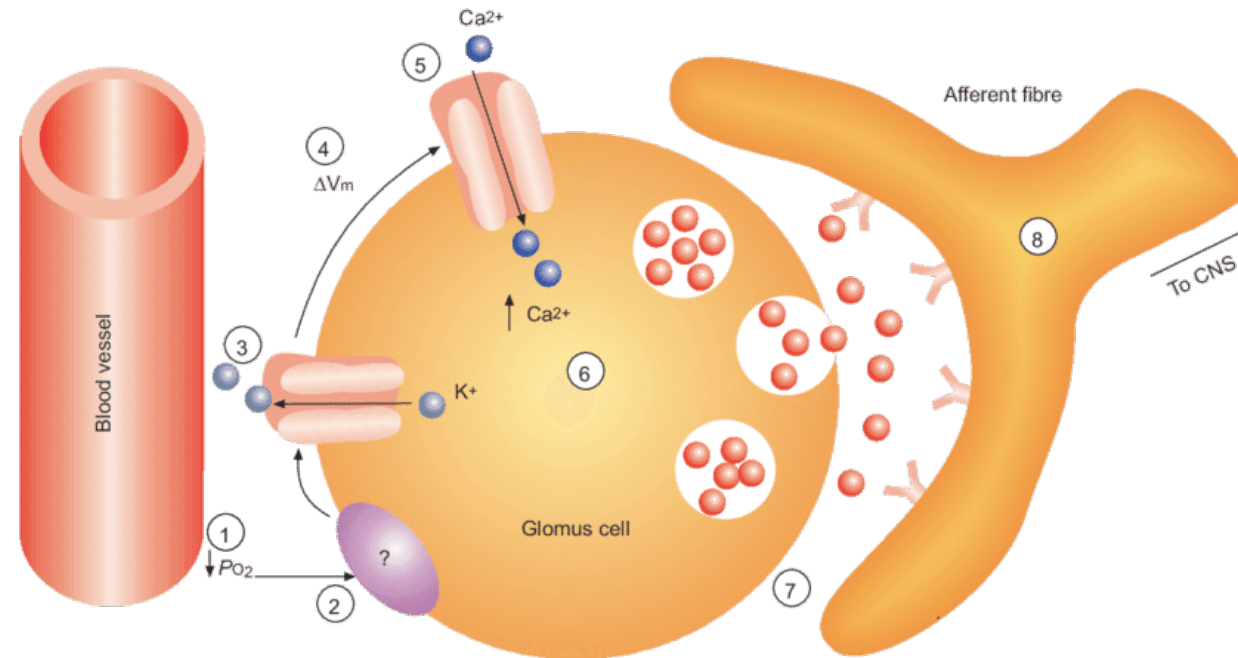
- Signals received by the pit organ, which is full of nerves



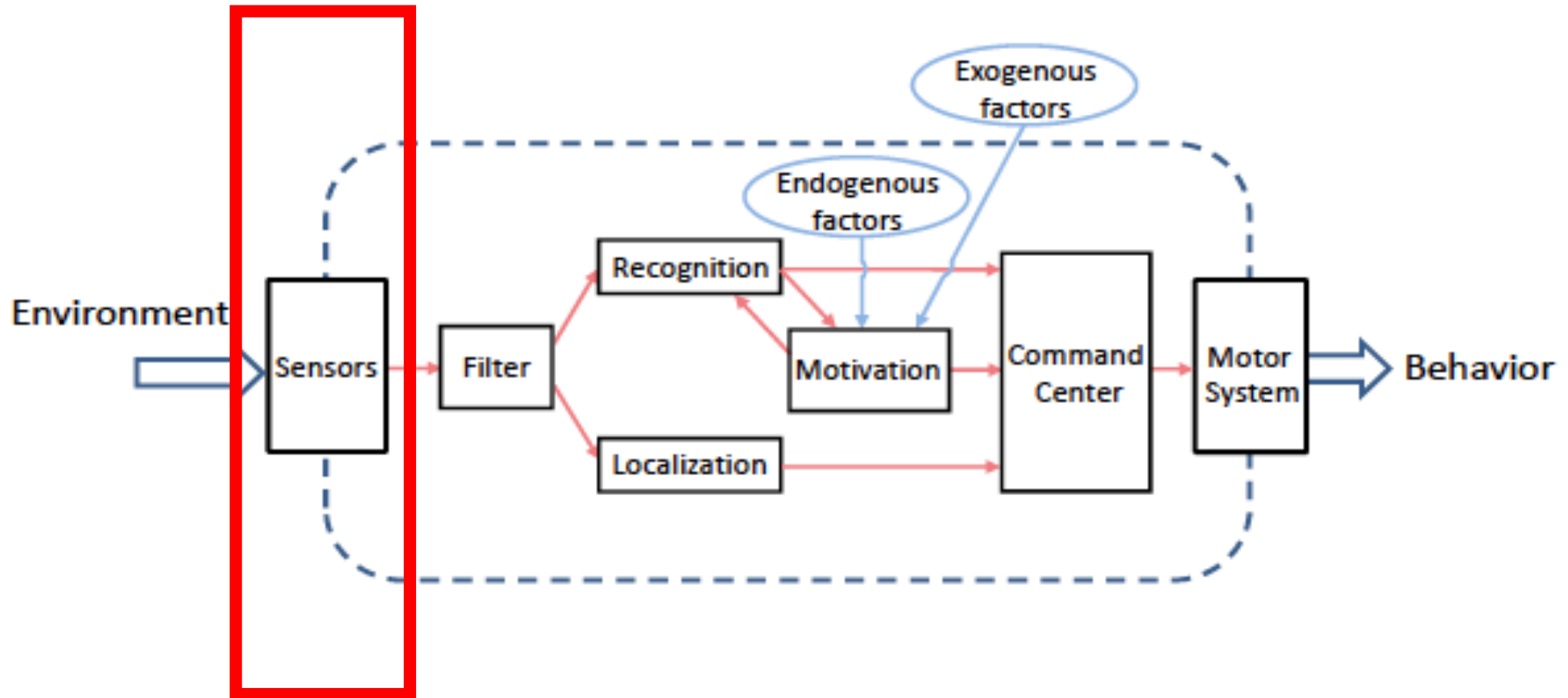
- (Grachva et al. 2010, Nature) TRPA1 channel is the infrared receptor in Pit Vipers
- TRPA1 is also an infrared receptor in vampire bats

Internal Receptors– Chemosensation

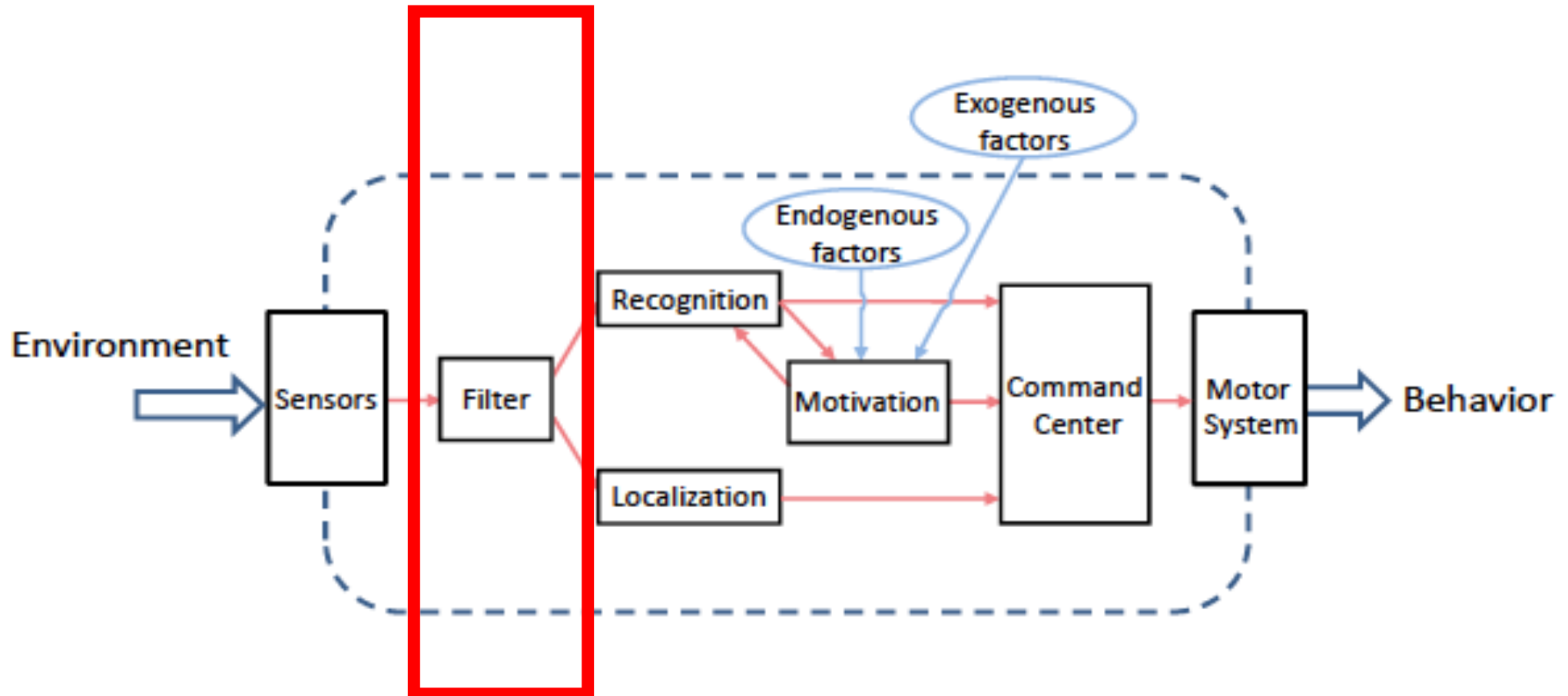
- Glomus Cells in the Blood– contain receptors which detect changes in chemical properties of blood -> help body regulate breathing



Sensors detect what is present in an organism's environment



Filtering throws away most of the information



Sensory Filtering



- **Sensory Gating:** neurological process of filtering out (losing) *redundant or unnecessary stimuli* from all possible environmental stimuli
- Sensory gating/filtering can occur at both early (at the sensory level) and later (in the brain) levels
- **Feature Detection:** a subset of sensory gating- how an organism filters complex natural stimuli in order to extract behaviorally relevant cues
- *Examples*

Why filter?

- Information is abundant and hard to store!
- **Cocktail Party Effect:**



How much information is necessary for a response?

- Toads -> prey-catching or threat behavior
- Moving a small stripe crosswise or lengthwise across a background
- Cells in the early visual system

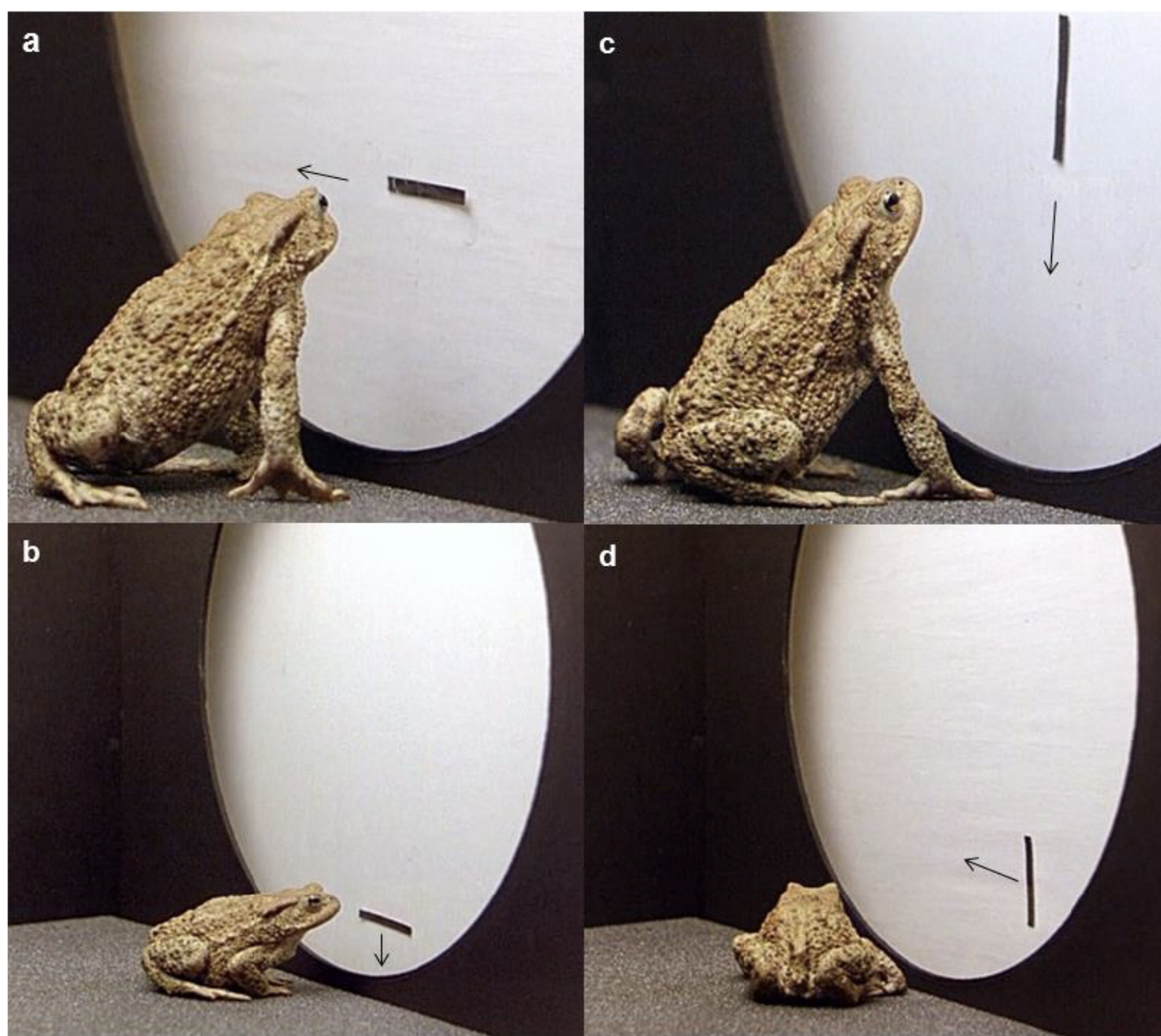


Fig.2.4 The prey (a,c) vs. threat (b,d) configuration of a stripe traversing a common toad's visual field in different directions (arrows). (Film analyses, Ewert & IWF 1993.)

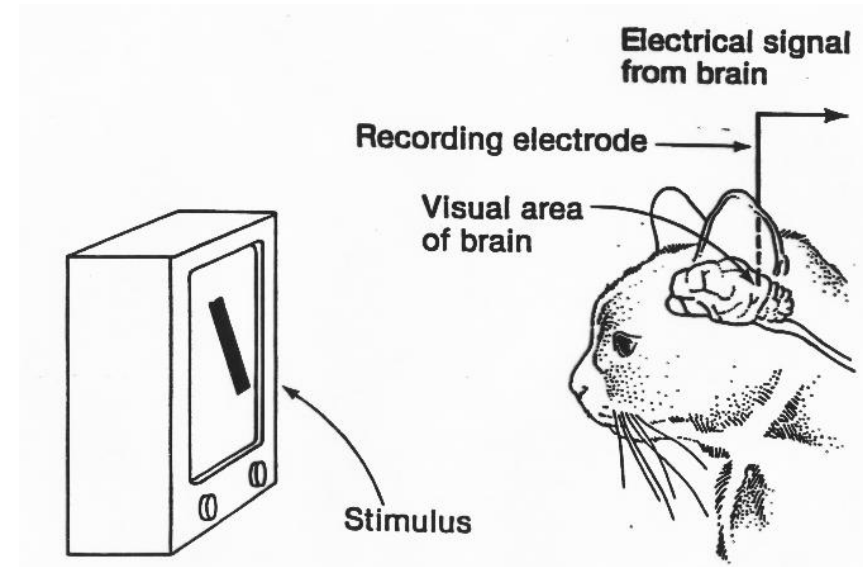
Information loss is a good thing here



Picking out what's "important" in the world

- Each neuron is only responding to a subset of what's out there
- **Receptive Field:** of a sensory neuron is the region of "sensory space" in which a stimulus will modify the activity of the neuron

Hubel and Wiesel (1981 Nobel Prize)



Innate behavior

- **Instinct/Innate behavior:** “genetically hard-wired”, can be performed in response to a cue without (much) prior experience
- Simplest example of innate behavior is a **Fixed Action Pattern (FAP)**
 - **FAPs** include **reflexes**, as well as longer behaviors



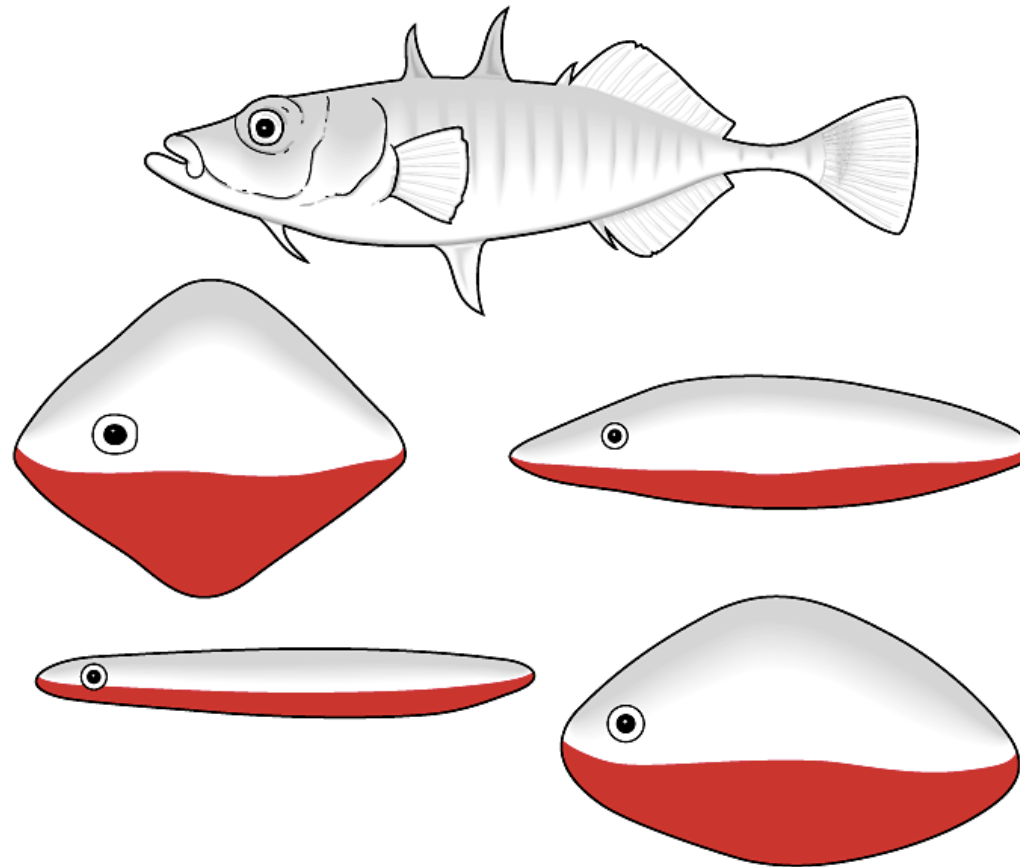
Primitive reflexes in infants include gripping and suckling

Fixed Action Pattern

- **Fixed Action Pattern:** instinctive behavioral sequence that is indivisible and runs to completion, often triggered by key stimulus
 - No learning required for FAP
- **Key (Sign) Stimulus:** stimulus that makes it through filters, triggers innate behavior
- **Releaser:** sign stimulus that has evolved to facilitate communication between animals of the same species (**conspecifics**)
- Stimulus is easily recognized and responded to... *because sensors and filters have evolved to do so*

Tinbergen's Stickleback Fish

- <https://www.youtube.com/watch?v=ZfcGZCGdGVE>



Tinbergen's Stickleback Fish

- What is the Sign Stimulus?
- What is the Fixed Action Pattern?



Nature

Tinbergen's Stickleback Fish

- Sign Stimulus: Red underside of object -> is a **releaser**
- Fixed Action Pattern: aggression and attack!



Nature

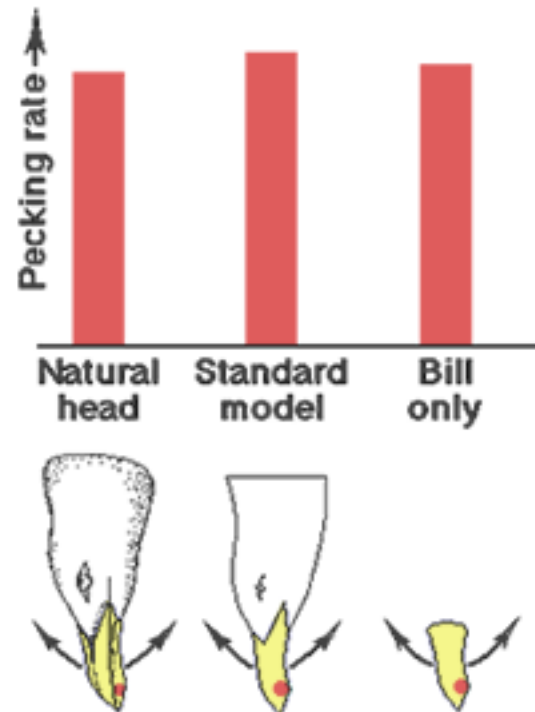
Herring Gulls

- Chicks peck at red spot on parent's bill to elicit feeding



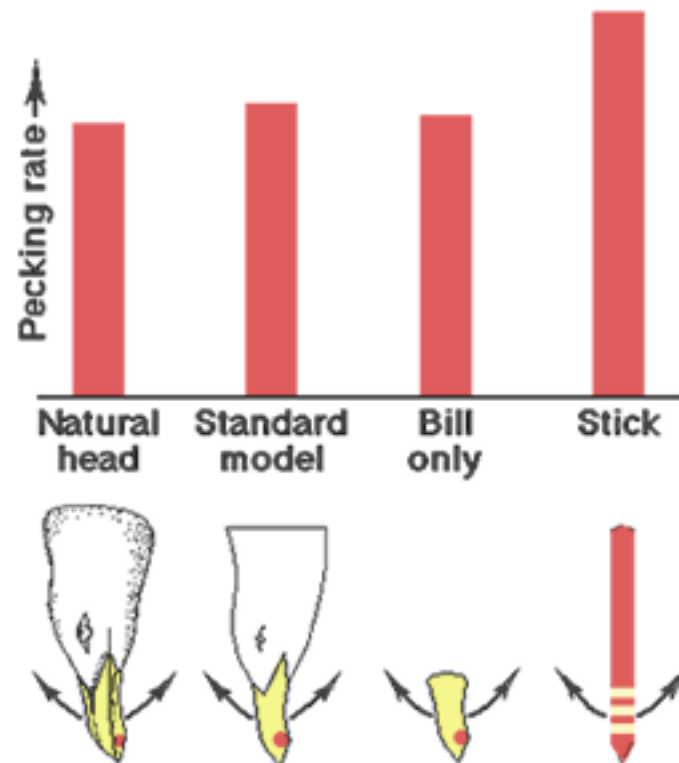
Herring Gulls- figuring out the sign stimulus

- Sign Stimulus/Releaser- experiment with different beak shapes, beak coloration, spot size and observe chick pecking response



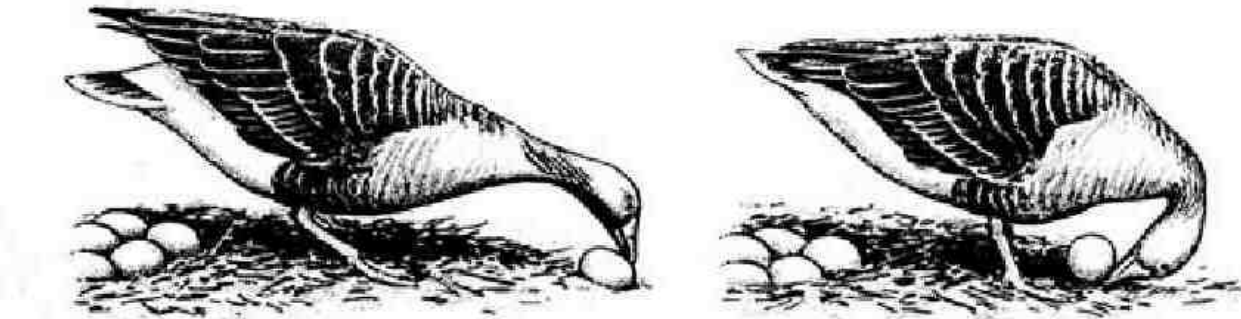
Herring Gull- a red stick elicits a big response

- **Supernormal Stimulus:** exaggerated version of a stimulus to which there is an exaggerated response



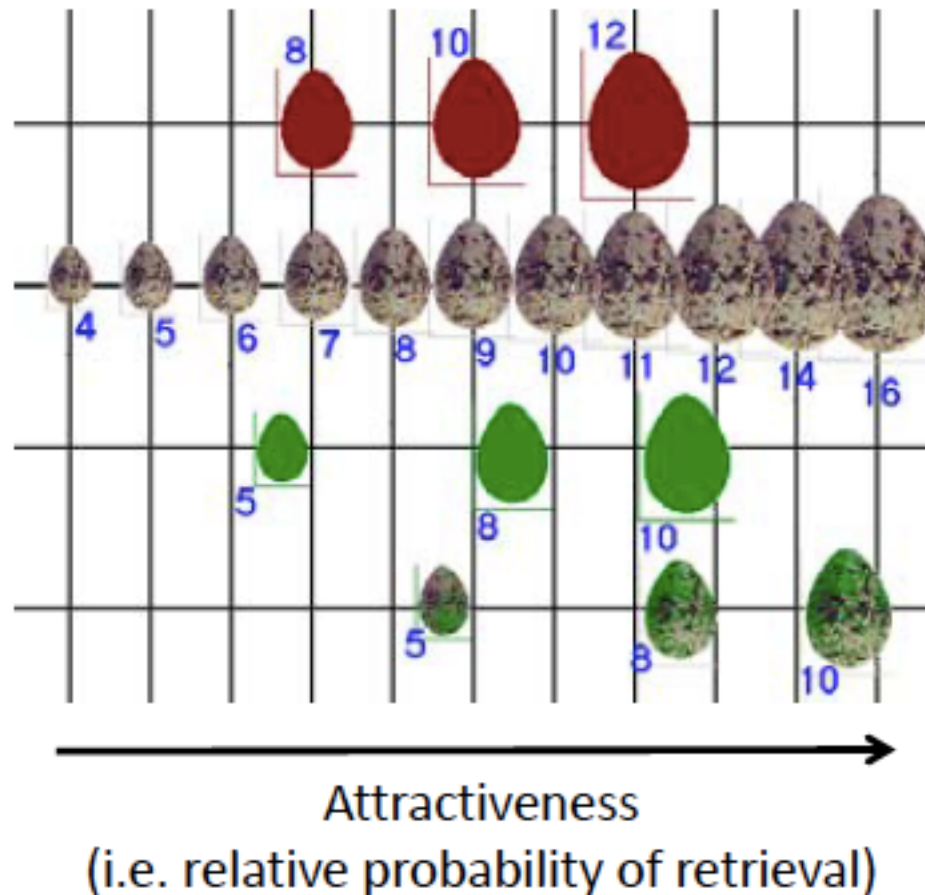
Greylag goose- egg retrieval

- <https://www.youtube.com/watch?v=7PcteKRA3zs>
- Tinbergen & Lorenz



Law of heterogeneous summation

- Stimuli can be complex and have multiple features



Red < Green

Uniform < Speckled

Small < Large

Individual features sum



Law of heterogeneous summation

Courtship Behavior

- Sign stimulus is usually the presence of a female, triggering FAP of courtship behavior
- Includes: ritualized movement (dances), vocalizations/sound, displays of beauty/strength

- Greater Sage Grouse:

<https://www.youtube.com/watch?v=m0M8pZnNlnI>



Of geese and men (1978)

- <https://archive.org/details/konradlorenzofgeeseandmen>
- 7:45 “Imprinting is a very special form of **learning**...with very special properties
 - Confined to a short period
 - Irreversible



Imprinting

- Greylag geese imprint on the first moving stimulus they see within a “critical period” of 13-16 hours post-hatch
- What’s learned?
 - Characteristics of the moving stimulus



Natal Homing and Navigational Imprinting

- Natal Homing: adult animal returns to birthplace to spawn/reproduce
- Pacific Salmon
 - Imprint on the chemical/olfactory cues of their home river
 - May also imprint on the earth's magnetic field
- Sea Turtle: (probably) magnetic field



FAPs are innate behaviors that have evolved to perform a function essential to survival/fitness

- Stickleback Fish– Aggression, red underside
- Herring Gull Chicks– Pecking, red object overhead
- Greylag Goose– Egg Retrieval, round objects on ground
- Courtship Behavior– Display, female presence
- Imprinting

- Despite their utility, they are **relatively inflexible!**
- Some parasitic species have evolved ways to take advantage of inflexibility

Brood Parasitism: cuckoo vs. warbler

- Cuckoo removes warbler eggs and puts own eggs in
- Hatched cuckoo chicks display supernormal stimulus (large gaping red mouth) to stimulate feeding



Cuckoo finch at Left, Warbler chick at Right

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