Hormonal Control of Behavior

This Week’s Topics:

- neural plasticity as the basis of motivational changes in behavior
  & how hormones affect these changes in neural plasticity and behavior
- neural mechanisms that mediate changes in behavior

Motivational Changes in Behavior

Major factors that determine an animal’s behavior are external environmental stimuli.

Different stimuli typically elicit different behaviors

Very often a stimulus given at the same intensity can elicit different responses in the same animal.  
[i.e., the Input/Output relationship is not fixed]
**Example: seasonal changes in reproductive behavior**

American Goldfinch

- **breeding season** + “female stimulus” = *courtship display*

- **non-breeding season** + “female stimulus” = *no display*

**Note:** there are many other seasonal changes in behavior for American Goldfinches (e.g., territoriality, aggression, and song production)

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**So... what counts for such a dramatic difference in the response??**
Motivational factors

structures within the CNS are regarded as motivational components of the neural network involved in the generation of the behavior

Motivation: the physiological state of an animal which defines the frequency and intensity of occurrence of a behavior when elicited by a given endogenous or exogenous stimulus (Zupanc 2004).

Major Neural Mechanisms that Mediate Changes in Behavior:

1) Neuromodulators: a chemical released by a neural or endocrine cell that acts on a neuron to modulate its response.

2) Structural reorganization of the neural network underlying the control of the respective behavior
Two categories of Neuromodulators:

(1) Neuropeptides and certain monoamine neurotransmitters
- chemicals that produced by modified nerve cells or neurosecretory cells and released in a non-synaptic fashion.
- Neuropeptide examples: GnRH and vasopressin
- Monoamine neurotransmitter examples: catecholamines (adrenaline, noradrenaline, dopamine) and serotonin

(2) Steroid hormones
- chemicals produced by an endocrine gland that act on specific target cells located at a distance from the site of synthesis.
- hormones coordinate the physiology and behavior of an animal by regulating, integrating, and controlling its bodily function.

Steroid Hormones: *Organizational & Activational Effects*

Organizational / Activational Hypothesis (1959) =

maintains that:
- *early differential exposure to hormones (prenatal) acts to organize the neural machinery responsible for sex specific behaviors, and then*
- *exposure to these hormones later in life will activate the neural circuitry previously organized.*

*A number of clinical syndromes exist among humans and nonhuman animals that cause errors during the process of sexual differentiation.*
An Example of Anomalous Sexual Differentiation:

$5\alpha$-reductase deficiency

T (testosterone) $\xrightarrow{5\alpha$-reductase} DHT (dihydrotestosterone)

Male w/ $5\alpha$-reductase deficiency are:

- born with ambiguous genitalia and small, undescended testes
- often considered females at birth and reared as females
- at puberty, T masculinizes the body, which develops male-
typical musculature and axillary hair growth, and the genitalia
develop to resemble a male-typical penis and scrotum.
(activational effects)

Case Study: $5\alpha$-reductase deficiency

In an isolated village in SW Dominican Republic, 2% of the live births
in the 1970's were guevedoces ("penis at 12").

These children appeared to be girls at birth, but at puberty these 'girls'
sprout muscles, testes, and a penis.

For the rest of their lives they are men in nearly all respects (see photo above).
Underlying pathology = deficiency of 5-alpha Reductase.
Vertebrates exhibit three general patterns of reproduction:

1) associated reproductive pattern – mating occurs at the time of maximum gonad activity (maturation of gametes & peak levels of sex steroids) Example = Green Anoles

2) dissociated reproductive pattern – mating occurs at a time of minimal gonadal activity (low levels of sex steroids).

3) constant reproductive pattern – gonadal activity is maintained at near maximum levels at all times.

Example = Zebra finch, which lives in the deserts of Australia, where rainfall occurs rarely and unpredictably. Breeding occurs after rainfall so males & females maintain their reproductive systems in a constant state of readiness.
Sex Steroids: \textit{Role of Testosterone}

The chemical structure of testosterone and its diverse effects on physiology and behavior.

Avoiding Prolonged T effects: T and Territorial Behavior
Avoiding Prolonged T effects: T and Territorial Behavior

Estrogen and territorial behavior (Male Song Sparrows)
Avoiding Prolonged T effects: T and Territorial Behavior

Estrogen and territorial behavior (Male Song Sparrows)

Other Effects of Estrogen on Male Sexual Behavior
Testosterone and the control of sexual motivation in Japanese Quail

Estrogen affects how sexually experienced males respond to the opportunity to view a mature female quail.

Estrogen and the control of sexual motivation in male Japanese quail

- Testosterone implanted
- Testosterone implant + aromatase inhibitor (at test 9)
- Controls (no testosterone implant)
How Might Hormones Mediate Changes in Behavior?

Behaving Animals can be thought of as 3 interacting components:

1. input systems (sensory systems)
2. integrators (the CNS)
3. output systems or effectors (e.g., muscles)

Hormones may affect any or all of these 3 components when influencing behavior.

Hormones influence these 3 systems so that specific stimuli are more likely to elicit certain responses in the appropriate behavioral or social context (i.e., hormones change the probability that a particular behavior will be emitted in the appropriate situation).

Hormones can influence target cells in many ways:

- commonly alter the rate of normal cellular function, but rarely alter the function of a cell.
- change a cell’s morphology or size
- affect neuronal growth and development as well as cell death throughout the nervous system

Note: The relationship between hormones and behavior is bidirectional.

_Hormones affect behavior, but behavior can also influence hormone levels and effects._
How Might Behavior Affect Hormones?

*Classic Example related to Bird Song is the Wingfield et al (1988) Challenge Hypothesis*

The sight or auditory playback of a territorial intruder can elevate blood T levels in the resident male and thereby stimulate singing and/or fighting behavior!

Male mice (Ginsbergand and Allee, 1942) and rhesus monkeys (Rose et al, 1971) that lose a fight can show reduced levels of T for several days after the incident.

Structural Reorganization of neural networks

Seasonal changes in the dendritic structure of neurons are implied to play a role in dramatic changes in behavior.

Prime example = Seasonal changes in the chirping behavior of weakly electric fishes

Electric organ discharge of the knifefish *Eigenmannia* during courtship

Chirps = short-term EOD modulations with complex changes in frequency and amplitude; often followed by a complete cessation or interruption of the EOD.
Functional Significance of Chirps

Males produce Chirps during courtship and reproduction

Pre-recorded male chirps and their playback to isolated gravid females can induce egg laying.

Reproductive behaviors can be induced by simulating the rainy season in the lab by decreasing the concentration of solutes (adding deionized water) and imitating rain by gently sprinkling water onto the surface of the aquarium water.

This procedure will induce gonadal recrudescence, elevate gonadal steroid levels and *chirping behavior* after several weeks.

Chirps are controlled by a subnucleus of the central posterior/prepacemaker nucleus (CP/PPn) in the dorsal thalamus (diencephalon).

Retrograde tracing with horseradish peroxidase in an anesthetized animal shows the innervation of pacemaker nucleus in hindbrain.
Seasonally induced changes in chirping behavior are accompanied by alternations in dendritic morphology of Central Posterior/prepacemaker nucleus neurons.

NR = nonreproductive condition
R = reproductive condition

Males in reproductive condition had significantly longer dendrites (greater arborization) in the CP/PPn nucleus.

Model of Structural Change in the Neural Network underlying seasonal changes in Chirping Behavior

Rainy season: triggers gonadal recrudescence and dendritic growth of the dorsomedial territory of the CP/PPn neurons. These neurons make predominantly excitatory synaptic contact with axons that originate in the nucleus electrosensorius (nE) [sensory/motor interface].

Structural changes are thought to be induced by a yet unknown substance (hormones??) diffusing from the ventricle into the CP/PPn dendritic field.