Chapter 10
Development and Behavior
Development of Behavioral Traits

Does development of the embryo occur in a motionless state? or do spontaneous patterns of behavior arise during early stages of development?
It appears that some behaviors develop in an anticipatory manner and help prepare the embryo for later life:

1) Premature babies can respond to light although they are not exposed to light in the womb
2) Fetal breathing movements are generated in mammals that only result in changes in liquid volume in the lungs not air flow
Some behaviors have an adaptive role and are transiently expressed. For example, the clicking noise of quail embryos is used to synchronize hatching.
Embryonic behaviors can serve as a substrate for building the nervous system. Neuronal circuits are not created in a perfect manner, functional use help to fine tune these circuits.
Motor Behavior

- One conserved form of embryonic behavior is the ability of the embryo to generate spontaneous movements of the body.

- In some animals, generation of spontaneous movement involves signaling between the axon and the muscles and could be necessary for proper functional maturation of the neuromuscular junction. In some animal species, movements are myogenic in which muscle activity is generated without synaptic transmission.
Is skeletal motor activity in the embryo spontaneous or reflexive? In some animals, like the leech, motor activity occurs in response to increased illumination (stimulus-induced behavior). In other cases, like in chick embryos, motor activity occurs prior to the establishment of sensory inputs. Notice that in the chick spinal cord sensory afferents do not contact the motoneuron pool until stage 37 (embryonic day 8).

From Lee et al., 1988
Motor Behavior

- Removal of neural crest cells in the chick embryo at very early stages of development prevent formation of dorsal rood ganglia (DRG)

- But lack of DRG does not prevent generation of spontaneous motor movements in the developing chick embryo
How are spontaneous movements generated? Nerve cell activity in the isolated chick spinal cord indicate that the spinal cord generate a rhythm that is close to that in the intact animal.

From O'Donovan & Landmesser, 1987
In the chick spinal cord, spontaneous activity begins somewhere around stage 26 (embryonic day 6) before the establishment of sensory afferent connections. As development progresses, the frequency of spontaneous activity increases and become more complex.

From O'Donovan & Landmesser, 1987; O'Donovan et al., 1998
Mechanism of Spontaneous Movements

Neuronal elements in the ventrolateral spinal cord are sufficient to generate patterned electrical activity in the developing chick embryo.

From Ho & O'Donovan, 1993
The early circuit that generate spontaneous activity in the spinal cord is driven by acetylcholine and GABA. At later stages of development the spinal cord circuits are driven by glutamate. This switch is likely mediated by changes in neurotransmitter expression during embryonic development.
Mechanism of Spontaneous Movements

GABA immunoreactivity in the chick spinal cord is transient. Notice that by E12 most inhibitory signaling in the spinal cord is generated by the inhibitory neurotransmitter glycine.

From O'Donovan et al., 1998
Mechanism of Spontaneous Movements

Embryonic movements are integrated. Behaviors build upon each other as the system matures and new components are added to the circuit.

This has been investigated in salamander embryos that like all amphibian embryos develop in shell-less eggs in water and are accessible for early observation from very early stages of development.
Mechanism of Spontaneous Movements

- In the salamander embryo, the first executed movement is the bending of the head.

- As development proceed, more body segments and muscles are recruited down the body axis resulting in flexure and bending of the body in a coordinated fashion. This result in the generation of various stereotypical movements like early flexure, coil, and S-shape.
In chick embryos, spontaneous motor movements result in uncoordinated twisting of the trunk, kicking of the legs. These movements involve alternating discharges from flexor and extensor muscles.

Coordinated movements between left and right limbs arise at later stages of development and involve new neuronal connections between the left and right spinal cord.
Spontaneous Activity and Coordinated Behavior

Does generation of early spontaneous activity regulate the generation of coordinated behavior at later stages of development? Raising salamander embryos in an anesthetic solution for extended periods of time does not interfere with their ability to swing like aged-matched controls.
Spontaneous Activity and Coordinated Behavior

It appears that development of coordinated movements does not require early spontaneous activity. However, it is possible that some motor patterns are hardwired into the developing anatomy.
Fetal Breathing Movements

- Another example of motor activity generated in developing embryos involve fetal breathing movements in mammals.

- Fetal breathing movements in mammals is not required for gas exchange, but they are important for proper lung development and overall development of the respiratory system.

- FBM can be recorded in vivo (ultrasound) or in vitro (brain stem-spinal cord preparation).

From Funk et al., 1997
Fetal Breathing Movements

FBMs are generated in the brain stem by a group of neurons in the pre-Botzinger area. The drive from the brain stem is transmitted to phrenic motoneurons in the cervical spinal cord for the recruitment of the respiratory muscles (diaphragm and intercostal muscles).

From Rekling & Feldman, 1998
Embryo-Specific Behavior

During development some behavior arise that serve no particular purpose. In the leech prodding to one side of the body result in circumferential indentation of the body due to contraction of circular muscles around site of prodding.

In the chick, hatching movements are highly stereotyped but only serve an specific purpose during a particular period of development.
Motor Learning: Vestibuloocular Reflex

Spontaneous motor activity and emergence of coordinated movements do not require sensory input. However, learning of new motor skills require sensory input and is coupled to the development of cerebellar circuitry.
Motor Learning

- Reeler mutant mice that show significant disruption of cerebellar structures show unsteady gait.

- The cerebellum is particularly important for the vestibuloocular reflex that allows us to keep the eyes fixed in a given point as the head turns. This allows an object to remain in the field of view as the head turns.
If a subject wears magnifying goggles that invert the left and right visual fields, the cerebellar circuit responsible for the VOR make the necessary adjustment to regulate head rotation under the new conditions.
The nervous system becomes active well before animals experience the world. But at some point newborns begin to sense the world. How is sensory information in newborns limited by cell physiology and morphology?
Development of Eyesight

- Human infants are capable of seeing at birth but have very small visual acuity (or the ability to detect fine details).

- Visual acuity can be measured by the number of black and white lines that can be observed by degree of visual space.

- In primates, low visual acuity is due to immature retina.
Development of Acute Hearing

- Similar to the development of the visual system, the sensitivity and discrimination of the auditory system increases during maturation.

- Kittens can respond to very loud sounds. As their auditory system matures, the auditory threshold decreases, and they can detect other sounds.
Temporal processing of auditory signals also show a significant improvement during development.

Adults can detect much faster a period of silence in an ongoing sound. Newborns take longer to detect this gap and usually process this information as a continuous sound.
Development of hearing capabilities is crucial to for the localization of objects like its mother or a predator.

Newborns ability to determine the source of a sound is limited. Adults can detect 1 degree change in the position of a speaker. Newborns can only detect a change of 25 degrees.
Newborns are poor at sound lateralization.

When adults are exposed to a sound, they turn their head quickly. When newborns are presented with a sound they take longer to respond and the head movements can be quite slow.
Development of Acute Hearing

- Improvements in sound localization are due to maturation of somatotopic maps and refinement of sensory projections that allow neurons to respond to smaller parts of the sensory world.
After birth many newborn animals relies on their parents for food and protection. This require learning new skills by the newborn.

Imprinting or learned behavior allows newborn to learn a specific behavior from their parents.
Learning and Imprinting

- For example, hatchling ducklings will follow the first moving object they see immediate after hatching. This allow ducklings to become attached to their mothers.

- Imprinting can occur later in life and allow mates to stay together.
Learning and Imprinting

- When ducklings are exposed to maternal vocalization of 4 notes/min, they will approach any assembly call with the same frequency (4 notes/min).

- Exposure to the assembly call alone is sufficient to promote imprinting in the duckling.
The ducking can respond to assembly call from their siblings.

When ducklings are devocalized and reared with an assembly call of 2 notes/min, they will show no preference for the maternal assembly call.
Beside learning how to obtain food and water, animals need to learn how to avoid danger like poisonous plants and predators.

Some animals are born with the innate ability to flight particular shapes. For example, many birds will run from a black-hawk shaped silhouette.
Fear

- Development of fear response can be studied by measuring the startle response in rodents.

- When a rat is exposed to a loud sound, they make a sudden movement called a startle response.

- If the loud sound is coupled to a pure tone, the rat will learn to predict the noise response and give a larger startle response. This is called fear-potentiated startle.
Newborn pups have significant difficulties learning this behavior.

But as they mature, they are able to learn faster and faster.
Animals use different methods to communicate with each other. Human use their vocal cords to generate sounds, whereas birds use songs for different purposes.

In any case, there is a period of learning when communication skills are acquired. Humans generate their first word between 9-12 months after birth.
Language

- Learning of communication skills depends greatly on sensory input. Deafening or disruption of sensory experience will prevent the ability of a newborn to generate appropriate sounds.

- Song learning in zebra finch occurs during a specific period of maturation (~within 60 days post hatching). During this period, the IMAN nuclei undergo a considerable increases in size and synapse formation.
Disruption of the IMAN nucleus responsible for song learning at early stages of development but not in the adult will prevent song production.
NMDA receptors are implicated in song learning

When the amount of NMDA receptors is assessed by binding to radiolabeled MK801, a significant increase in the number of NMDA receptors is detected during the learning period.

Injection of the NMDA antagonist into the IMAN nucleus significantly reduce the ability of the bird to learn the tutor song.