Introduction to Neuroscience – Behavioral Neuroscience

From classic ethology (animal behavior) to neuroethology

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Outline

What is behavior?

What are the different aspects in the research of behavior?

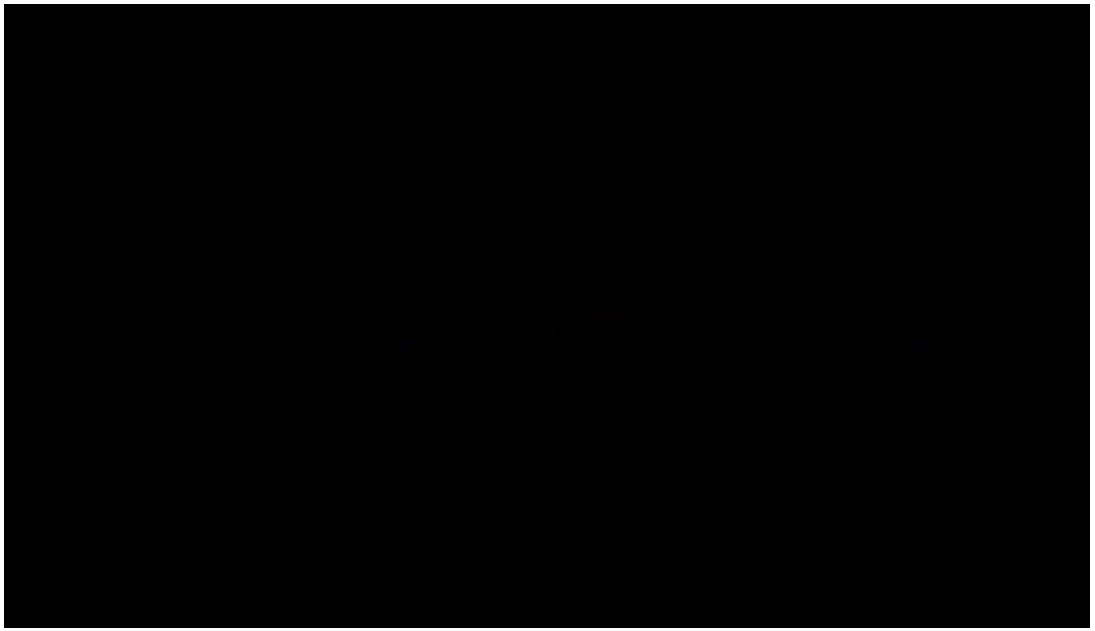
Types of behavior

Neuroethology

What is animal behavior?

- The total movements made by the intact animal (Niko Tinbergen, 1955)

- Anything an organism does that involves action (either alone or with other animals) and/or response to a stimulus" (Wallace et al 1991)



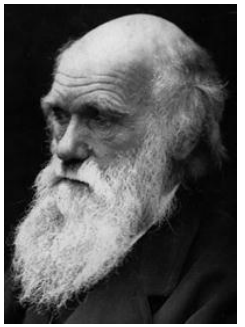
Causes of behavior

Behavior is crucial to the survival of the individual and species.
Allowing animals to: find food, avoid predators, mate, raise young

Animals behave in ways that maximize their fitness

Fitness = the ability to survive and reproduce

Natural selection of behavior (evolution of behavior)



Charles Darwin
(1809-1882)

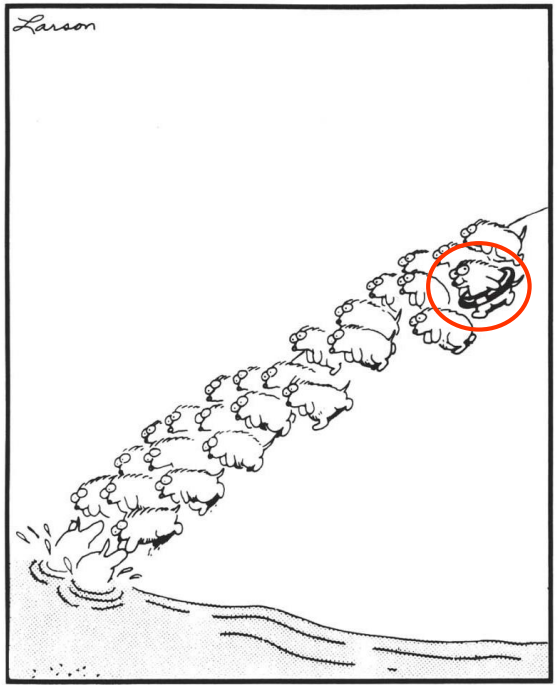
Natural selection acts on behavioral traits as on other traits:

1. Variations also exist in behavioral traits

2. Some of these behavioral variations are heritable

3. Certain behavioral variations make individuals better adapted to their environment

4. These individuals have the chance to survive longer and leave more offspring than those with less successful behavioral traits



Natural selection of behavior

Favors animals who present beneficial behavior (increases fitness)

and reduces fitness to those that present unhelpful behaviors

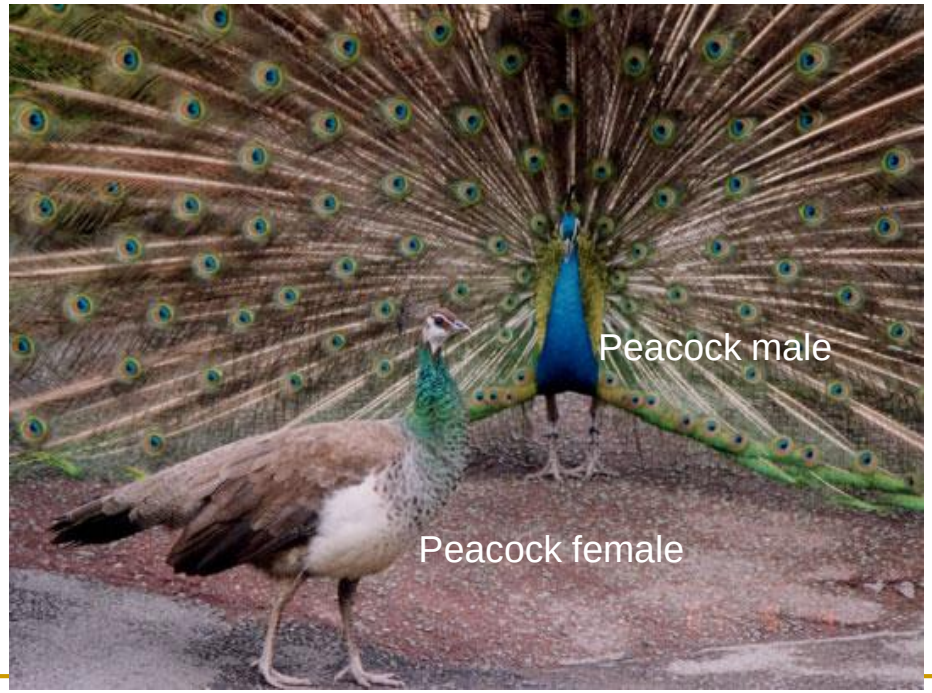
Beneficial behavior

Unhelpful behavior

Sexual selection of behavior

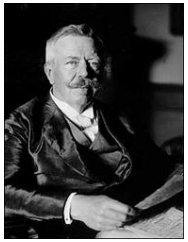
Darwin realized that some behavioral traits directly relate to mate acquisition and mate choice.

He termed this evolutionary process “**sexual selection**”.



Sexual selection in male courtship behavior

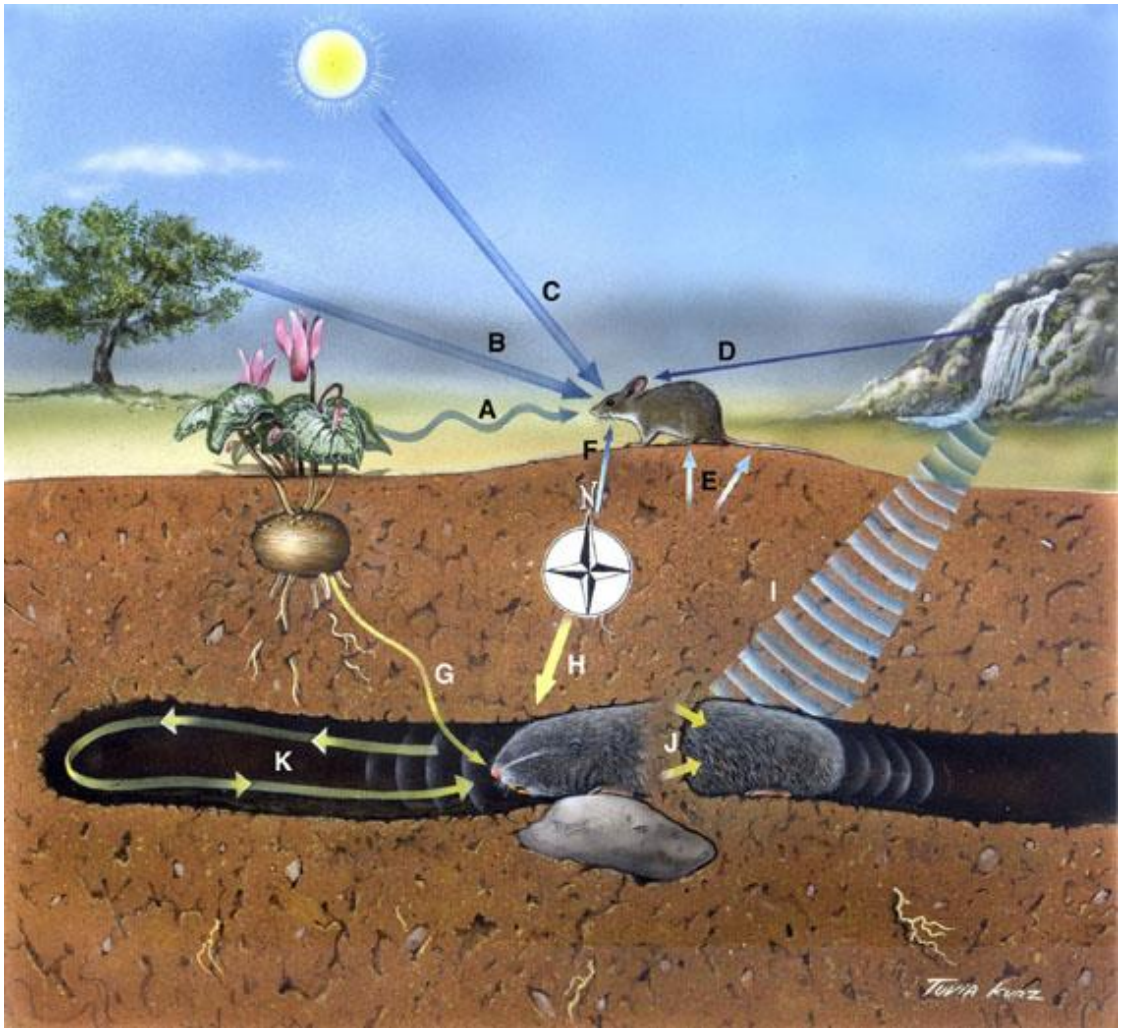
The animals "Umwelt" (environment)



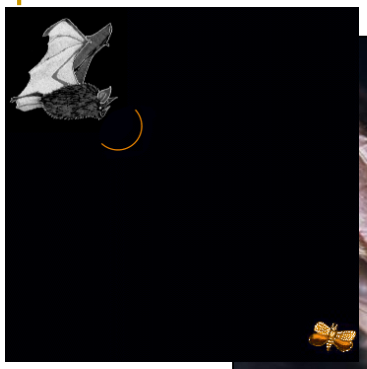
Jakob von Uexküll
(1864-1944)

The organism's model of the world: how the animal perceives things in the world and the actions (behaviors) that are performed by each species.

The umwelt of a surface-dwelling rodent's vs a subterranean rodent

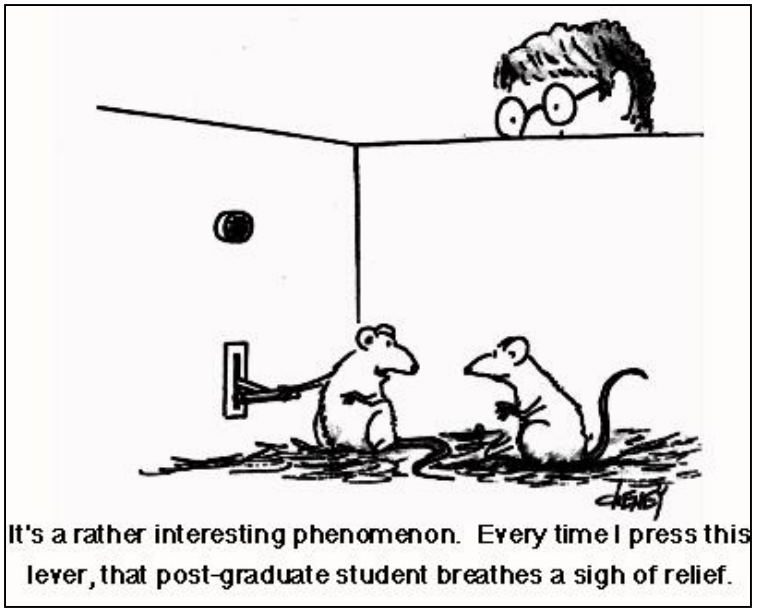


Species-specific sensory adaptations to the niche



Different ways to study animal behavior

Field study (natural conditions)
Wild animal



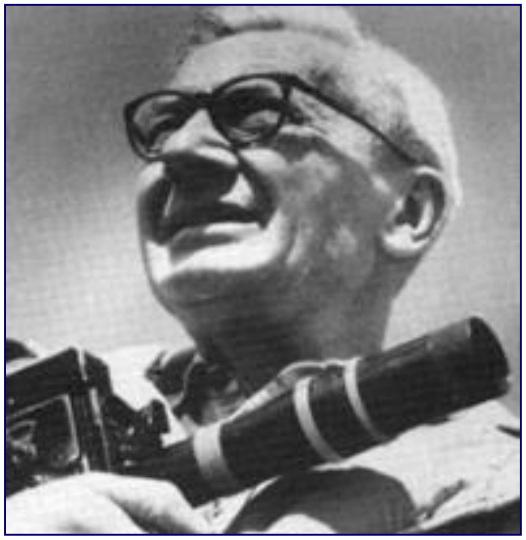
Lab study (controlled restricted conditions)
Lab animal

Ethology

- The study of naturalistic animal behavior and its relationship to its evolutionary origins

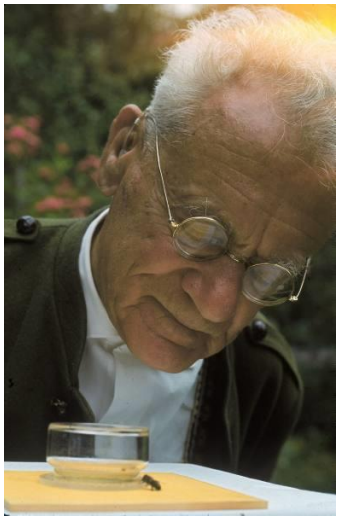
- Whole animal approach- the animal is kept under conditions as natural as possible (preferably field observations)

Founders of animal behavior research in the natural habitat: Ethology



Niko Tinbergen
(1907-1988)

Konrad Lorenz
(1903-1989)



Karl von Frisch
(1886-1982)

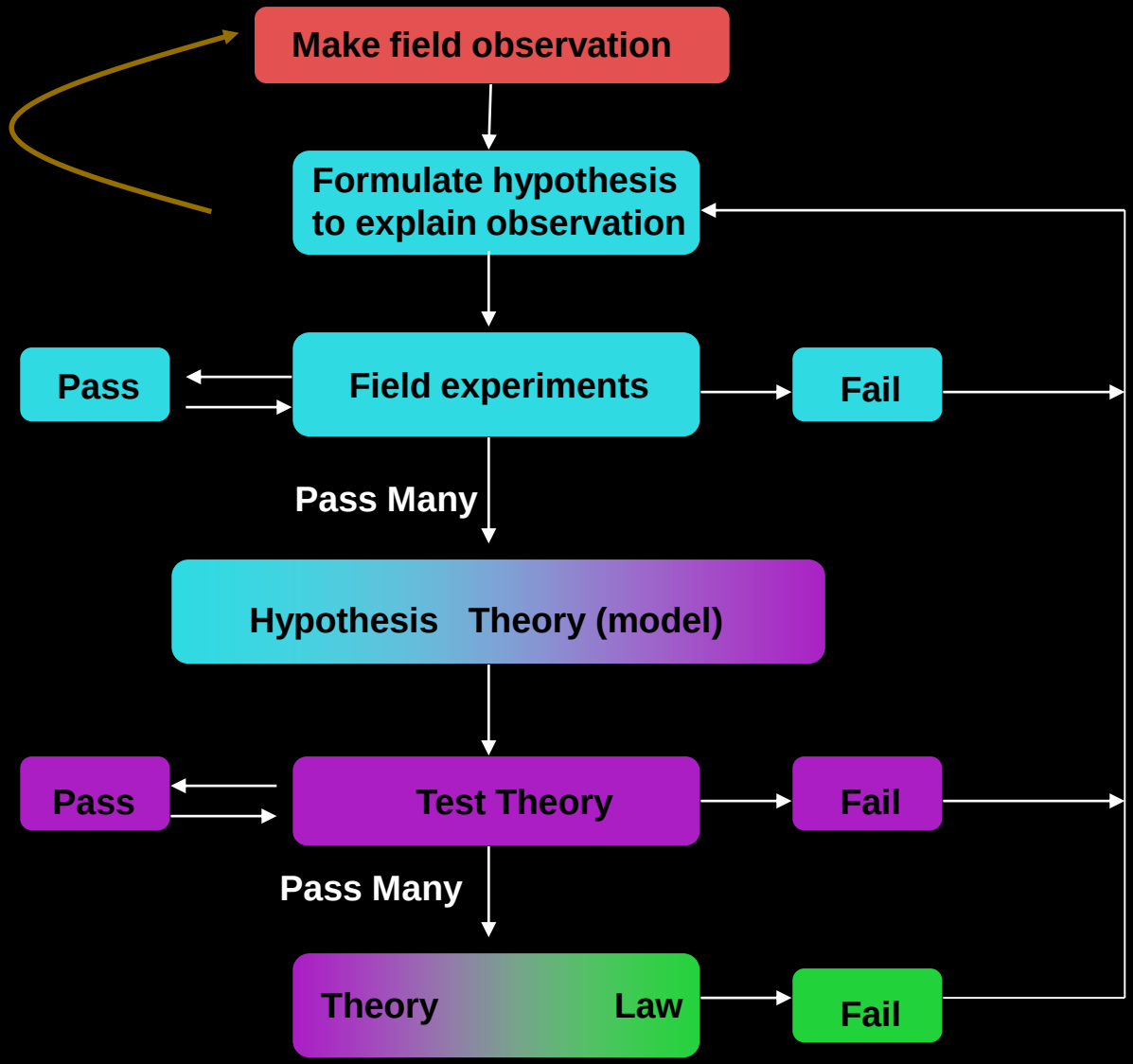
The Nobel Prize in Physiology or Medicine 1973
"for their discoveries concerning organization and elicitation of individual and social behavior patterns"

Ethology

- An ethological research program starts with picking the appropriate animal model for the research question, or with field observations

- **The study of *how* and *why* animals interact with each other and their environment (engage in a certain behavior).**

Scientific approach



The 4 questions asked in behavior (Tinbergen Niko, 1963)

	Short-term	Long-term
How?	Mechanism	Development
Why?	Function	Evolution

Proximate

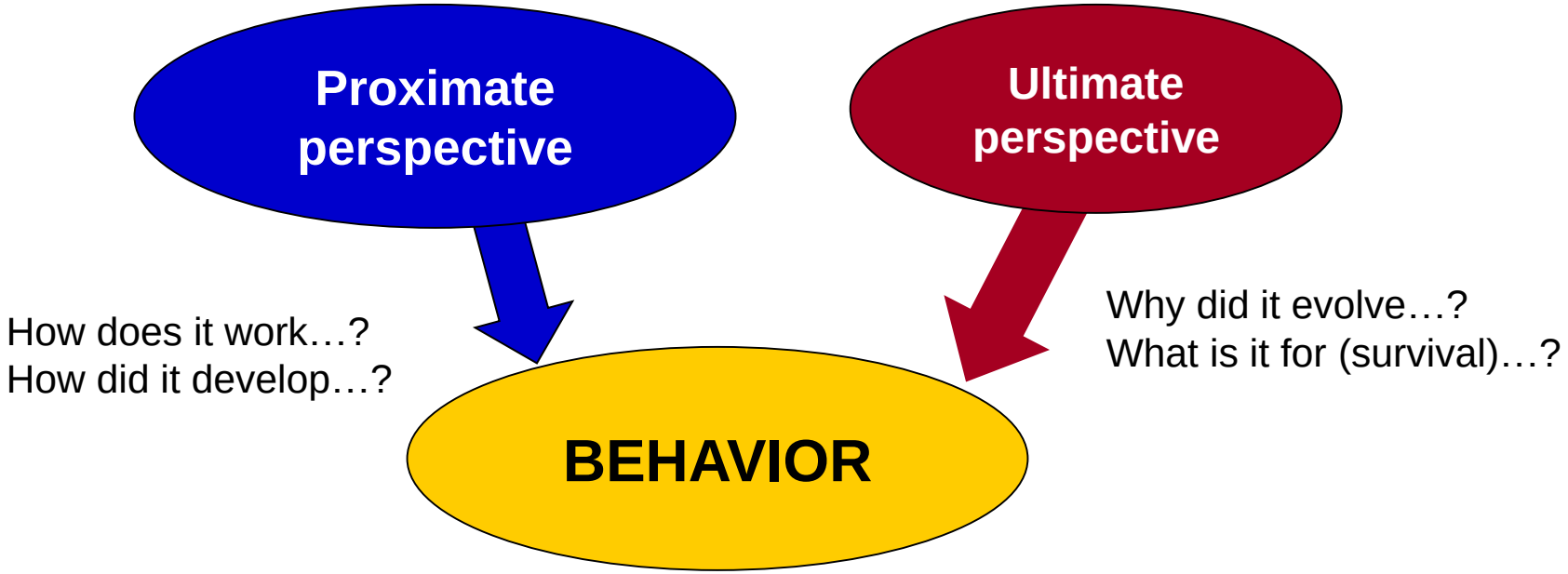
Mechanism: Reactions or reflex to immediate stimulus (immediate causation)

Development: The lifespan of the organism in its environment (genetics, experience)

Ultimate

Function: What is the behavior good for (the value of the behavior to the animal)?

Evolution: The ancestral history of the organism



Studying the mechanisms of the immediate causation and development of the behavior

Studying what is the adaptive significance and evolution for survival and reproduction

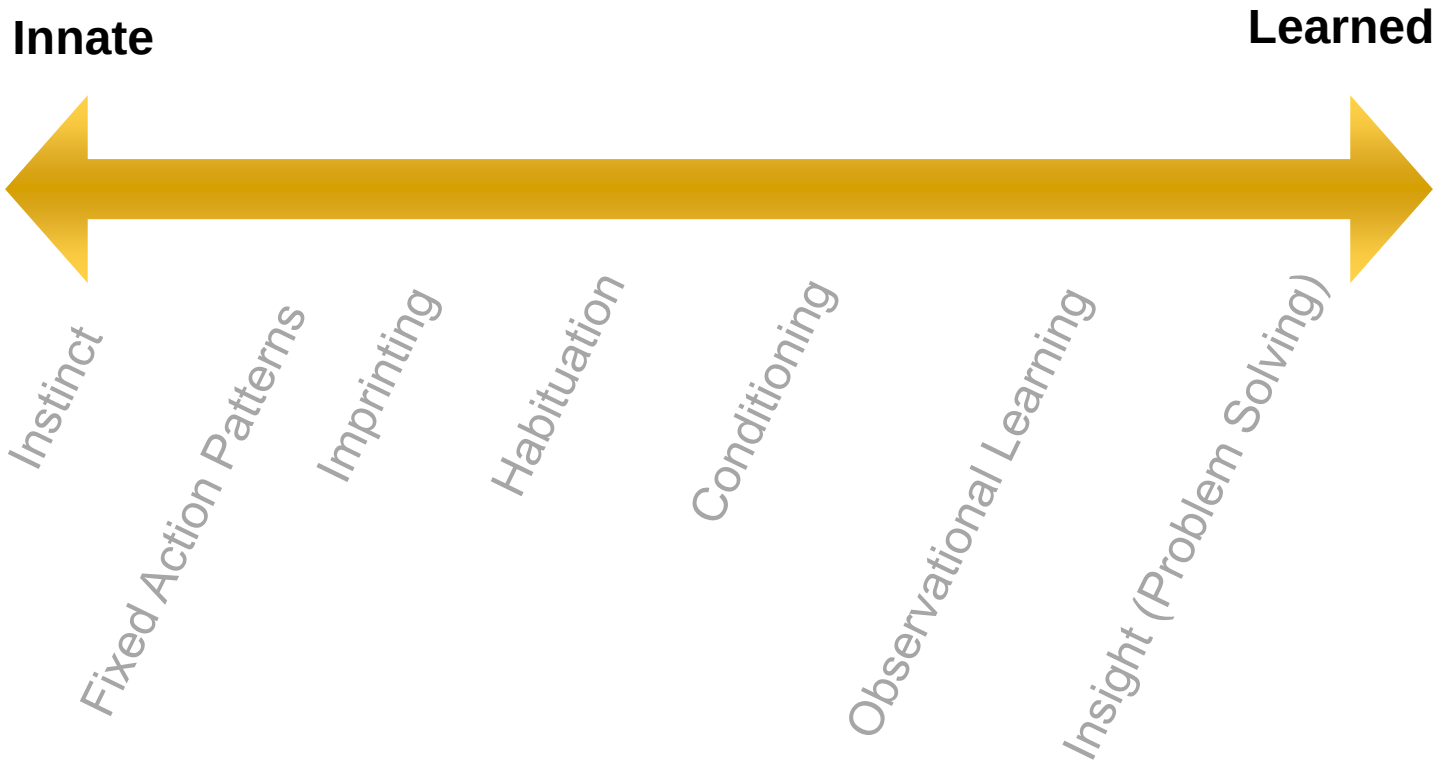
Lion Intimidation

Young lions have to leave their pride and take over other prides

Lion intimidation	*Short-term*	*Long-term*
How?	Big, dark manes	More testosterone
Why?	Indicates more strength – better chances of survival	Females found more attractive – selection of dark maned lions

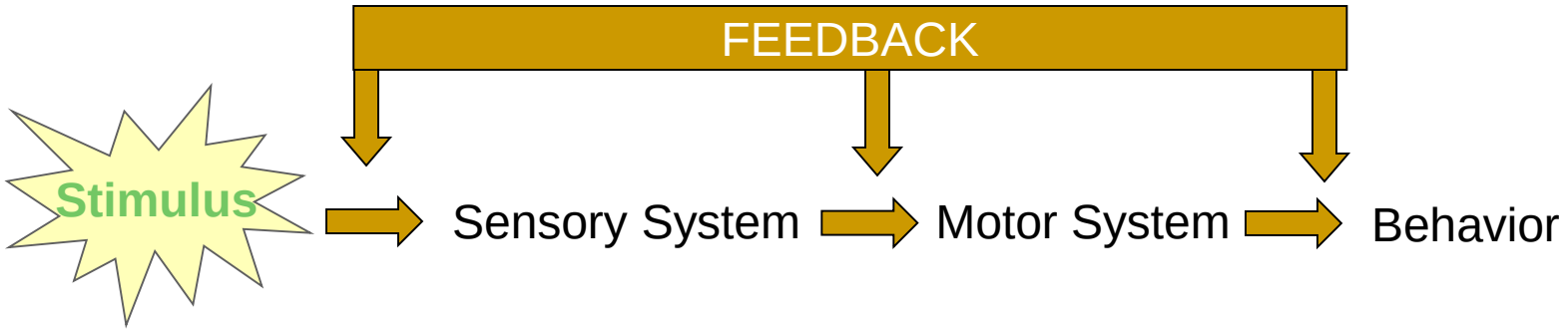
	Short-term	Long-term
How?	Mechanism	Development
Why?	Function	Evolution

Types of behaviors



Learned Behavior

- Behavior that is modified by experience (trial-and-error pattern)
- Flexible. Phenotype is changing with time/experience
- Often affects even innately programmed behaviors

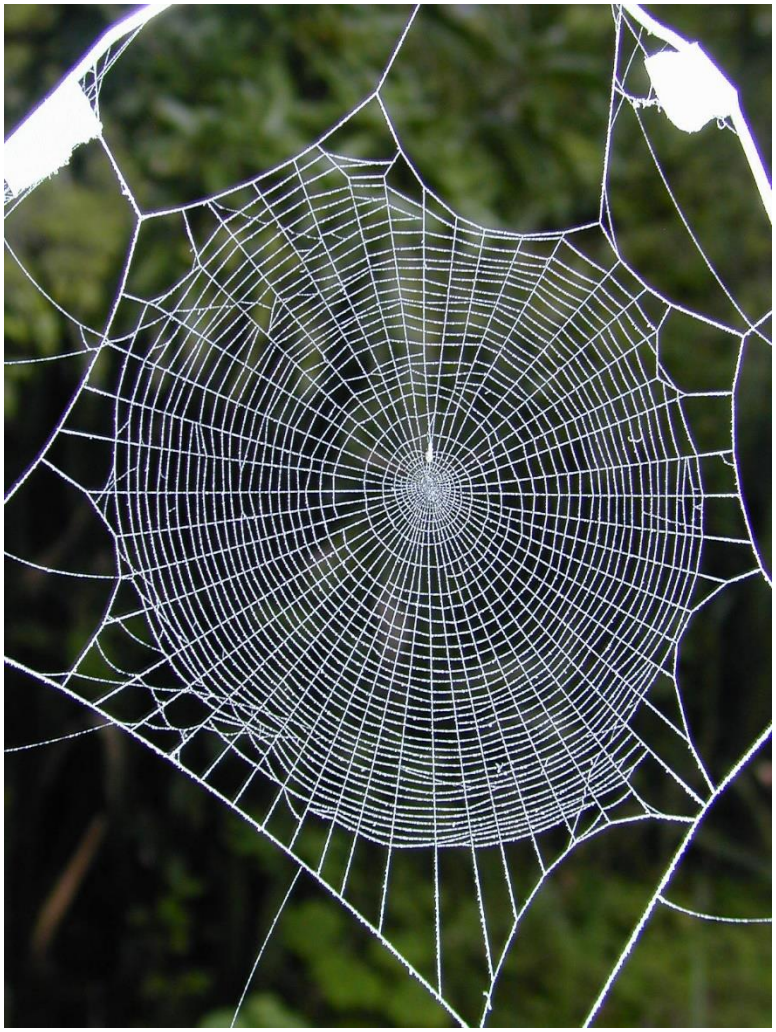


Crow mastering in cracking nuts

Innate Behavior

- First time performance is completely functional
- Animals don’t have to witness the behavior (inborn)
- Uniform, stereotyped
- Triggered by a simple sign stimulus (sensory releaser)
- Has a strong genetic (inherited) basis: controled by pre-programmed fixed neural circuitries

Innate behavior



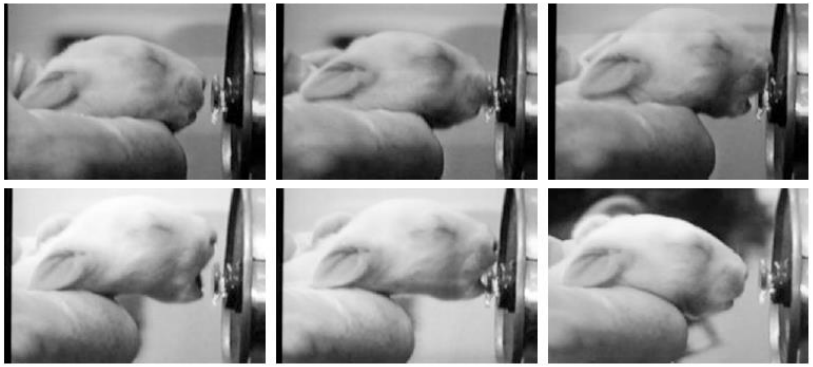

© D.O'Daniel

Instinct behaviors: Freeze or Flee

Reflex behavior

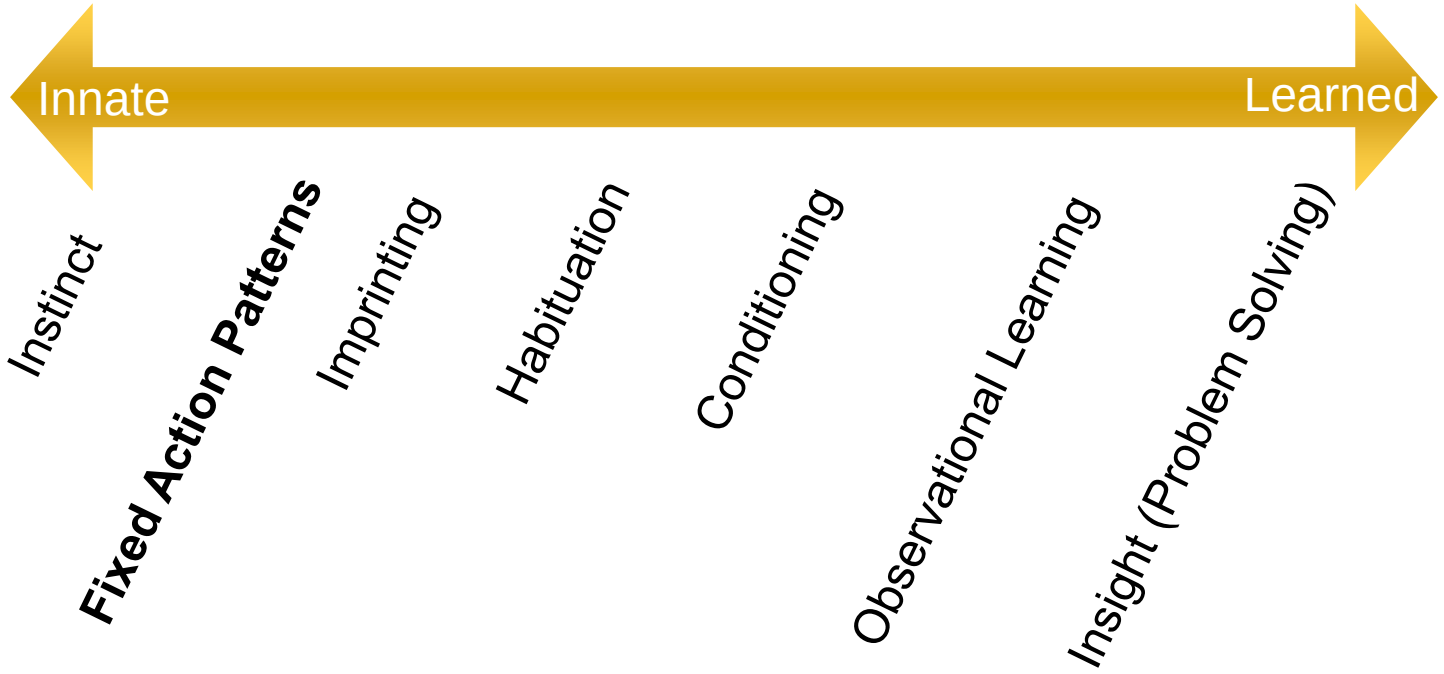
Grasping reflex

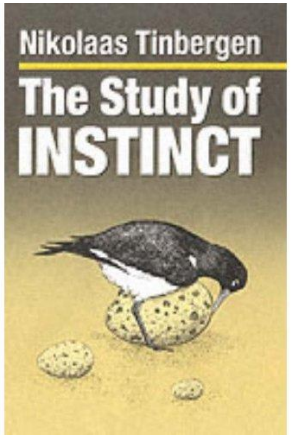
Sucking reflex



Schaal et al 2003

Types of behaviors





Fixed Action Pattern (FAP)

- Highly stereotypic behavior
- Triggered by a **sign stimulus** (external stimuli)
- When the stimuli are exchanged between members of the same species, the stimuli are called **releasers**
- Once begun, the behavior will continue to completion

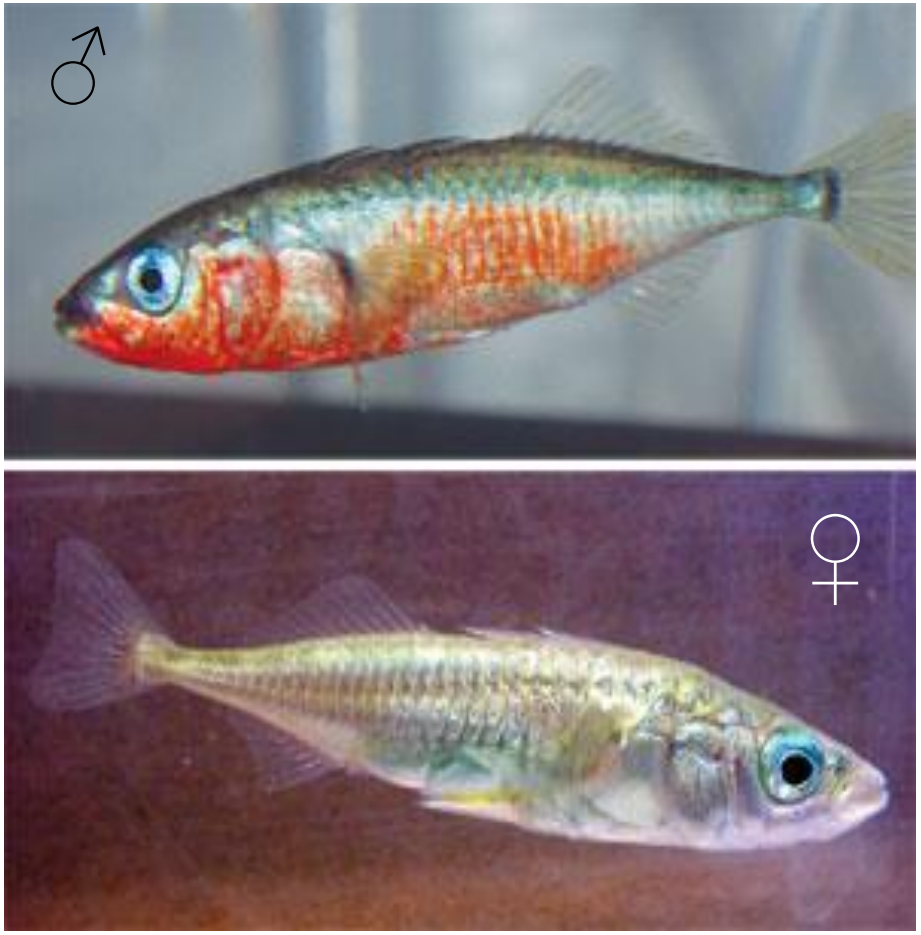
Fixed Action Patterns:
Egg-rolling behavior in greylag goose

FIG. 69. Grey lag goose retrieving egg. After Lorenz and Tinbergen, 1938.

FIG. 70. Grey lag goose attempting to retrieve giant egg. After Lorenz and Tinbergen, 1938.

- The goose will roll an egg that is outside the nest back into the nest in the same manner every time.
- The goose will do this with any round object placed outside the nest.
- Each time this action pattern is initiated, it is carried through to completion.

FAP: social behavior in three-spined stickleback

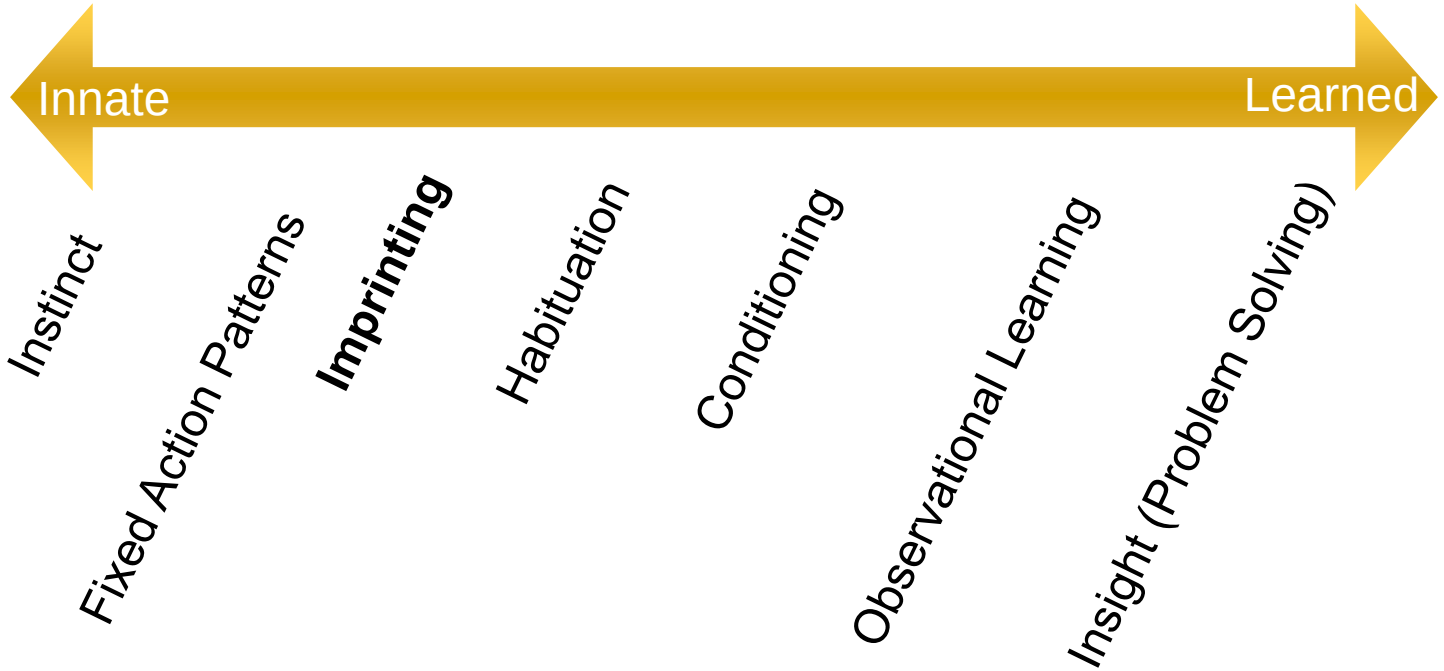


Fixed action pattern in three-spined stickleback

- Will attack: as long as a red spot is present on the ventral part of the body

- Will court if: white swollen belly (i.e. a pregnant female)

Types of behaviors



Learning who is your mother- Imprinting behavior

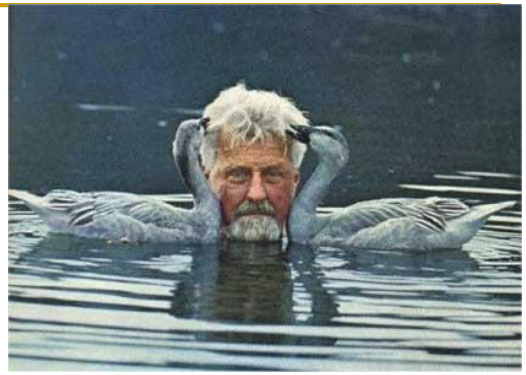
Imprinting - Konrad Lorenz

- Behavioral observation: geese hatchlings closely follow their mother
- Explanation: Mother-offspring bonding in animals is crucial to safety & development of the offspring
- Hypothesis: Geese hatchlings follow the first thing they see mooving

Imprinting- Konrad Lorenz

- A learned behavioral pattern that is dependent on innate mechanisms
- Learning that occurs during a critical period in the early life of an individual
- Irreversible

Lorenz's experiment

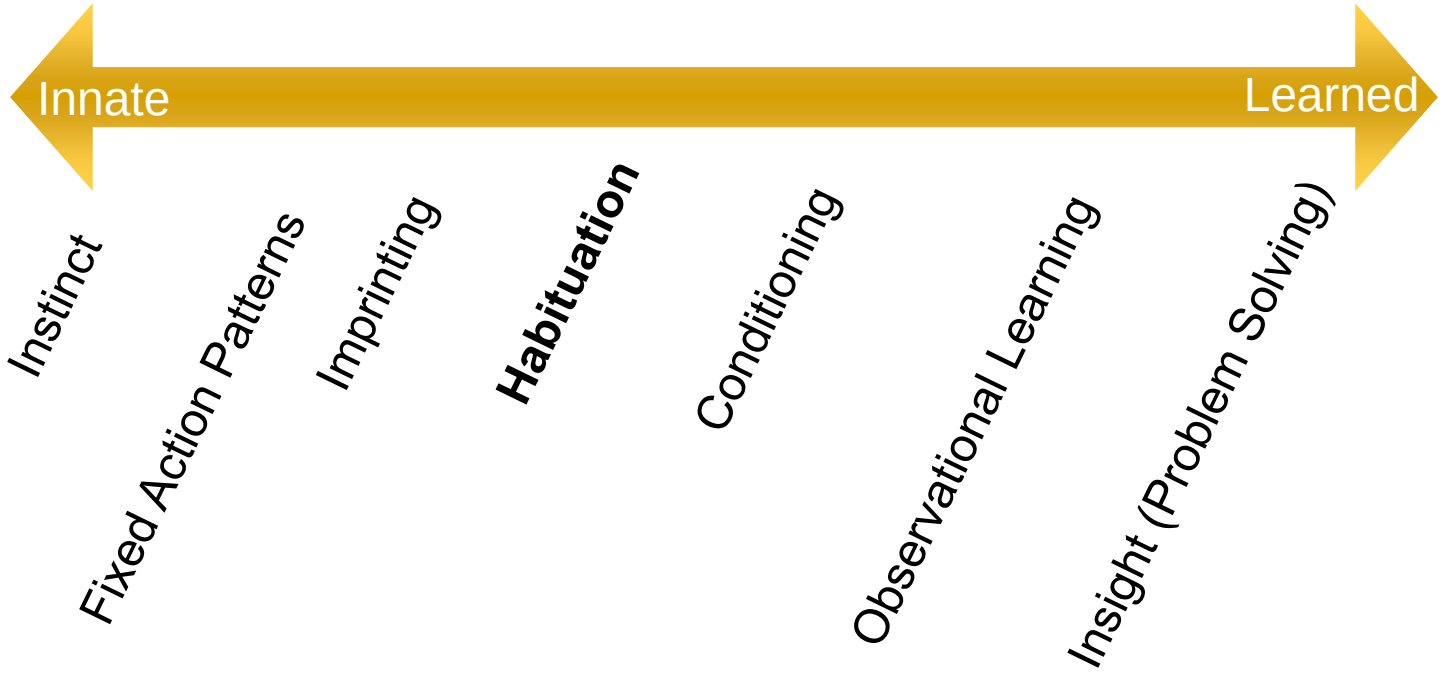


Experiment: A clutch of goose eggs was divided between the mother goose and an incubator (treated by Lorentz).

Results: Goslings reared by the mother behaved normally and mated with other geese.
-Goslings that spent their first hours of life with Lorenz followed him and even tried to mate with humans.

Conclusions: Greylags goose have no innate sense of "mother" or "gooseness". They identify with and respond to the first object with certain characteristics they encounter. *The ability or tendency to respond is innate.*

Types of behaviors



Habituation – Reduction of innate responses

Crows present in corn field

Introduction of scarecrow

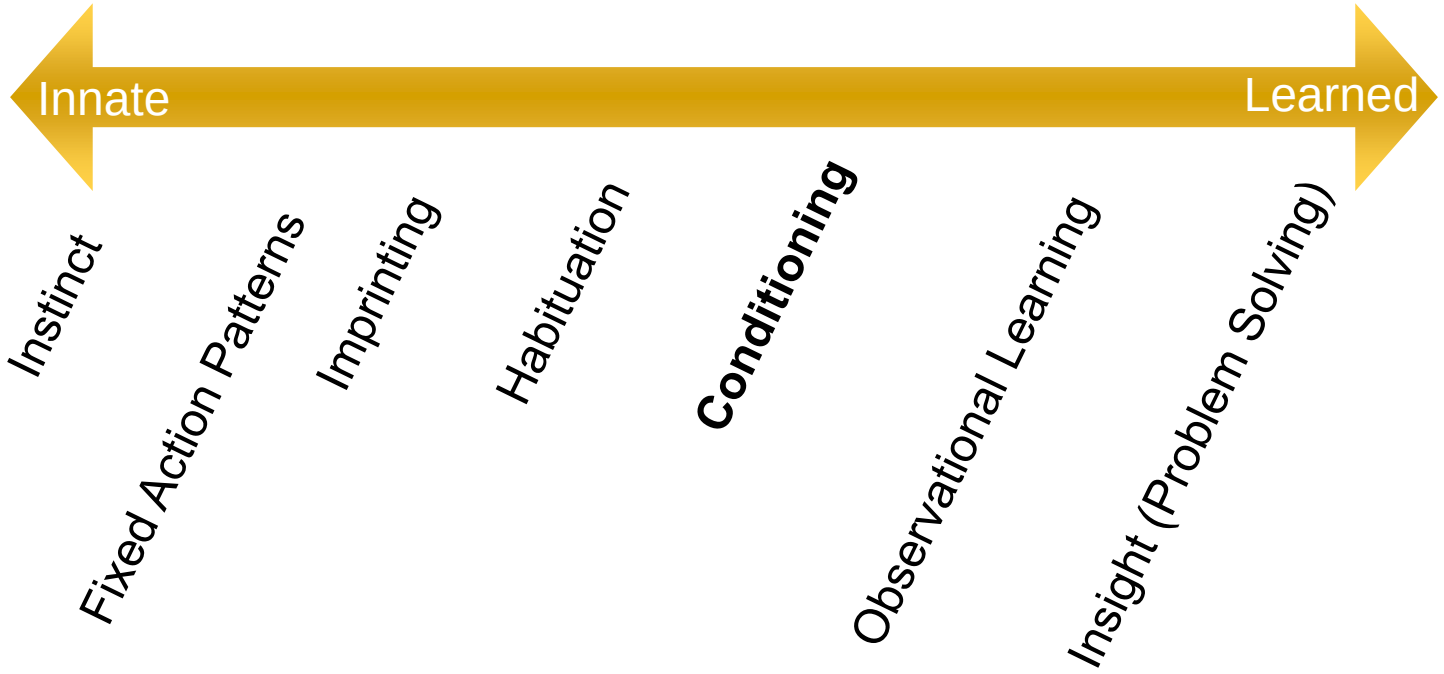
Prolonged exposure to scarecrow

AESOP'S FABLES

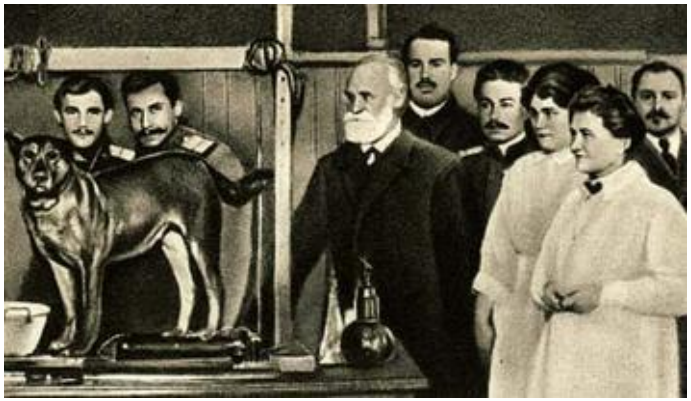
The Boy Who Cried Wolf

If you often lie, people won't believe you
when you really are telling the truth.

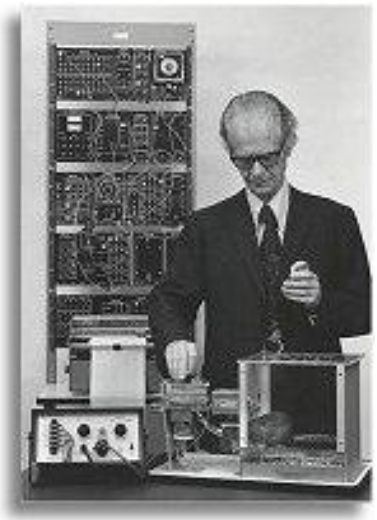
Types of behaviors



Experimental studies of conditioned behavior in the laboratory



Ivan Pavlov
(1849-1936)



Burrhus Frederic Skinner
(1904-1990)

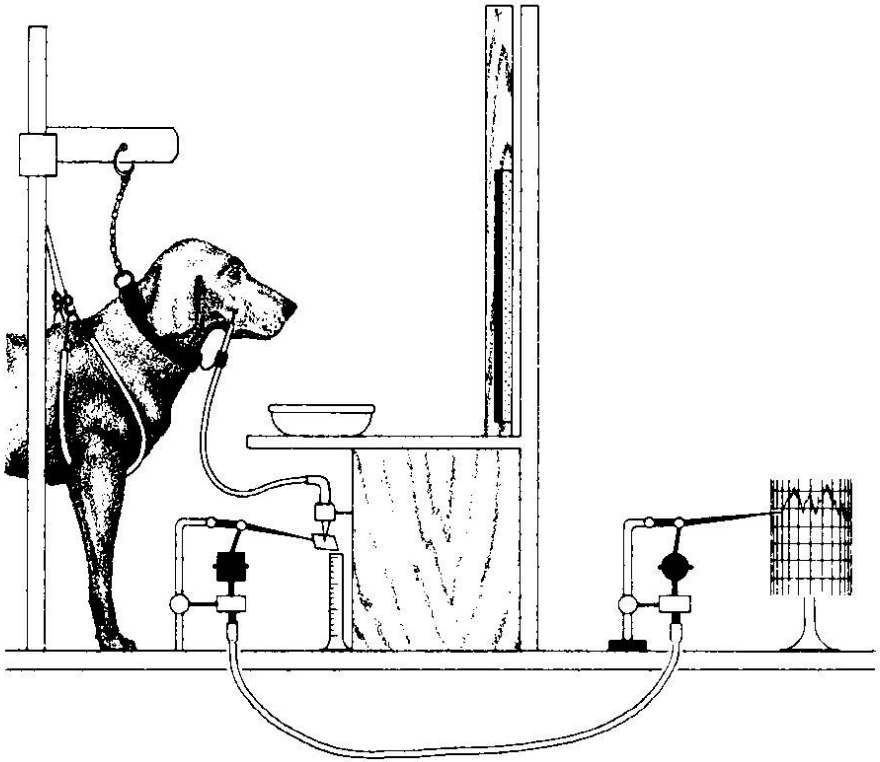
Ivan Pavlov

The Nobel Prize in Physiology or Medicine 1904

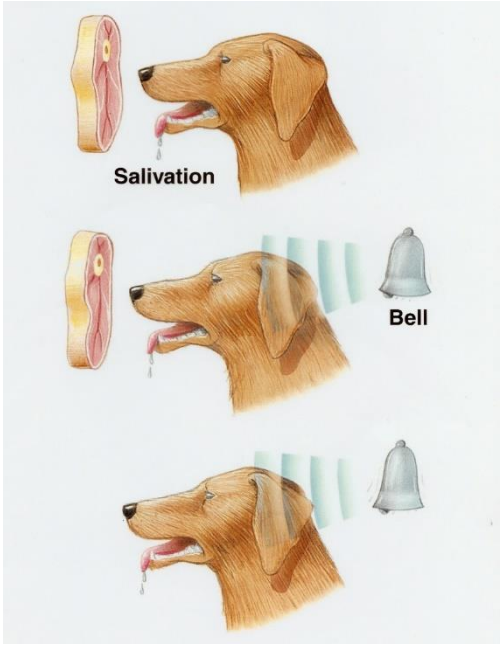
For his research in temperament, conditioning and involuntary reflex actions of the digestive glands

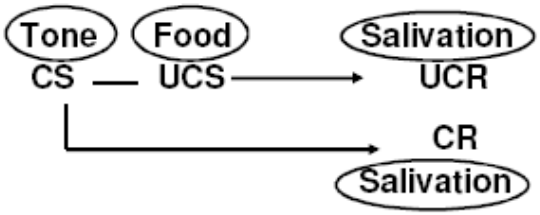
Pavlov's experiment:
The original and most famous example of classical conditioning involved the salivary conditioning reflex of Pavlov's dogs.

Pavlov's Classical Conditioning experimental setup



Pavlov's Classical Conditioning





Before Training/Conditioning

Food ⟶ Salivation

Tone ⟶ ???? (nothing)

During Training/Conditioning

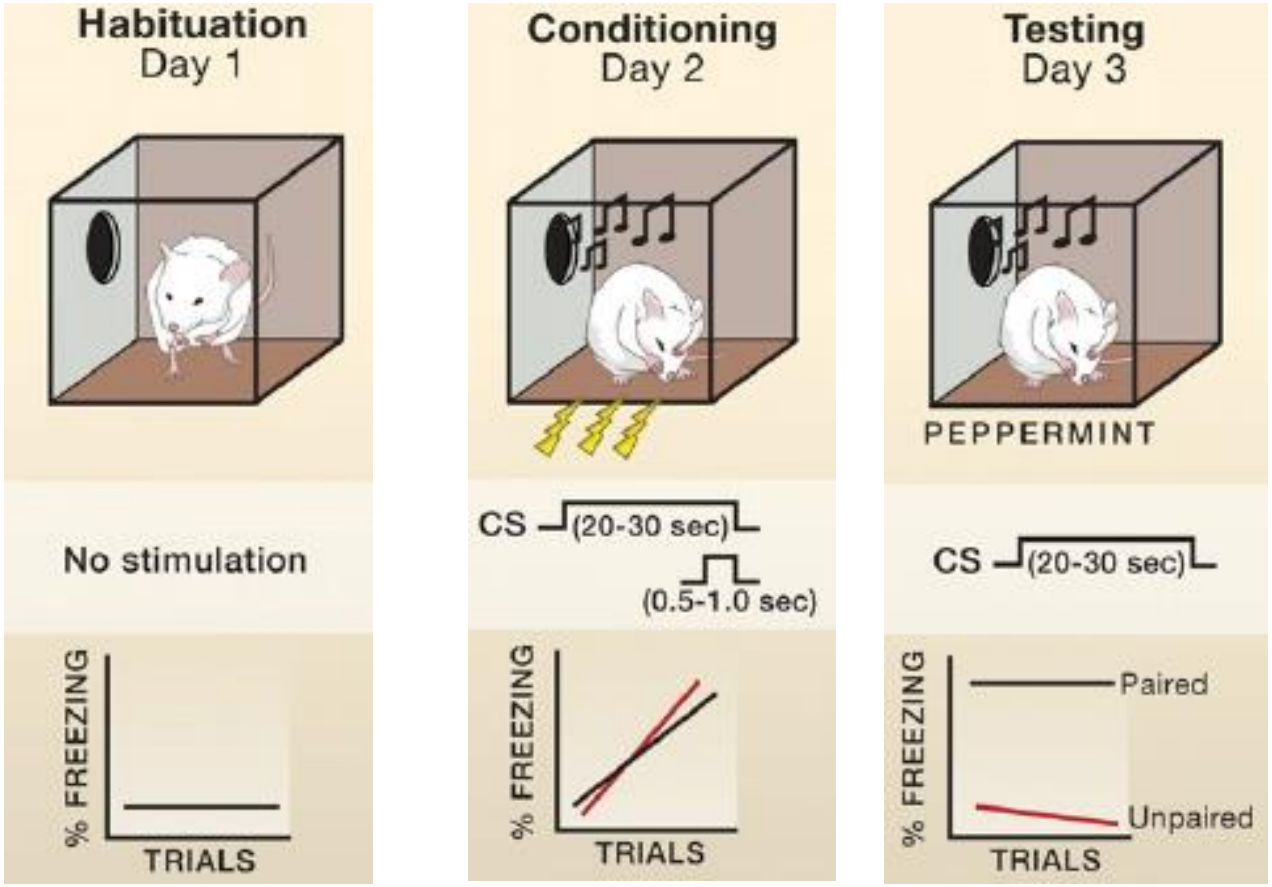
Tone — Food ⟶ Salivation

After Training/Conditioning

Tone — Food ⟶ Salivation

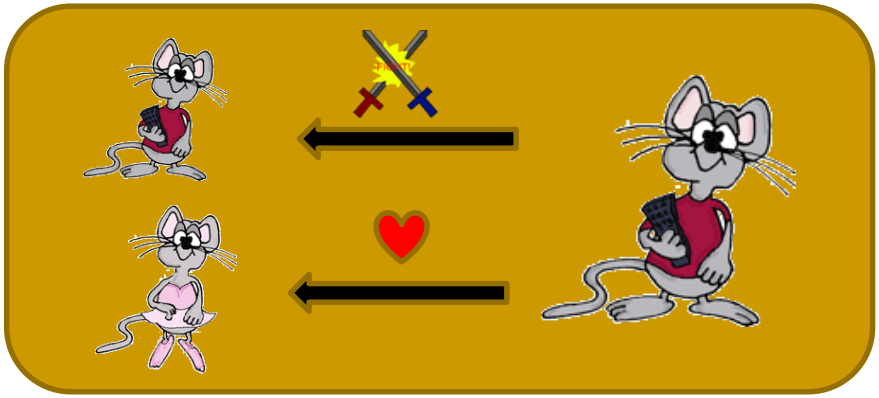
Tone ⟶ Salivation

Example: Negative Classical Conditioning



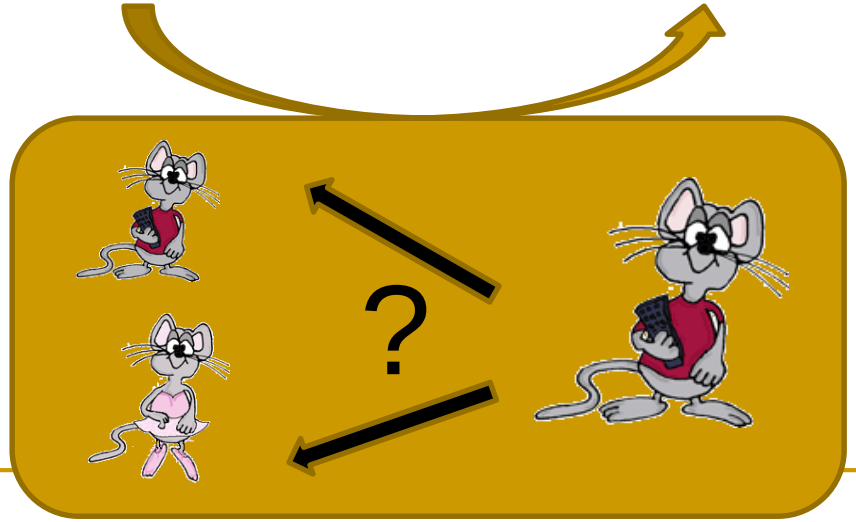
Jonathan et al 2011; Cell

Classical conditioning on innate behavior (sexual preference)



Conditional sex-specific pheromonal aversion

Associating female odor to a mild stomach ache /nausea



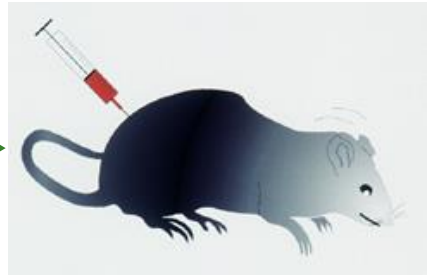
Beny and Kimchi 2016

Conditioned taste aversion

LiCl injection

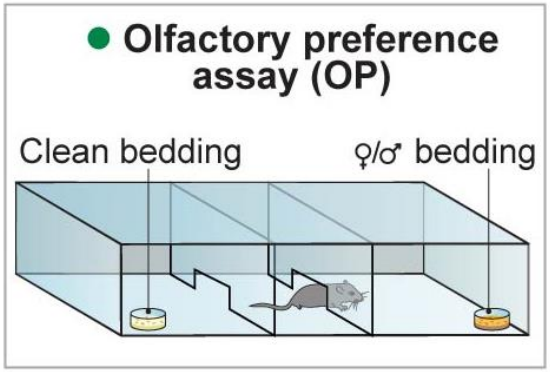
Conditioned odor aversion

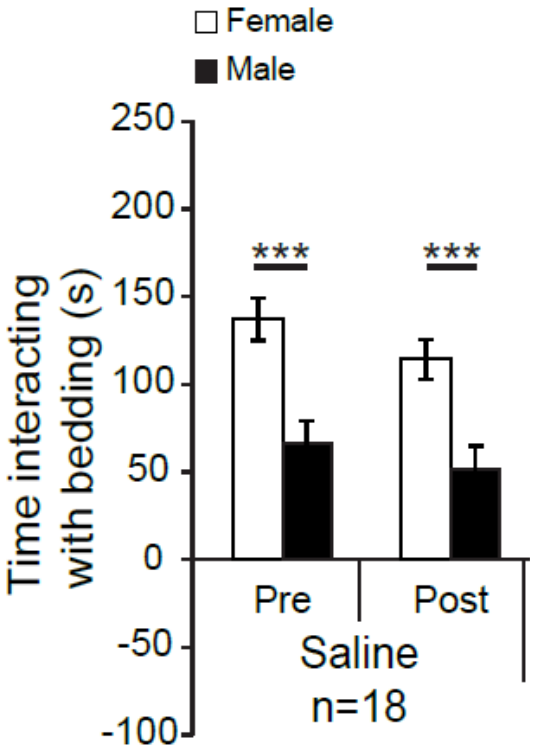
Female soiled bedding (pheromones)



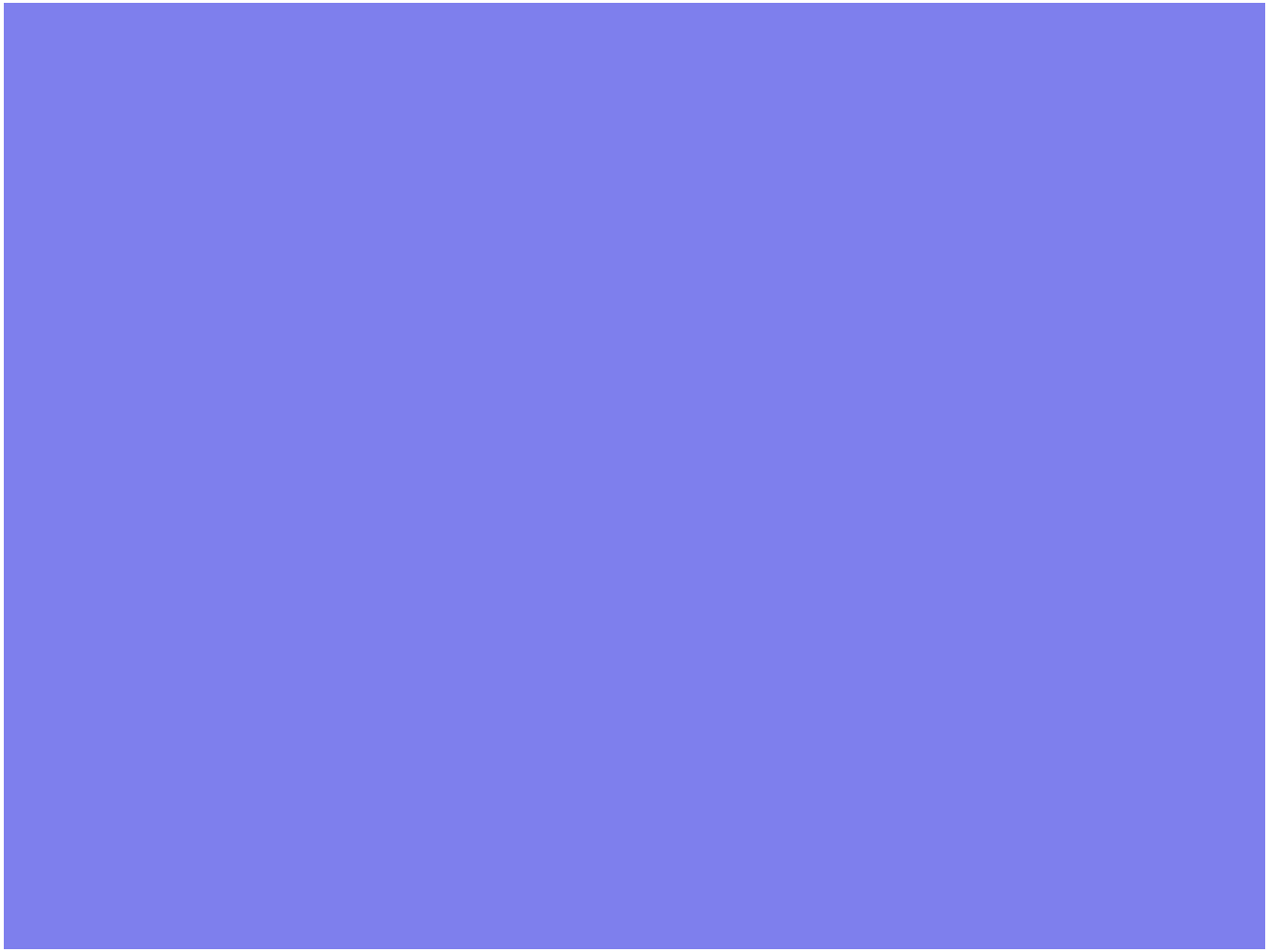
Sexual preference?

Female-specific negative conditioning impairs sexual preference





Female-specific negative conditioning impairs sexual interaction



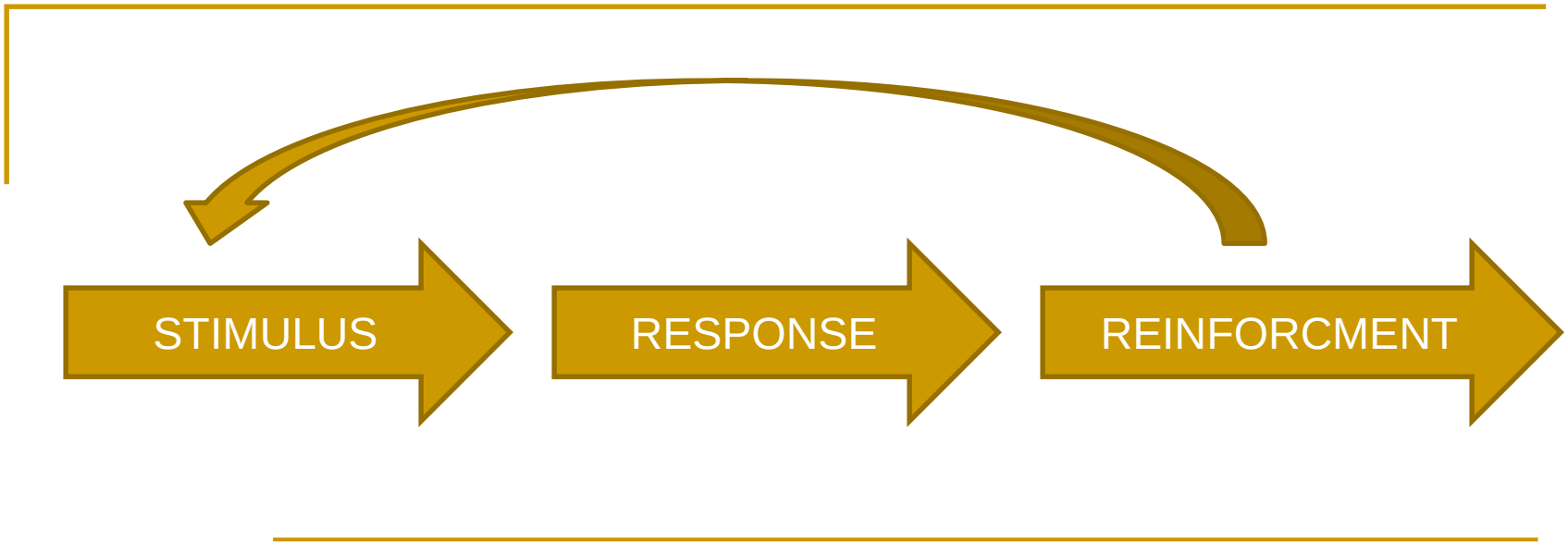
Skiner's Operant Conditioning

"Everything we do and are is determined by our history of rewards and punishments."-BF Skinner

•A process where an animal learns to associate one of its behaviors with a reward or punishment and then tends to repeat or avoid that behavior

•In contrast to classical conditioning the response is voluntary (it is NOT a reflex) and the animal must do something to gain a reward (or avoid punishment)

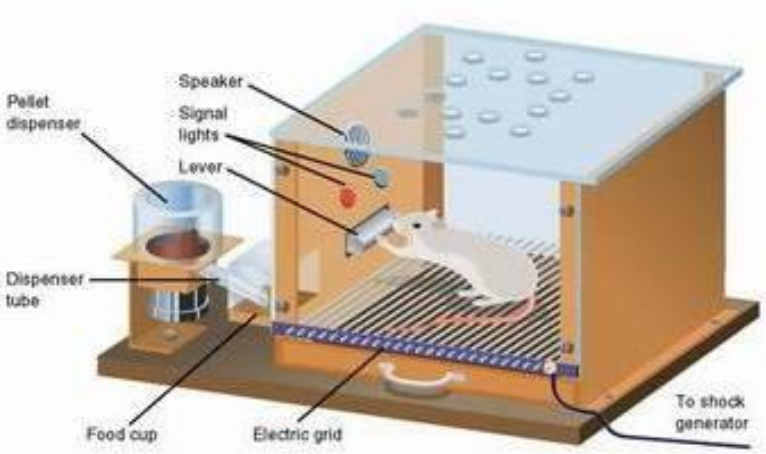
Skiner's Operant Conditioning

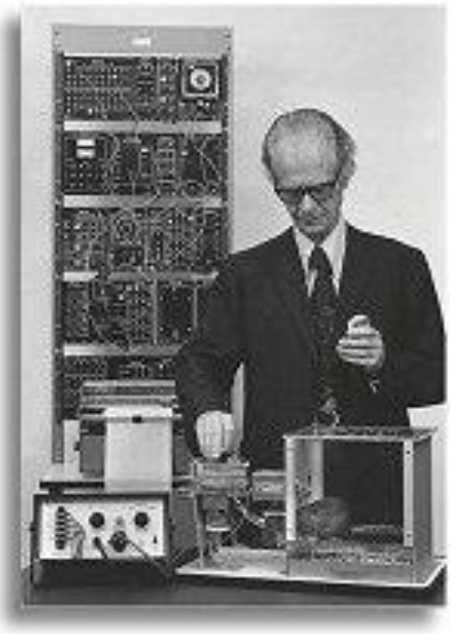


If your behavior is followed by a positive consequence, you are more likely to repeat the act in the future.

If it is followed by a negative consequence, you are less likely to repeat it.

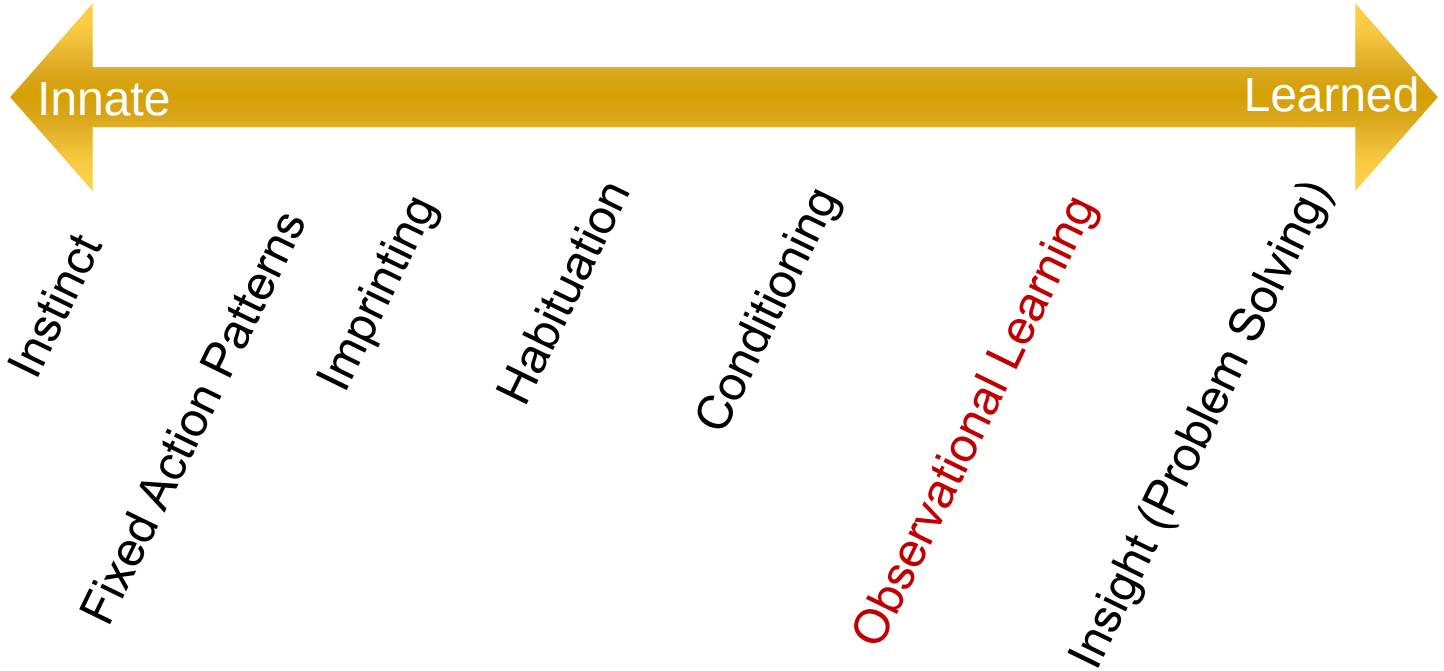
Operant Conditioning: The Skinner Box





Example: Positive Operant Conditioning

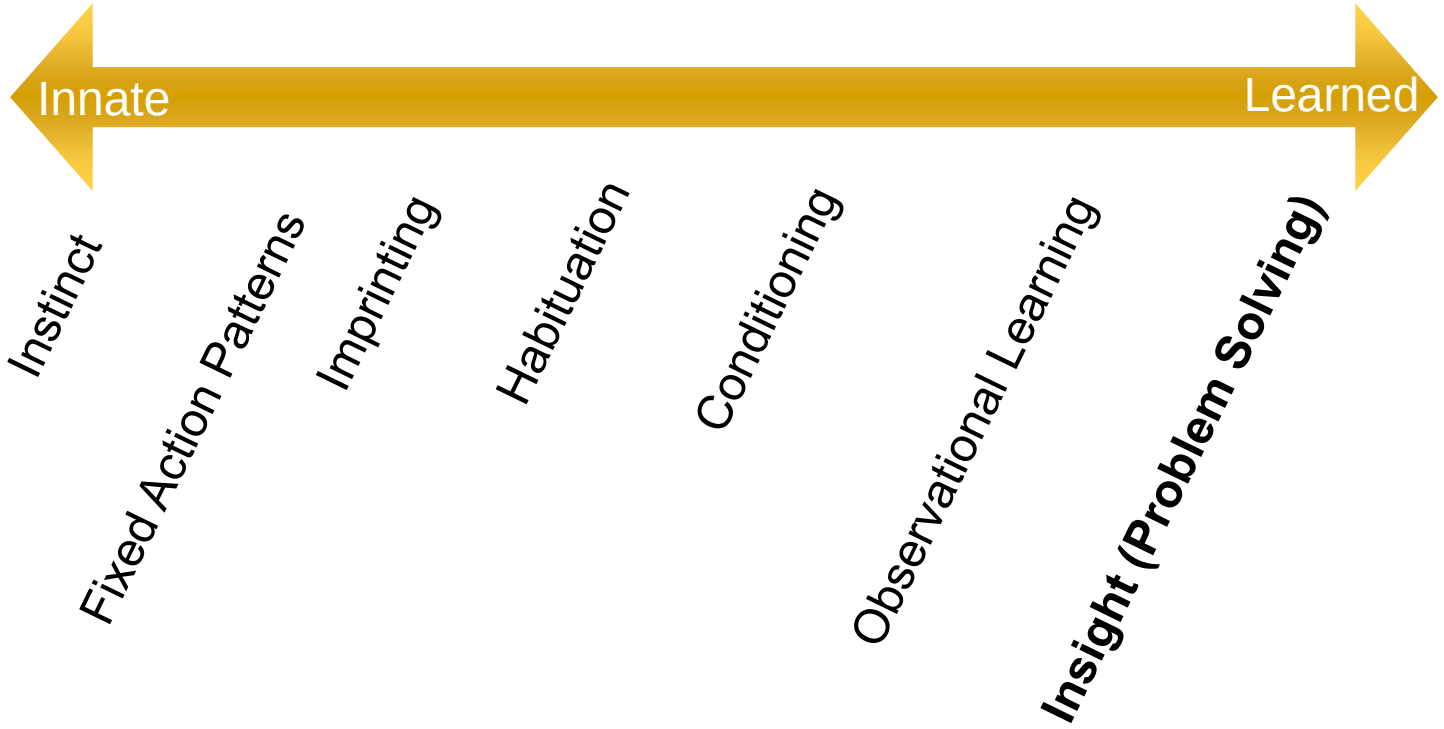
Types of behaviors



Observational Learning – Cultural transmission

Some Japanese monkeys learned to wash food before eating in 1950s, the effect still persists in the group

Types of behaviors



Insight (problem solving)- Chimpanzees

Kohler, circa 1920

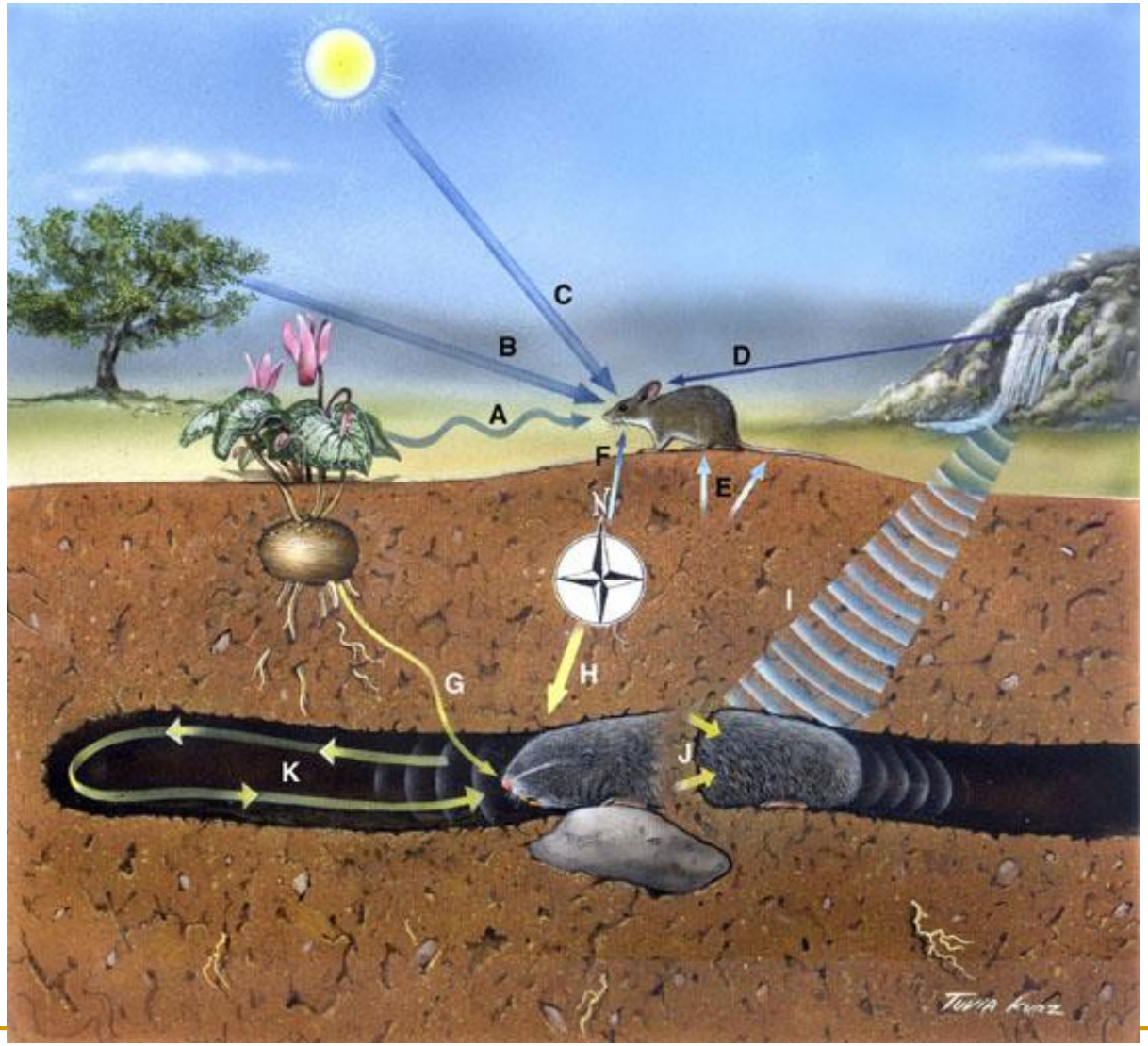
From Ethology to Neuroethology

A discipline that combines the study of animal behavior and study of neuroscience, to inquire how the brain controls behavior in wild-derived animals, using lab conditions mimicking the natural environment.

The neural basis for seismic social communication

The blind mole rat (*Spalax ehrenbergi*)

Mole rats are exposed to unique environmental conditions



The blind mole rat (BMR)

Lifespan: max ~20 yr (rat: up to 3yr)

Size: 120-300gr, 15-20cm

Sociality: Solitary (interaction for mating), highly aggressive

Senses: Blind, poor hearing and smell, develop somatosensory perception, vibrational perception, detection of the earth's magnetic field

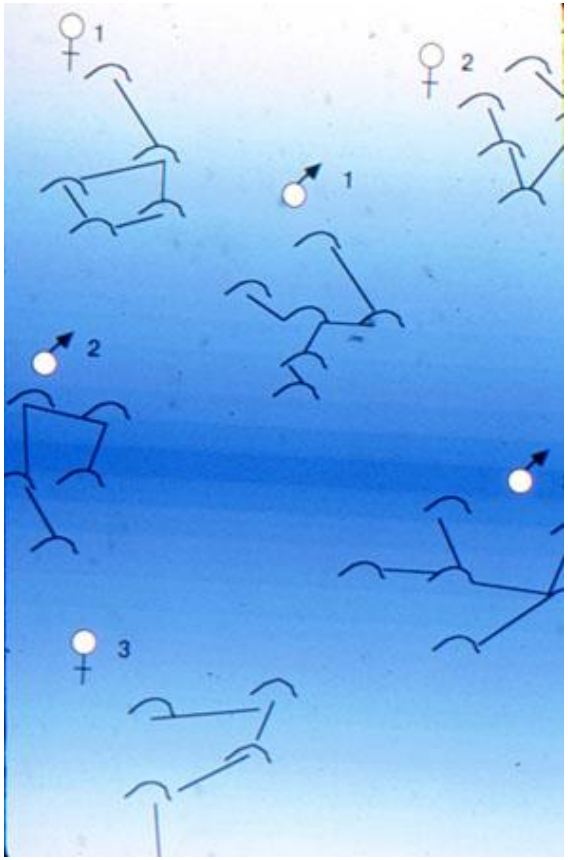
Diet: Herbivorous, Geophytes

Habitat: Subterranean, sealed branched tunnel systems, different types of soils

Superpower: Survive with almost no oxygen, don't drink, cancer resistance, extraordinary navigation in the dark, social communication with seismic signals

Sensory adaption to the underground niche

How do blind mole rats communicate with each other (find their mate/ avoid aggressive)?



Behavioral observations:

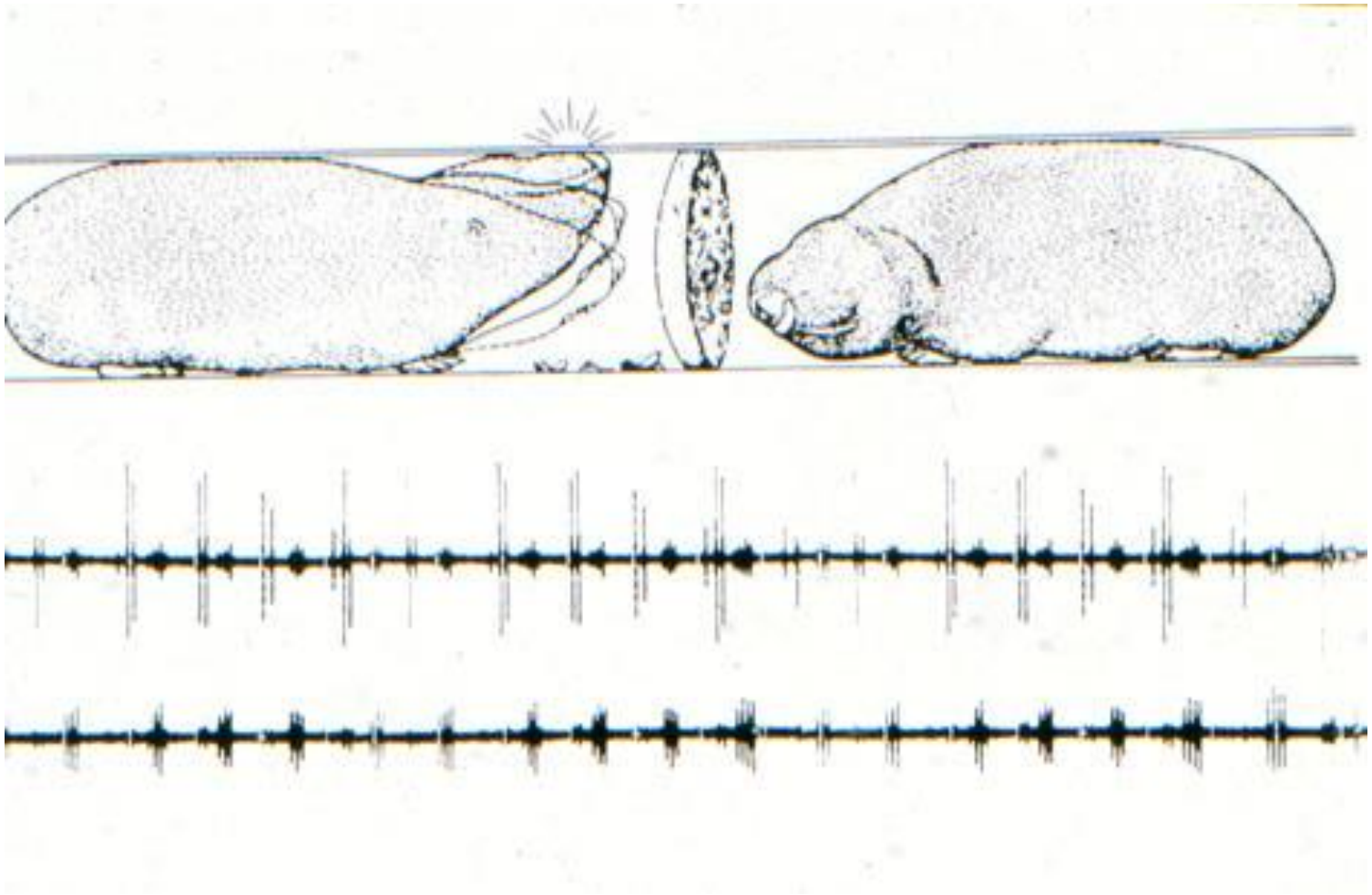
Mole rats produce head drumming
Mole rats often press their lower jaw to the tunnel side

Hypothesis:

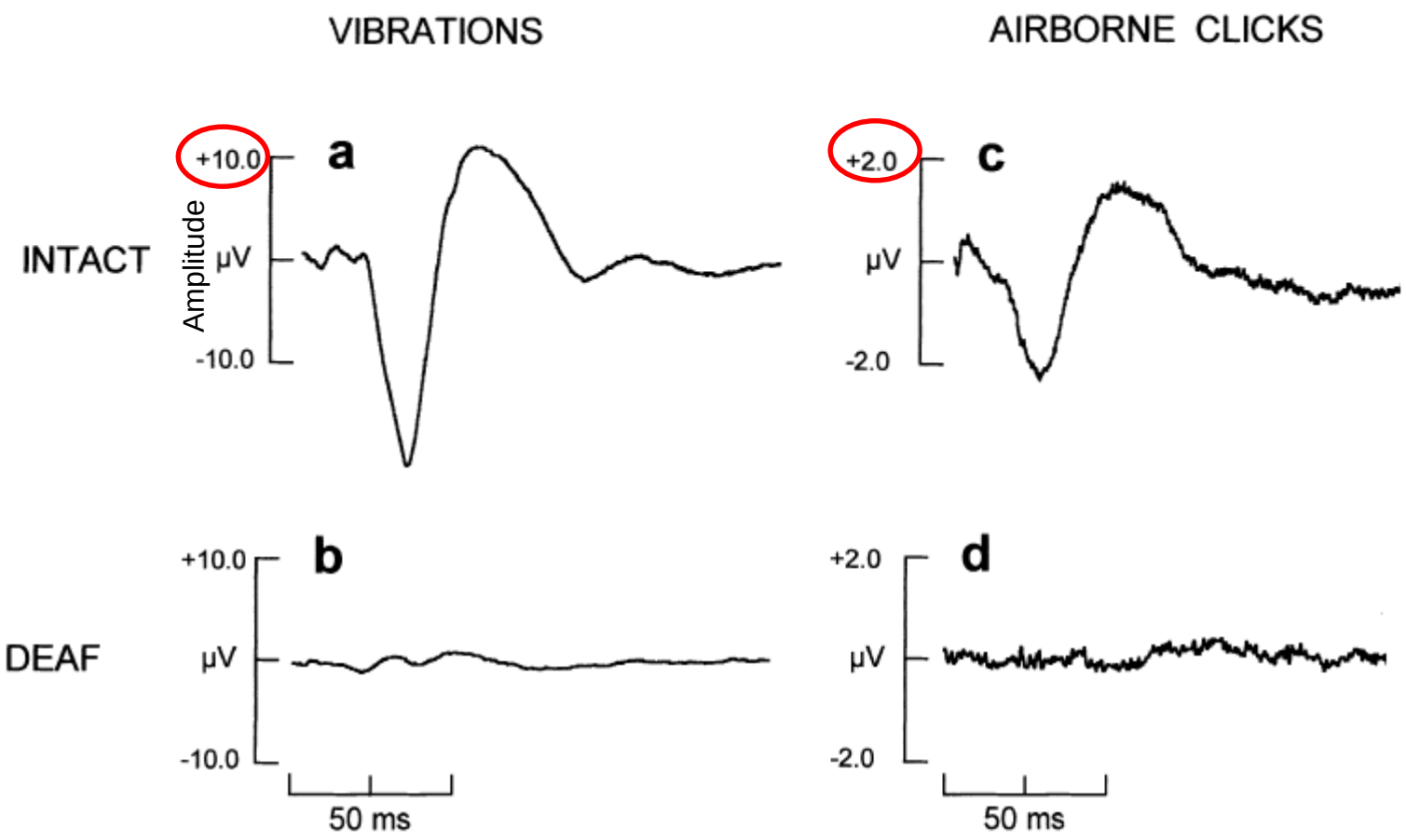
Mole rats communicate using soil-borne vibrations

Seismic social communication in blind mole rats

Lab experiments

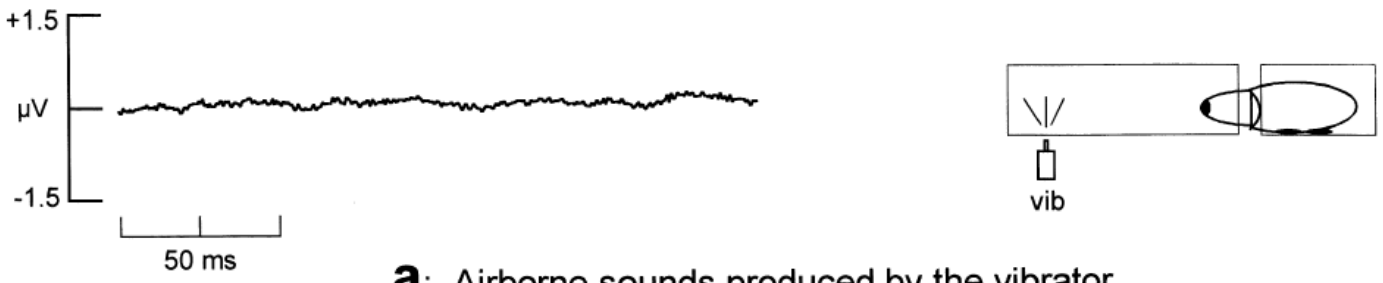


Rado, R (1998); J Comp Physiol

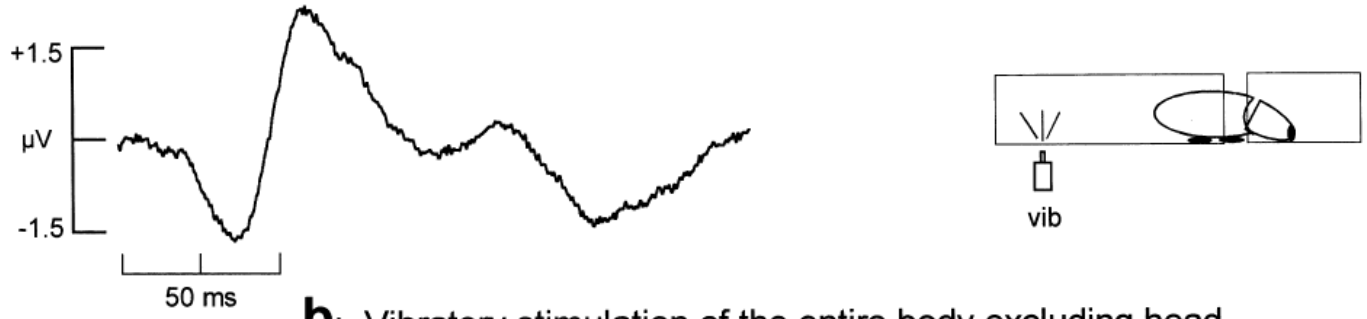


Middle latency response (MLR): the response of the auditory pathway to an auditory stimulus

Rado, R (1998); J Comp Physiol



a: Airborne sounds produced by the vibrator

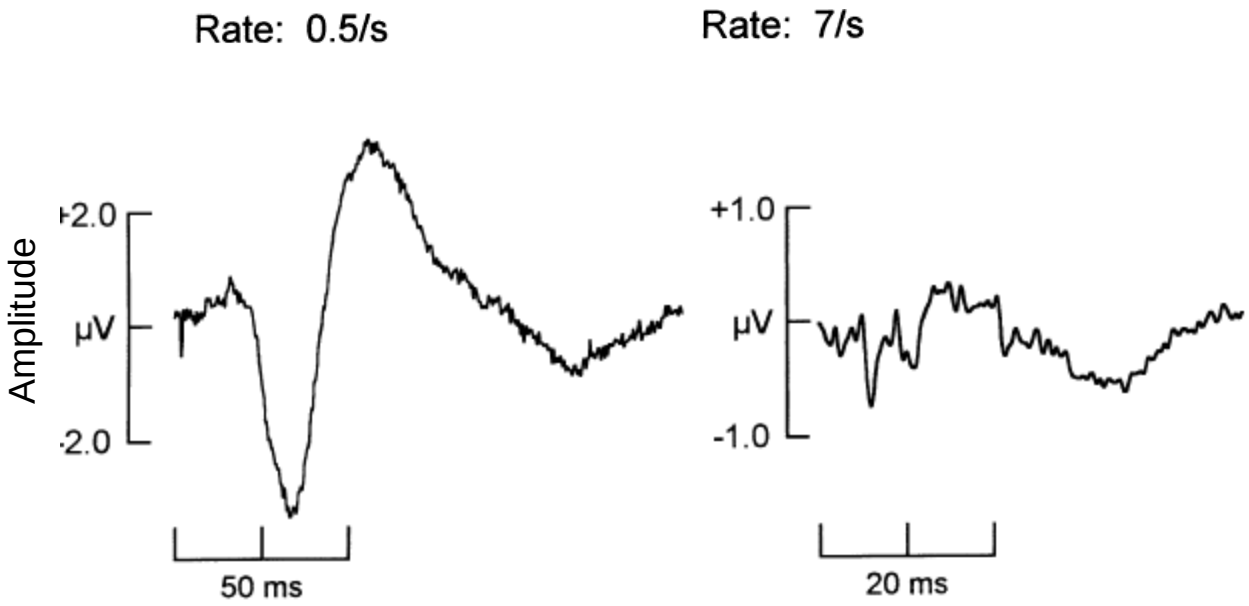


b: Vibratory stimulation of the entire body excluding head

c: Vibratory stimulation of the head - mainly the lower jaw

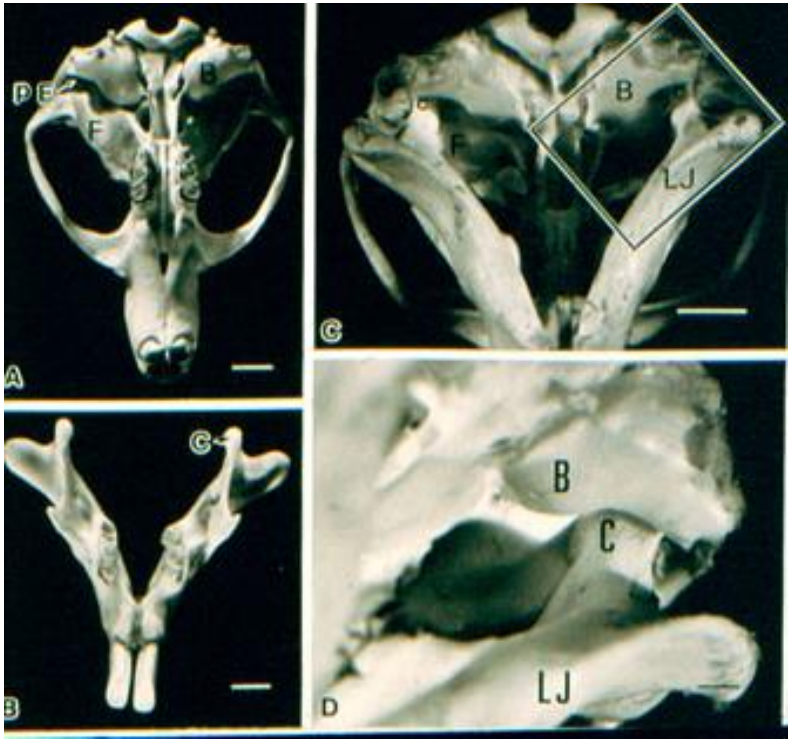
Rado, R (1998); J Comp Physiol

Vibration signal frequency



Rado, R (1998); J Comp Physiol

Vibration detection via bone conduction, through the lower jaw



The neuronal basis of pair bonding in voles

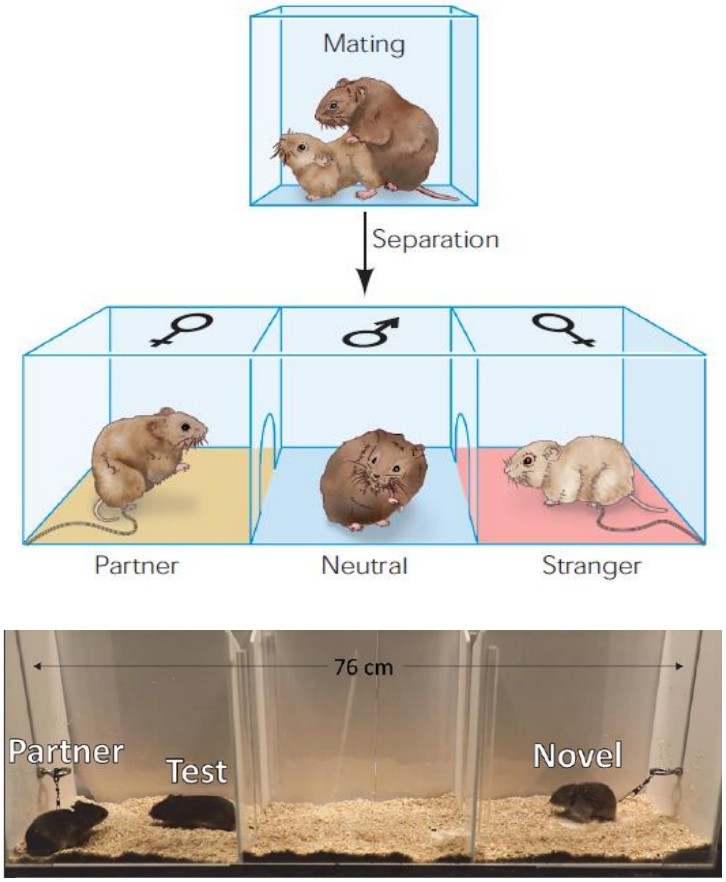
Pair bonding and social behavior in voles

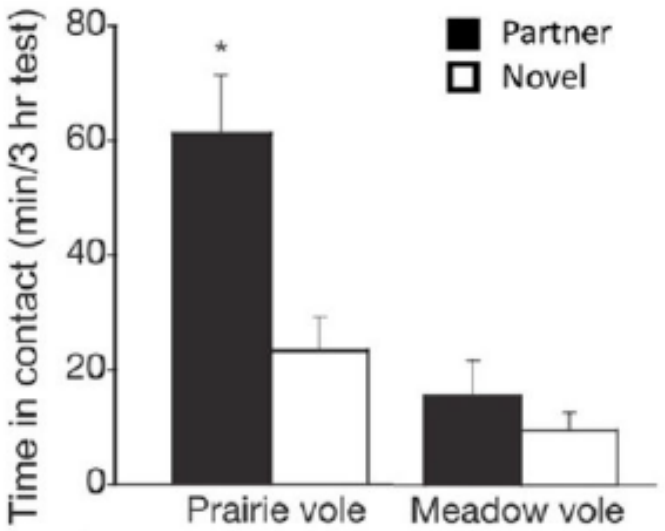
Prairie voles

- Highly social
- Monogamous
- Spend most of their time in social interaction

Montane/Meadow voles

- Avoid social contact except for the purpose of mating
- Polygamous
- Spend ~5% of their time in social interaction





Hemanth et al 2006

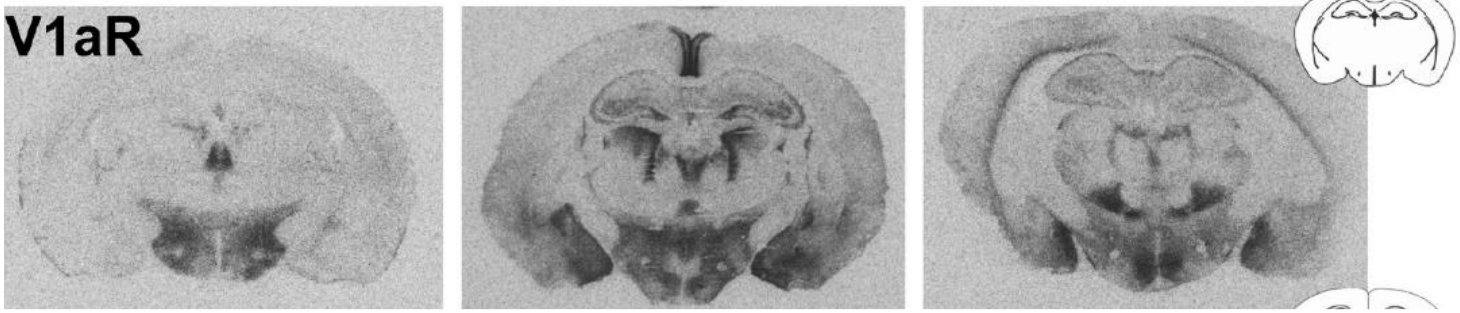
Sadino and Donaldson, 2018

Diversity in V1aR expression in across species

Mouse (Mus)

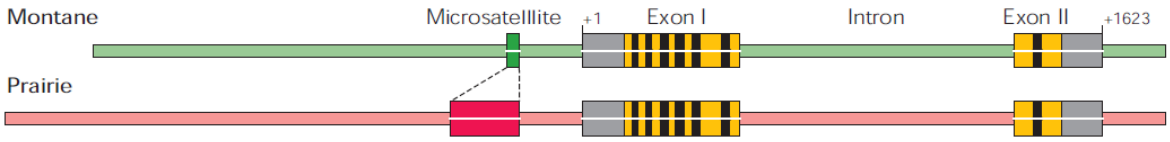
Prairie vole

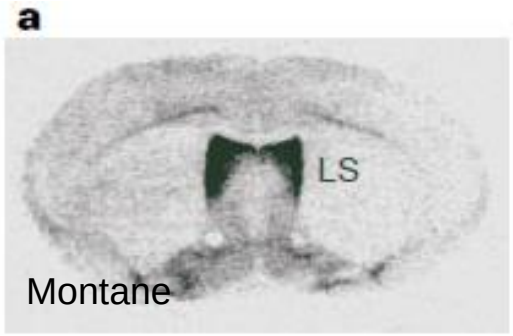
Meadow vole

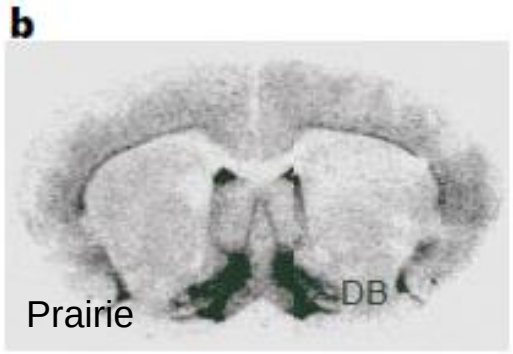


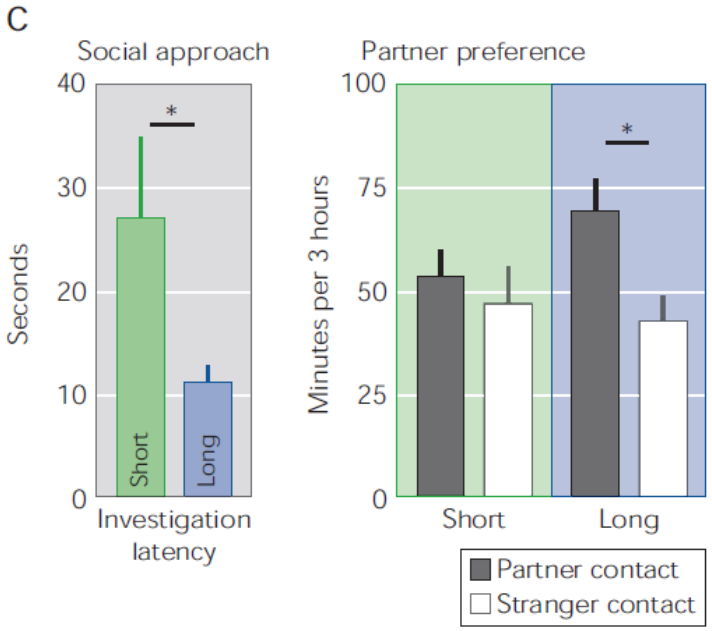
Sadino and Donaldson, 2018

Polymorphism in V1aR microsatellites generate differences in the brain and in social behavior







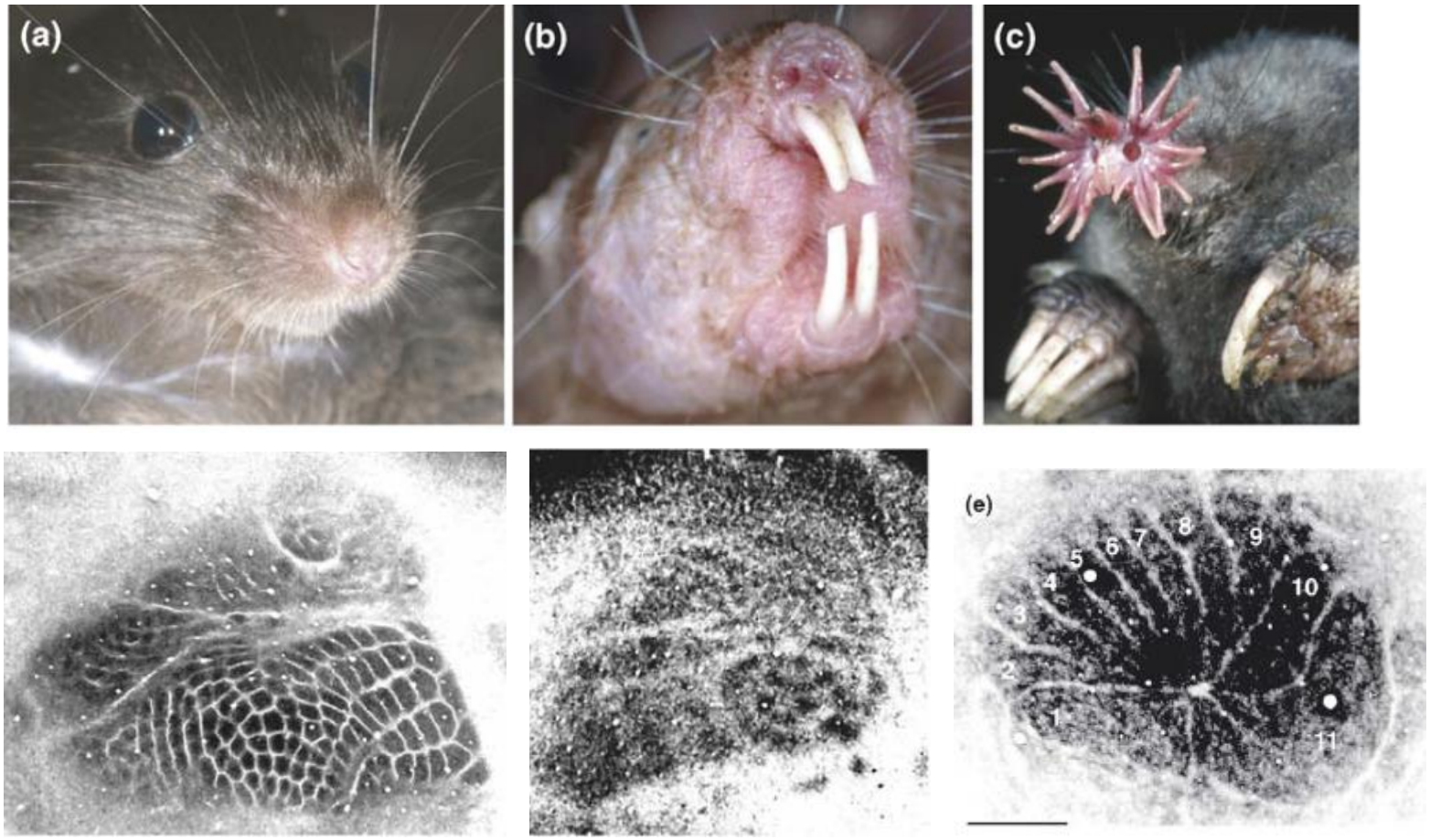


Hammock & Young, 2005 *Science*

Neuroethology – Brain structure

Species-specific somatosensory map in the cortex

Mouse | Naked mole rat | Star mole rat



Catania and Henry 2006, Curr Opin Neurobiol

Observe the natural animal behavior and choose the appropiate animal model for your research

Proximate and ultimate perspectives on aggressive behavior by male sticklebacks

BEHAVIOR: A male stickleback fish attacks other male sticklebacks that invade its nesting territory

PROXIMATE CAUSE:

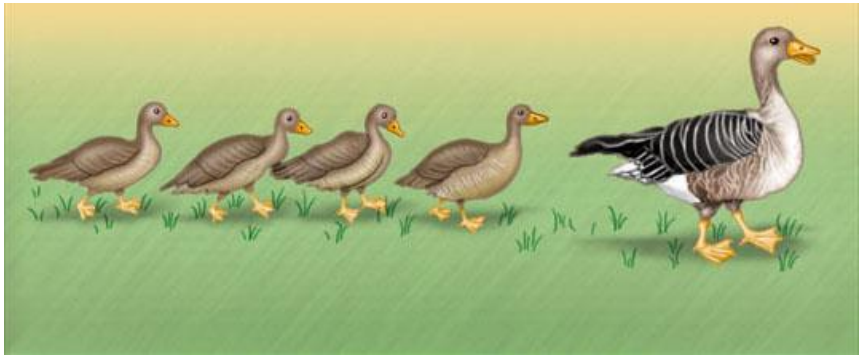
The red belly of the intruding male acts as a sign stimulus that releases aggression in a male stickleback

ULTIMATE CAUSE:

By chasing away other male sticklebacks, a male decreases the chance that eggs laid in its nesting territory will be fertilized by another male

Proximate and ultimate perspectives on imprinting in graylag geese

BEHAVIOR: Young geese follow and imprint on their mother



PROXIMATE CAUSE:

During an early, critical developmental stage, the young geese observe their mother moving away from them and calling

ULTIMATE CAUSE:

On average, geese that follow and imprint on their mother receive more care and learn necessary skills, and thus have a greater chance of surviving than those that do not follow their mother

Imprinting for conservation

Conservation biologists have taken advantage of imprinting by young whooping cranes as a mean to teach the birds a migration route.

A pilot wearing a crane suit in an Ultralight plane acts as a surrogate parent.