The Biology of Mind and Consciousness

Chapter 2
The Endocrine System

• The body’s “slow” chemical communication system, a set of glands that secrete hormones into the bloodstream

• **Hormones** are chemical messengers manufactured by endocrine glands
  – Some are chemically identical to neurotransmitters
The Endocrine System

• *Slow and steady* sometimes wins the race
  – Effects of endocrine messengers outlast those of neural messages
  – “Endocrine hangover” – angry feelings for no reason, from lingering emotion-related hormones

• Hormones (messengers of endocrine system) influence many aspects of our lives
  – Growth, reproduction, metabolism, mood.
The Pituitary Gland

• The **pituitary gland**, in the brain’s core, is the endocrine glands’ control center
  – Influences growth
  – Send messages to other glands to release their hormones
  – Controlled in turn by the **hypothalamus** – part of the brain that controls endocrine system

brain ➔ pituitary ➔ other glands ➔ hormones ➔ brain
The Endocrine System

- **Hypothalamus**
  (brain region controlling the pituitary gland)

- **Pituitary gland**
  (secretes many different hormones, some of which affect other glands)

- **Thyroid gland**
  (affects metabolism, among other things)

- **Parathyroids**
  (help regulate the level of calcium in the blood)

- **Adrenal glands**
  (inner part helps trigger the “fight-or-flight” response)

- **Pancreas**
  (regulates the level of sugar in the blood)

- **Testis**
  (secretes male sex hormones)

- **Ovary**
  (secretes female sex hormones)
Studying the Brain

• The mind is what the brain does. Neuroscientists add to our understanding of the mind by studying activity and structure at the brain down to the molecular level. Tools of their study:
  – EEG (electroencephalograph) studying waves of electrical impulses,
  – PET (positron emission tomography) scan, studying areas of the brain using glucose,
  – MRI (magnetic resonance imaging) showing structures of the brain, and
  – fMRI (functional MRI) showing parts of the brain with increased blood flow.
Older Brain Structures

- Some components of the brain are found in simpler organisms, or at least lower mammals, and function similarly in humans
  - Brainstem
  - Thalamus
  - Reticular Formation
  - Cerebellum
  - Limbic System
The Brainstem

• The brain’s oldest and innermost region
• Begins where the spinal cord enters the skull
• **Medulla**: the base of the brainstem; controls heart rate and breathing
• **Pons**: helps coordinate movements
Crossover Point

- Nerves to and from each side of the brain connect to the opposite side of the body
The Brainstem
The Thalamus

• Area at the top of the brainstem
  – Joined pair of egg-shaped structures

• The brain’s sensory switchboard
  – Directs sensory messages to the cortex
  – Transmits replies from the cortex to the cerebellum and medulla
The Reticular Formation

• Network of nerves running through the brainstem and thalamus
  – *Reticular* = “netlike”

• **Plays important role in controlling arousal/alertness**: if the RF is active, you’re awake; if it’s cut, you’re in a coma

• Acts as a filter for some of the sensory messages from the spinal cord to thalamus
The Cerebellum

Cerebellum

Spinal cord
The Cerebellum

- Means “little brain”
- Integrates sensory input
- **Coordinates voluntary but unconscious movement** (walking, speaking)
- Helps judge time, discriminate sounds and textures, and control emotions
- Helps **process and store unconscious memories** (see lightning, except thunder)
The Limbic System

• Lies in between (the word “limbus” means “border”) the evolutionarily oldest and newest brain areas, and between the cerebral hemispheres (see next slide)

• Associated with basic/primitive emotions and drives and memory formation

• Includes:
  – Amygdala
  – Hypothalamus
  – Hippocampus
The Limbic System

- Hypothalamus
- Pituitary gland
- Amygdala
- Hippocampus
The Amygdala

- Two lima-bean-sized clusters, one in each hemisphere
- **Linked to aggression and fear**
- Removal of rhesus monkeys’ amygdala turned normally aggressive animals very mellow and tame
- **Note:** Aggression and fear involve activity in all levels of the brain, not just the amygdala
More fun with the Amygdala

- Electrical stimulation of a cat’s amygdala can provoke reactions such as this ➔

- Move the electrode very slightly, cage the cat with a mouse, and it cowers in terror
The Hypothalamus

• Lies just below ("hypo") the thalamus
• Directs body maintenance activities (eating, drinking, stable body temperature)
• Helps govern endocrine system (via pituitary gland), linked to emotion
• Stimulation of part of the hypothalamus linked to pleasure
The Hypothalamus

- Olds & Milner (1954): a rat that could press a lever to stimulate its hypothalamus would endure painful shocks to do so.
- Pressed up to 7000 times an hour, until dropped from exhaustion.
The Hippocampus

• Processes conscious episodic memories
• Animals or humans who lose or damage their hippocampus may lose the ability to form new memories of facts and events
• More in Chapter 7
Review of Brain Structures

Corpus callosum: axon fibers connecting the two cerebral hemispheres

Thalamus: relays messages between lower brain centers and cerebral cortex

Hypothalamus: controls maintenance functions such as eating; helps govern endocrine system; linked to emotion and reward

Pituitary: master endocrine gland

Reticular formation: helps control arousal

Medulla: controls heartbeat and breathing

Spinal cord: pathway for neural fibers traveling to and from brain; controls simple reflexes

Cerebellum: coordinates voluntary movement and balance and supports memories of such

Cerebral cortex: ultimate control and information-processing center

Amygdala: linked to emotion

Hippocampus: linked to memory
The Cerebral Cortex

• Thin layer (“cortex” means “bark”) of interconnected neurons covering the cerebral hemispheres

• The body’s ultimate control and information-processing center

• Contains networks of neurons responsible for perception, thinking, speaking, and more
Structure of the Cortex
Each hemisphere is divided into four lobes
The Cortex: Motor Functions

• The **motor cortex**, at the rear of the frontal lobes, controls voluntary movements

• Body areas requiring precise control occupy the most cortical space (see next slide)
Mind Over Matter

Monkeys learned to guide a mechanical hand with a 100-electrode brain implant in the motor cortex
The Cortex: Sensory Functions

• The *sensory cortex*, at the front of the parietal lobes, registers and processes body touch and movement sensations

• The more sensitive body regions have larger devoted sensory cortex areas (see next slide)
Motor and Sensory Cortices

Output: Motor cortex
(Left hemisphere section controls the body’s right side)

Input: Sensory cortex
(Left hemisphere section receives input from the body’s right side)
The Cortex: Location for Other Sensory Functions

- Visual processing occurs in the **visual cortex**, in the occipital lobes.
- Sounds are processed in the **auditory cortex**, in the temporal lobes.
  - Also active during schizophrenic auditory hallucinations.
The Visual Cortex

- fMRI scans show increased activity in the visual cortex when a person looks at a photograph
Association Areas

• Sensory and motor areas occupy ¼ of cortical space

• In the remaining association areas, networks of neurons are busy with higher mental functions, such as learning, remembering, thinking, and speaking

• Found in all four lobes
  – Harder to map than sensory and motor areas
Association Areas

Larger in more complex species
Association Areas: Frontal Lobe

• Enable judgment, planning, and processing of new memories
• Damage may hinder ability to plan for new activities
• Damage can have more serious effects: can alter personality and remove inhibitions
  – Unrestrained moral judgments

http://youtu.be/Li5nMsXg1Lk
Phineas Gage

• 1848: 25-year-old railroad worker
• An accident sends a railroad spike through his skull, damaging frontal lobe
• Was able to speak and work, but changed from friendly and soft-spoken to being irritable, profane, and dishonest (see next slide)
Phineas Gage
Language: Specialization and Integration

• Damage to any one of several areas can impair language, in different ways

• **Broca’s area**: directs muscle movements for speech, controls language expression
  – If damaged, struggle to form words (but can still sing!)

• **Wernicke’s area**: involved in language comprehension and expression, controls language reception
  – If damaged, speak meaningless words, unable to understand others’ words
The Many Steps of Reading Aloud

1. Register words in **visual cortex**
2. Words are related to **angular gyrus**, transforms them into auditory code
3. **Wernicke’s area** receives and processes the code, and sends it to
4. **Broca’s area**, which processes translates the words into motor responses
5. The **motor cortex** signals the muscles to pronounce the words
Language Processing: Reading Aloud

1. Visual cortex
   (receives written words as visual stimulation)

2. Angular gyrus
   (transforms visual representations into an auditory code)

3. Wernicke's area
   (interprets auditory code)

4. Broca's area
   (controls speech muscles via the motor cortex)

5. Motor cortex
   (word is pronounced)
Seeing, hearing, and speaking words
Evidence from PET scans

(b) Hearing words (auditory cortex and Wernicke’s area)
(a) Seeing words (visual cortex and angular gyrus)
(c) Speaking words (Broca’s area and the motor cortex)
The Brain’s Plasticity

• This 6-year-old had a hemispherectomy to end life-threatening seizures

• Her remaining hemisphere compensated by putting other areas to work
The Brain’s Plasticity

• The bad news
  – Severed neurons usually do not repair themselves
  – Some brain functions seem forever linked to specific areas

• The good news
  – The brain’s plasticity allows it to modify itself after some types of damage, especially during childhood
  – The brain is constantly changing, building new pathways as it adjusts to new experiences
How Plasticity Works

- The brain often self-repairs by reorganizing existing tissue
- It sometimes attempts to mend itself by **neurogenesis** (producing new neurons)
  - Baby neurons originate deep in the brain and then migrate elsewhere
Our Divided Brain

• Our left and right hemispheres exhibit important differences
  – Language processing resides mostly in the left hemisphere
  – Damage to left hemisphere seems to have more dramatic effects than to right hemisphere

• Until 1960, researchers thought the right hemisphere was “minor” or “subordinate”
Which Face Looks Happier?

The right hemisphere is more involved in expressing and perceiving emotion
The Divided Brain

- Some split brain patients complain that their left hand seems to have a “mind of its own”
- Can simultaneously draw two different shapes
Right-Left Differences in Intact Brains

• **Left hemisphere**
  – Quick, literal language processing

• **Right hemisphere**
  – High-level language processing
  – Perceptual tasks
    • Copying drawings, recognizing faces, perceiving differences and emotions, expressing emotion
Splitting the Brain

- Researchers cut the **corpus callosum** to control seizures from severe epilepsy
- These **split brain** patients had their seizures disappear, and seemed mostly normal
Splitting the Brain

• Normally, the corpus callosum allows information sharing between the hemispheres
• This does not occur with a split brain
• Researchers could now present information to each hemisphere independently
Testing the Divided Brain

“Look at the dot.”

Two words separated by a dot are momentarily projected.

“What word did you see?” or “Point with your left hand to the word you saw.”
Brain States and Consciousness

• **Cognitive neuroscience** studies the connections between brain activity and mental processes

• **Consciousness** is our awareness of ourselves and our environment
  – Arises not from one area, but from coordinated activity of the whole brain
Selective Attention

• Focusing conscious awareness on a particular stimulus
• Switching attentional gears is costly
  – People talking on cell phones, even hands-free, are slower to detect and respond to traffic signals, signs, and other cars
Inattentional Blindness

• Failure to see visible objects when our attention is directed elsewhere

• People watched a video of men throwing a basketball and asked to press a key when a black-shirted player passed the ball

• Most missed seeing a young woman carrying an umbrella stroll across the screen!
Inattentional Blindness

Only 25% of students talking on a cell phone noticed this unicyclist in their midst
Change Blindness

2/3 of people didn’t notice when the construction worker they were giving directions to was replaced by another worker.
Circadian Rhythm

• We have an internal biological clock
• **Circadian rhythms** are regular body rhythms that occur on a 24-hour cycle

• Involves cycles of body temperature, arousal, and mental acuity
• Changes with age
  – Younger people are more likely to be “night owls”
Sleep Stages

- **Alpha waves**: relatively slow brain waves of a relaxed, awake state
- **Stage 1 sleep**: slowed breathing, irregular brain waves, hallucinations/images
- **Stage 2 sleep**: more fully asleep but still could be awakened; “spindles” of activity in brain waves
- **Stage 3 sleep**: a transition to Stage 4 (omitted in some models)
- **Stage 4 sleep**: Such deep sleep that many kids wet the bed, yet you can waken to baby’s cry
- **REM (rapid eye movement) sleep**: recurring sleep stage during which dreams occur.
Measuring Sleep Activity

- Left eye movements
- Right eye movements
- EMG (muscle tension)
- EEG (brain waves)
A look at brain waves for all of the sleep stages

- **Awake, relaxed**: Alpha waves
- **Falling asleep**: Sleep
- **Stage 1 sleep**: Spindle (burst of activity)
- **Stage 2 sleep**: Delta waves
- **Stage 3 sleep**
- **Stage 4 sleep**
- **REM sleep**: Eye movement phase
Five Sleep Stages

• We cycle through the stages of sleep about every 90 minutes.
• As the night goes on, more time is spent in REM sleep, less in deep sleep.” Final bullet, “At no stage do we typically fall out of bed.
REM Sleep

• Rapid eye movements often related to dreams
• Muscles are relaxed; Brainstem blocks motor cortex activity
• Heart rate increases
• Breathing rapid and irregular
• Snoring stops
• Genital arousal
Our many different sleep patterns

• Newborns sleep about 16 hours per day
• Most adults sleep no more than 8
• Genetics
  – Identical twins have more similar sleep patterns than fraternal twins
• Individual and socio-cultural differences
  – Shift work and social activities keep us up
  – Electric lights trick our brain into lowering melatonin levels as if it’s time to get up
Theories about Sleep’s Functions

• Sleep protected our ancestors from predators and from falling at night
• Sleep physically restores the brain, repairing tissue, mopping up free radicals
• Sleep builds memories and enables creative insight
• Sleep may help growth: Growth hormone is produced during deep sleep (which we get less of as we age)
The Effects of Inadequate Sleep: Getting sick, old, dumb, & fat

- *Sleep loss* suppresses immune system
- Alters metabolism and hormonal function in ways that mimic aging
  - High blood pressure, memory impairment
- Makes us irritable, slow, uncreative, and impairs communication
- Weight gain: Inadequate sleep increases ghrelin (*hunger hormone*), decreases leptin (*“feeling full” hormone*)
Major Sleep Disorders

- **Insomnia**  Worsened by Alcohol and sleep aids, which reduce REM sleep, and require increasing amounts to induce sleep
- **Narcolepsy**  Uncontrollable sleep attacks, sometimes lapsing directly into REM sleep
- **Sleep apnea**  (apnea = “with no breath”)  Waking repeatedly to gasp for oxygen as breathing stops during sleep; sleep is not restful
- **Sleepwalking/talking**  Harmless; genetic basis
- **Night terrors**  NOT nightmares: tense, agitated, wide-eyed sleep, not recalled in morning
**TABLE 2.2 Looking for a Better Night’s Sleep?**

- Exercise regularly, but not in the late evening. (Late afternoon is best.)
- Avoid caffeine, especially in the afternoon or later, and avoid food and drink near bedtime. The exception would be a glass of milk, which provides raw materials for the manufacture of serotonin, a neurotransmitter that promotes sleep.
- Relax before bedtime, using dimmer light.
- Sleep on a regular schedule (rise at the same time even after a restless night) and avoid naps.
- Reassure yourself that a temporary loss of sleep causes no great harm.
- If all else fails, settle for less sleep, either going to bed later or getting up earlier.
Dreams

• The link between REM sleep and dreams opened up new research possibilities
• Researchers can awaken people during or within 3 minutes of REM sleep for a vivid account of dreams

• Dream: a sequence of images, emotions, and thoughts passing through a sleeping person’s mind.
What We Dream

The information below is from waking people after a few minutes of REM sleep; normally we don’t recall most of our dreams.

• 8 in 10 dreams are bad dreams

• Few dreams are sexual
  – 1 in 10 for young men
  – 1 in 30 for young women

• Sensory stimuli from our sleeping environment may be integrated into a dream story
What We Dream

• Cultural Influences
  – People in hunter-gatherer tribes often dream of animals
  – Urban Japanese rarely do
Why We Dream

- **Manifest content**: Freud’s term for the remembered story line of a dream
- **Latent content**: Freud’s term for the underlying meaning of a dream

- **Freud’s wish-fulfillment theory**: dreams act to discharge feelings that cannot be expressed in public
  - Little scientific validation
  - Dreams can have many interpretations
Why We Dream

• **Information-processing**: dreams may help sift, sort, and fix the day’s events in memory
  – Research shows REM sleep is important for memory consolidation

• **Physiological function**: dreams allow for useful neural pathways to develop

• **Activation-synthesis theory**: Dreams are our brain trying to make sense of random neural activity
Why We Dream

• **Cognitive-development perspective:** Dreams reflect brain maturation and cognitive development
  – Dreams draw on current knowledge and concepts we understand

• **REM rebound:** REM sleep increases following REM sleep deprivation