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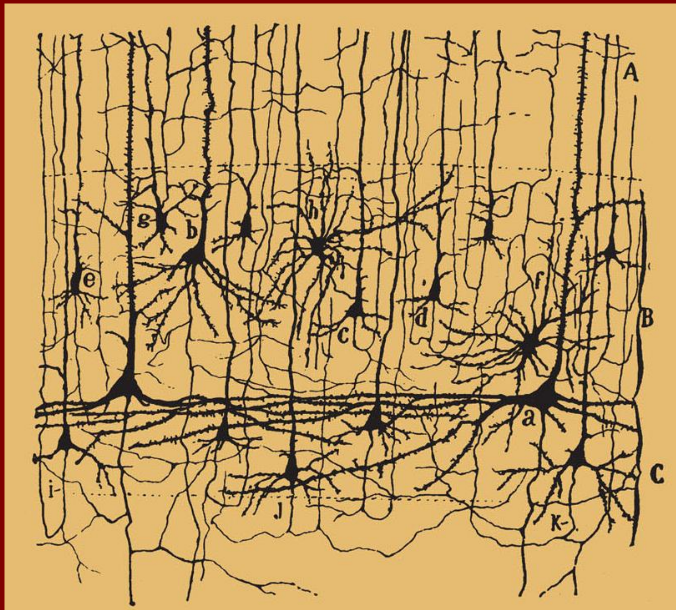
Introduction



- Welcome to Our World
- Thresholds and the Dawn of Psychophysics
- Sensory Neuroscience and the Biology of Perception

Introduction

- What do we mean by "Sensation & Perception?"
  - Sensation: The ability to detect a stimulus and, perhaps, to turn that detection into a private experience.
  - Perception: The act of giving meaning to a detected sensation.
- Sensation and perception are central to mental life.
  - Without them, how would we gain knowledge of the world?

Introduction

Psychologists typically study sensation and perception.

- Also studied by biologists, computer scientists, medical doctors, neuroscientists, and many other fields

Introduction

The study of sensation and perception is a scientific pursuit and requires scientific methods.

- Thresholds: Finding the limits of what can be perceived.
- Scaling: Measuring private experience.
- Signal detection theory: Measuring difficult decisions.
- Sensory neuroscience: The biology of sensation and perception.
- Neuroimaging: An image of the mind.

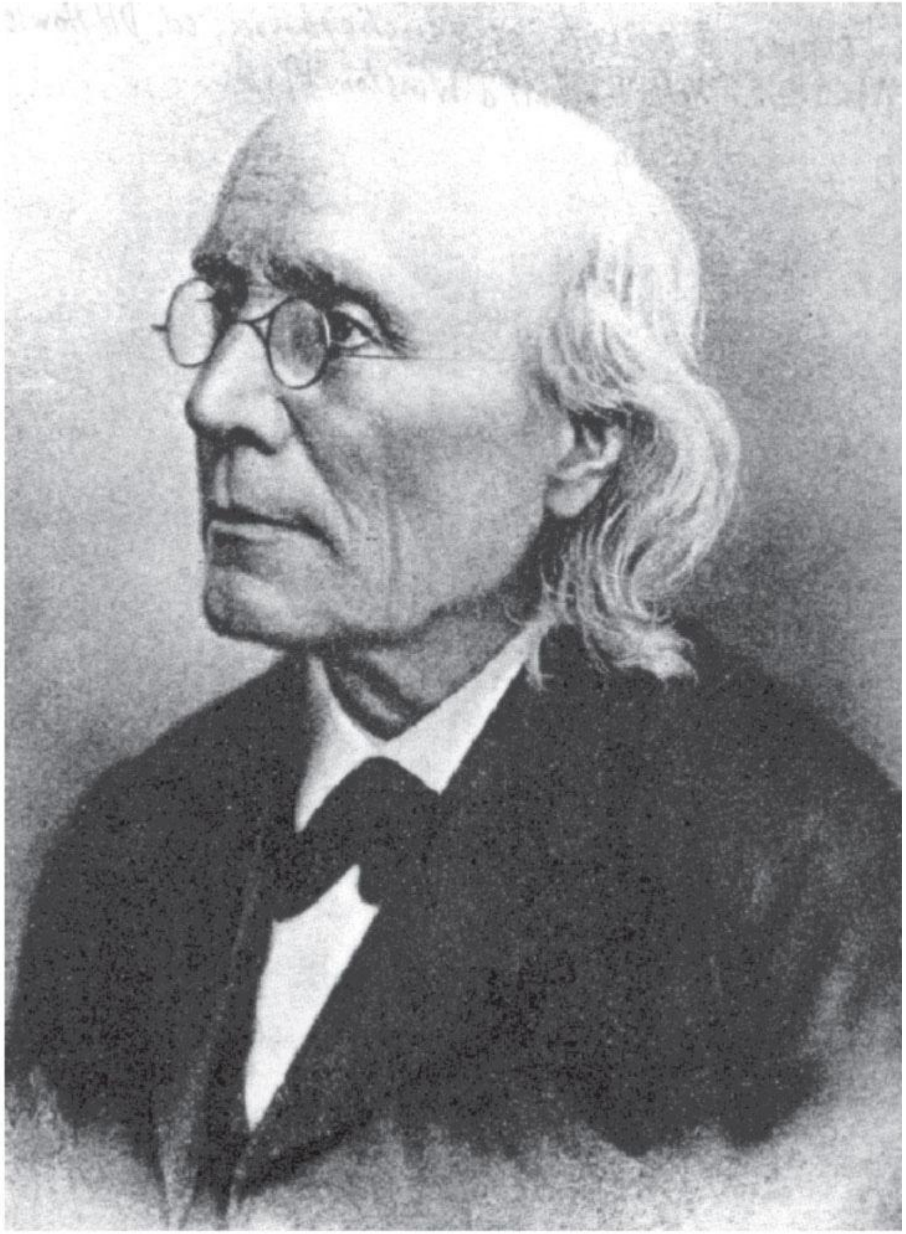
Thresholds and the Dawn of Psychophysics

Gustav Fechner (1801–1887) invented “psychophysics” and is often considered to be the true founder of experimental psychology.

Fechner was an ambitious and hard-working young man who worked himself to the point of exhaustion.

- Damaged his eyes by staring at the sun while performing vision experiments

Figure 1.3 Gustav Fechner invented psychophysics and is thought by some to be the true founder of experimental psychology



***SENSATION & PERCEPTION* 4e, Figure 1.3**

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Thresholds and the Dawn of Psychophysics

Fechner thought about the philosophical relationship between mind and matter.

- Dualism: The mind has an existence separate from the material world of the body.
- Materialism: The only thing that exists is matter, and that all things, including mind and consciousness, are the results of interactions between bits of matter.
- Panpsychism: The mind exists as a property of all matter—all matter has consciousness.

Thresholds and the Dawn of Psychophysics

Fechner attempted to describe the relationship between the mind and body using the language of mathematics.

- Psychophysics: The science of defining quantitative relationships between physical and psychological (subjective) events.

Thresholds and the Dawn of Psychophysics

Psychophysics adopted several new concepts for understanding sensation and perception.

- Two-point threshold: The minimum distance at which two stimuli (e.g., two simultaneous touches) can be distinguished.

Thresholds and the Dawn of Psychophysics

- Just noticeable difference (JND): The smallest detectable difference between two stimuli, or the minimum change in a stimulus that can be correctly judged as different from a reference stimulus; also known as difference threshold.
- Absolute threshold: Minimum amount of stimulation necessary for a person to detect a stimulus 50% of the time.

Thresholds and the Dawn of Psychophysics

Ernst Weber discovered that the smallest change in a stimulus that can be detected is a constant proportion of the stimulus level.

- Weber’s law: The principle describing the relationship between stimulus and resulting sensation that says the JND is a constant fraction of the comparison stimulus.
    - Thus, larger stimulus values have larger JNDs and smaller stimulus values have smaller JNDs.

Figure 1.4 Ernst Weber discovered that the smallest detectable change in a stimulus is a constant proportion of the stimulus level

SENSATION & PERCEPTION 4e, **Figure 1.4**

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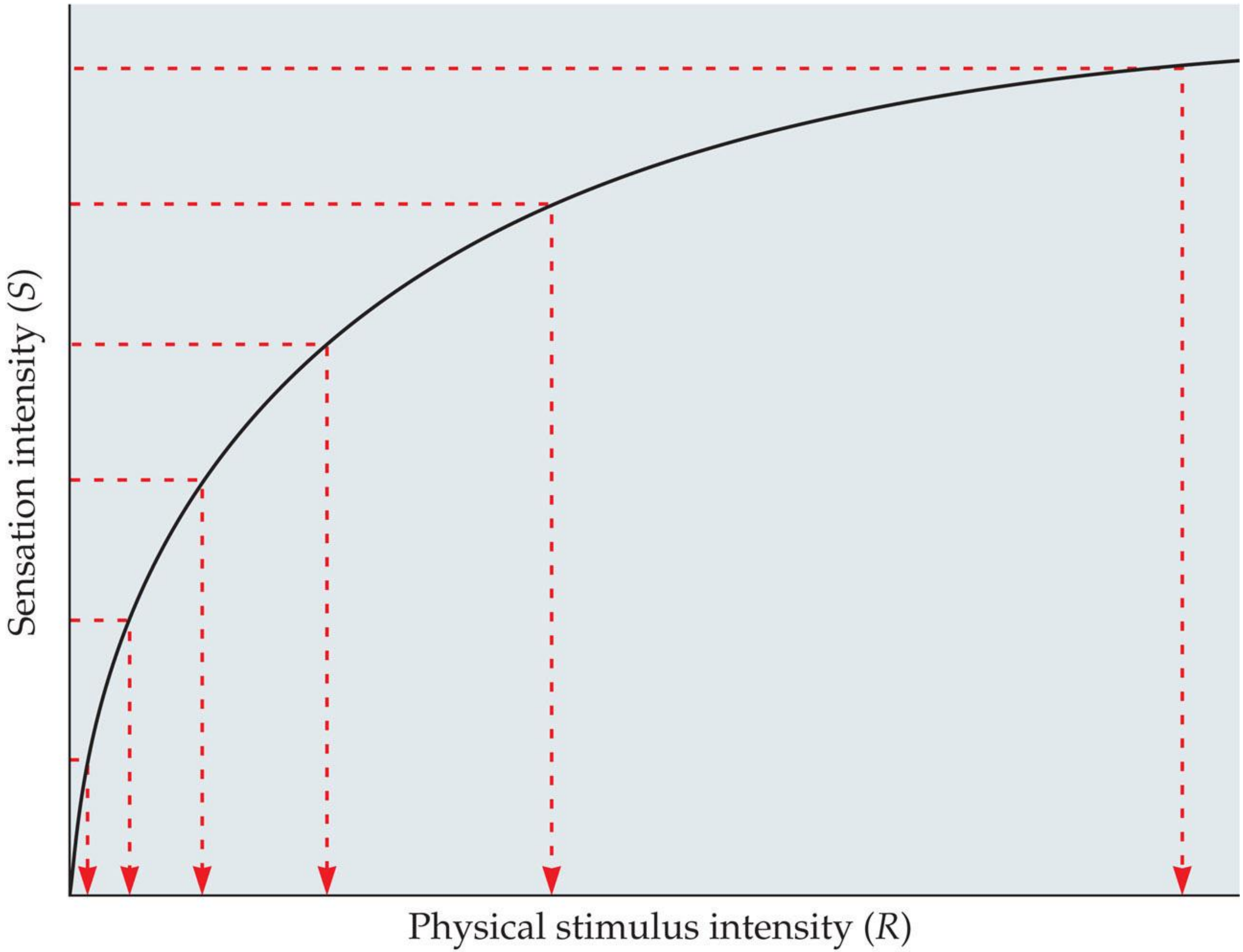
Thresholds and the Dawn of Psychophysics

Fechner mathematically extended Weber's law to make it more universal.

- Fechner's law: A principle describing the relationship between stimulus magnitude and resulting sensation magnitude such that the magnitude of subjective sensation increases proportionally to the logarithm of the stimulus intensity.

Figure 1.5 Fechner's law: as stimulus intensity grows larger, larger changes are required for the changes to be detected by a perceiver



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Psychophysical methods

- Method of constant stimuli: Many stimuli, ranging from rarely to almost always perceivable, are presented one at a time.
- Method of limits: The magnitude of a single stimulus or the difference between two stimuli is varied incrementally until the participant responds differently.

Psychophysical methods (*continued*)

- Method of adjustment: Similar to the method of limits, but the participant controls the stimulus directly.
- Magnitude estimation: The participant assigns values according to perceived magnitudes of the stimuli.

Figure 1.6 The method of constant stimuli (Part 1)

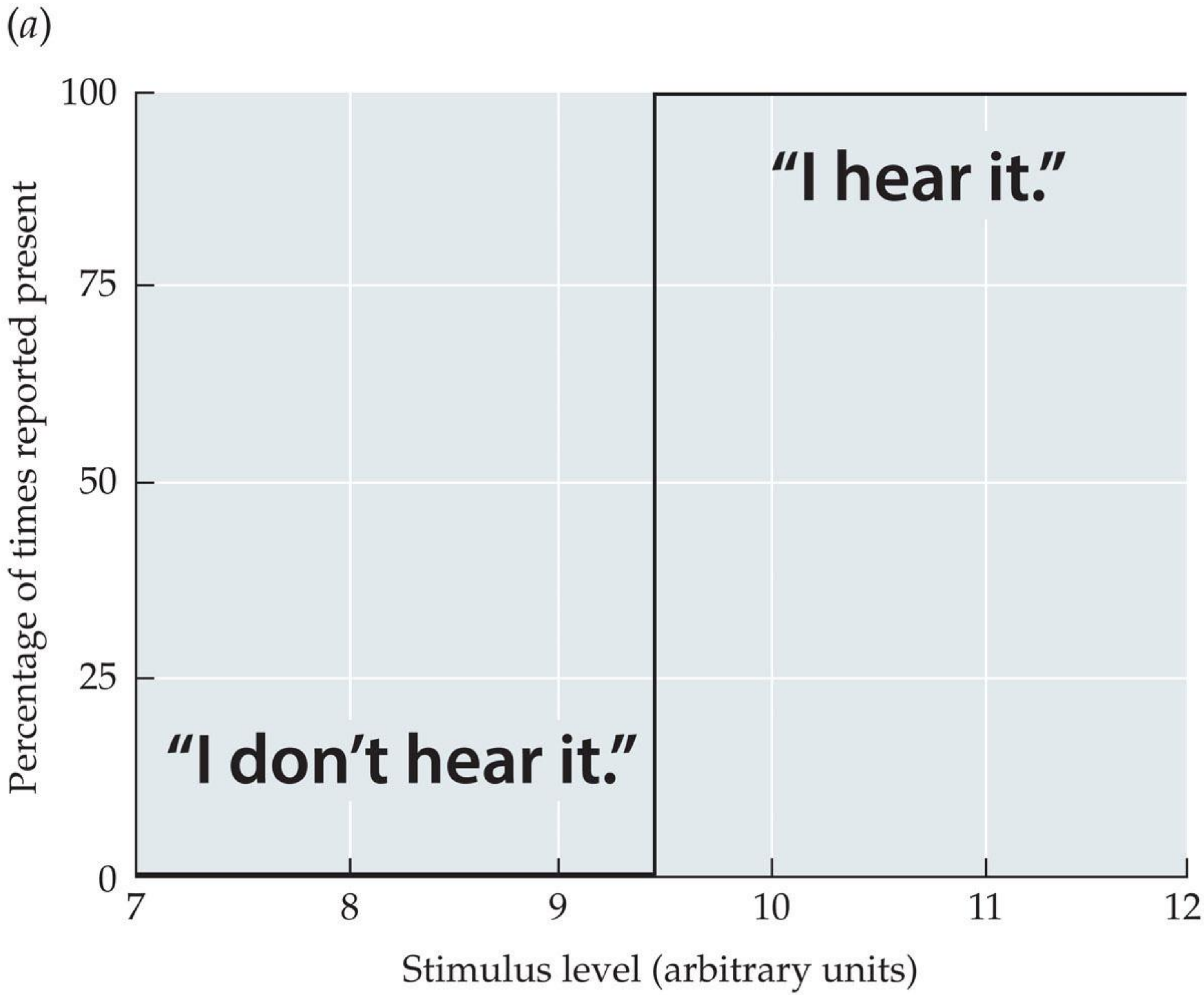

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Figure 1.6 The method of constant stimuli (Part 2)

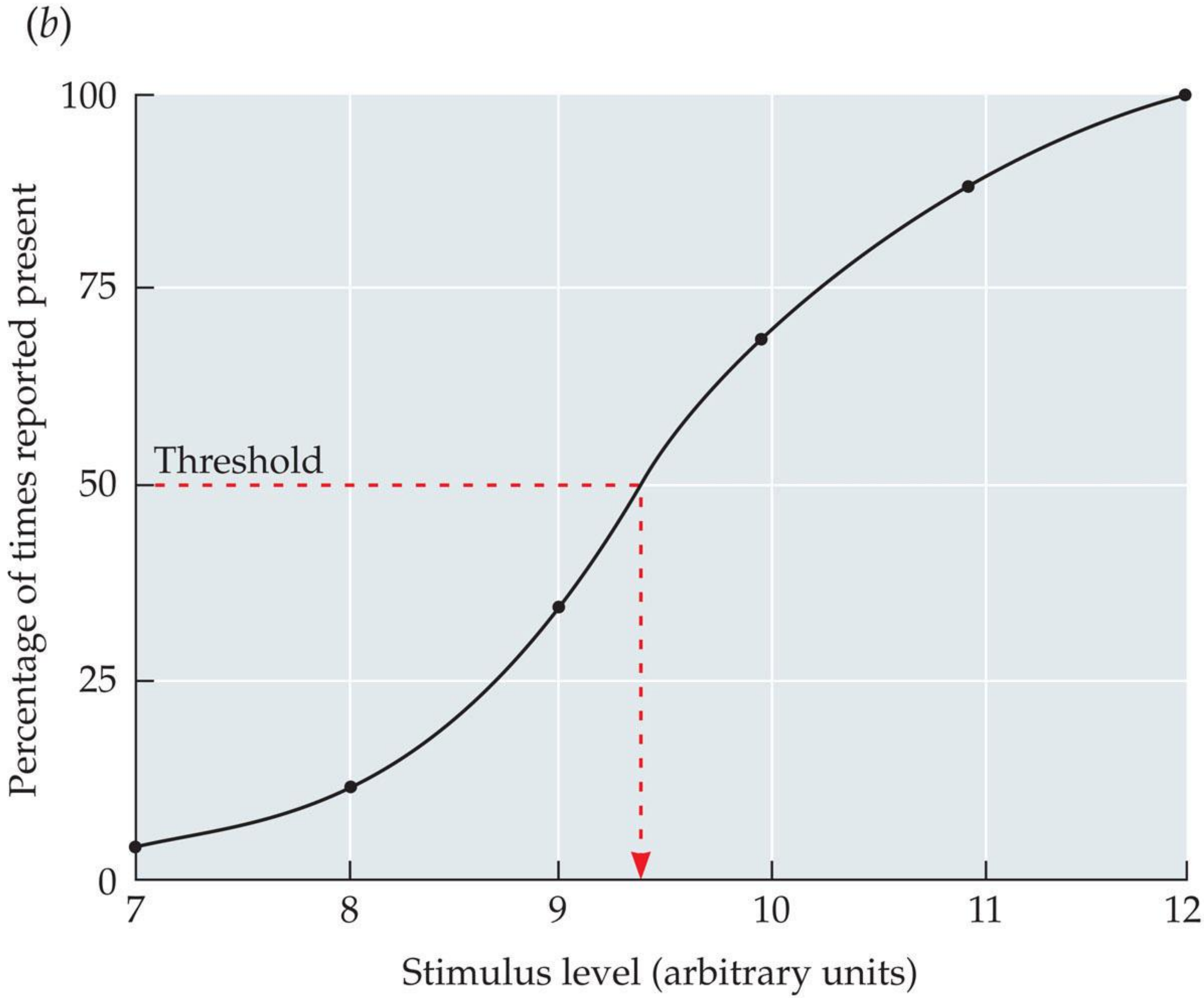

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Figure 1.7 The method of limits

Trial series

Intensity (arbitrary units)	↓1	↑2	↓3	↑4	↓5	↑6	↓7	↑8
20	Y						Y	
19	Y		Y		Y		Y	
18	Y		Y		Y		Y	
17	Y		Y		Y		Y	
16	Y		Y		Y		Y	Y
15	Y	Y	Y	Y	Y	Y	Y	Y
14	Y	N	Y	N	Y	N	Y	Y
13	N	N	Y	N	Y	N	N	Y
12		N	N	N	N	N		N
11		N		N		N		N
10		N		N		N		N
	13.5	14.5	12.5	14.5	12.5	14.5	13.5	12.5

Crossover values (average = 13.5)

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Thresholds and the Dawn of Psychophysics

Magnitude estimates are well described by Stevens' power law.

- $S = aI^b$
  - Perceived Intensity (S) is related to stimulus intensity (I) by an exponent (b) multiplied by a constant (a).

Same formula, different notation

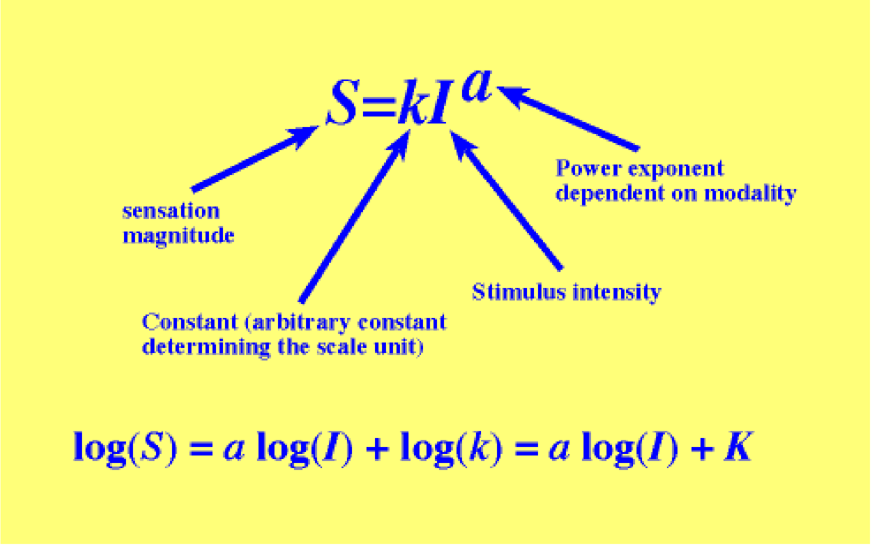
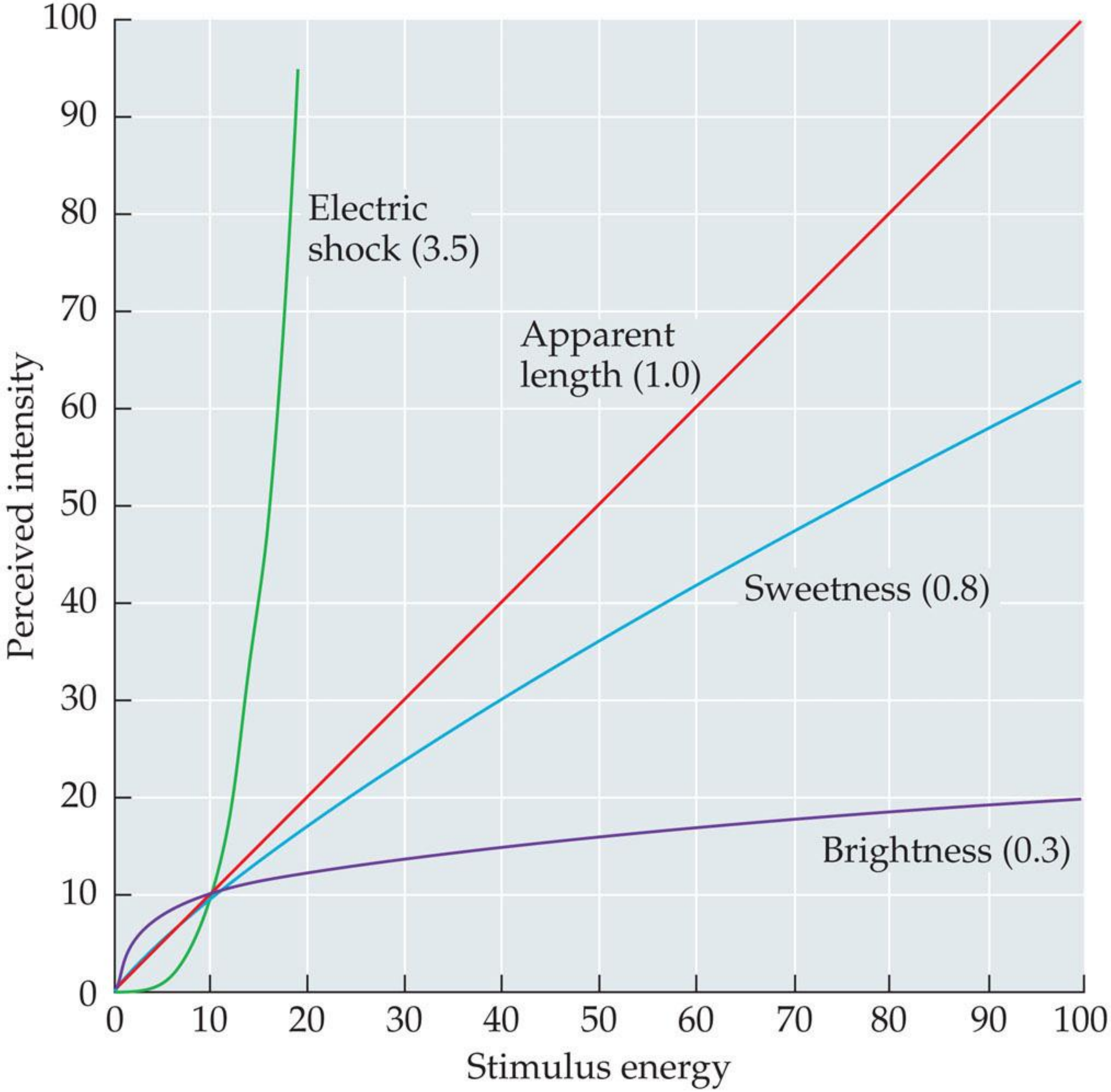


Figure 1.8 Magnitude estimation



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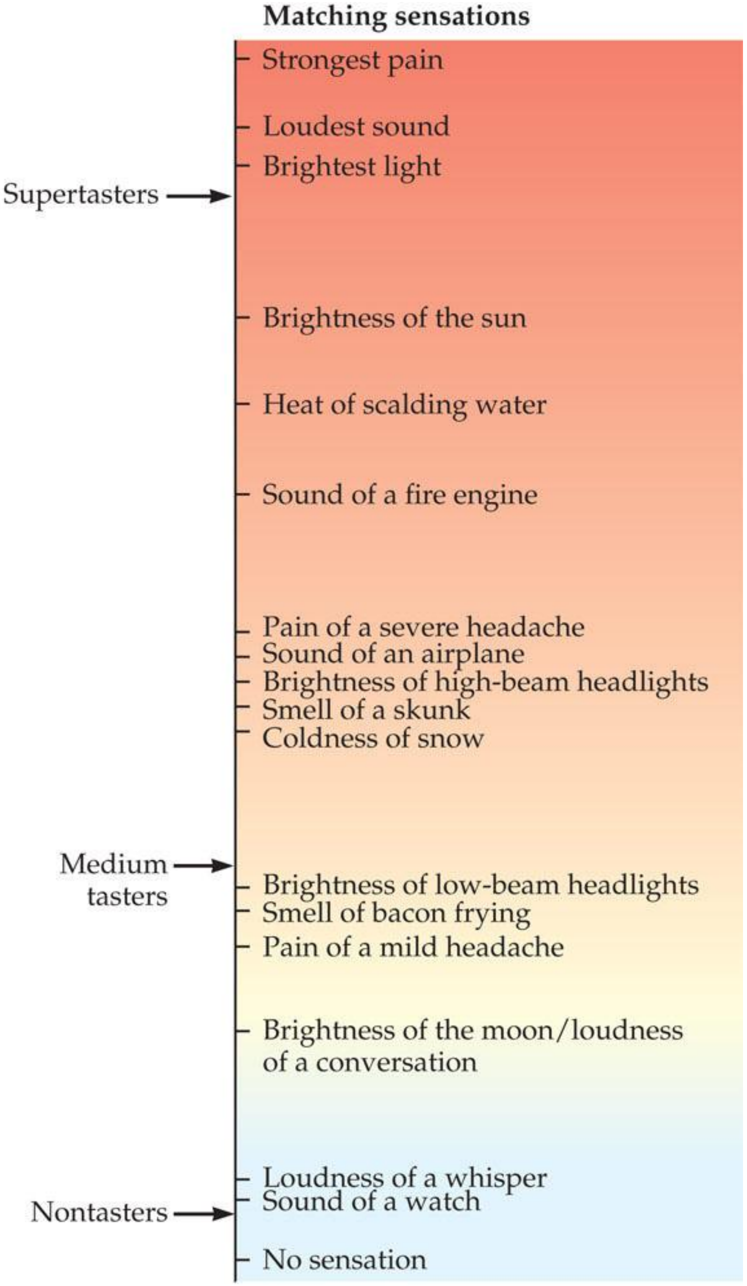
Cross-modality matching: The participant matches the intensity of a sensation in one sensory modality with the intensity of a sensation in another.

- Useful method for allowing people to classify how dull or intense a flavor is
  - Supertaster: An individual whose perception of taste sensations is the most intense.

Figure 1.9 Cross-modality matching



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Signal detection theory: A psychophysical theory that quantifies the response of an observer to the presentation of a signal in the presence of noise.

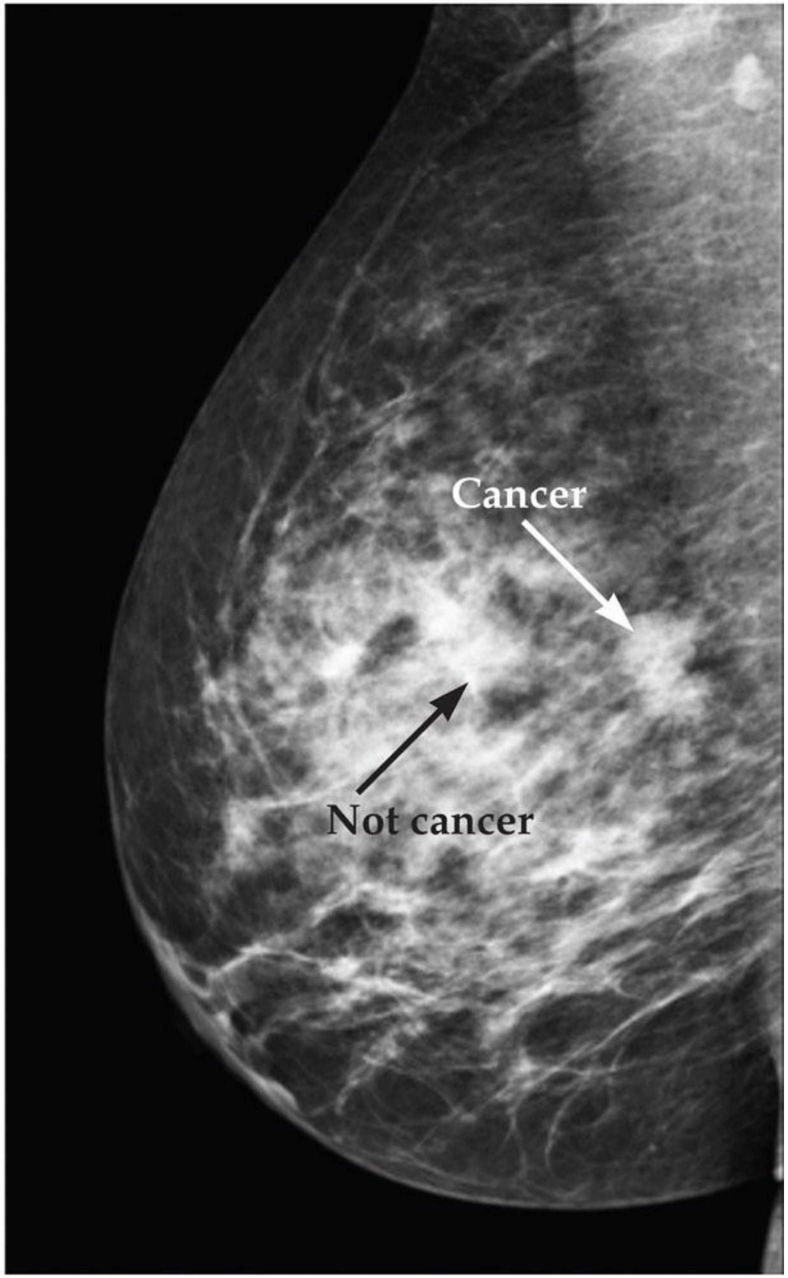
Four possible stimulus/response situations in signal detection theory:

- Hit: Stimulus is present and observer responds “Yes.”
- Miss: Stimulus is present and observer responds “No.”
- False alarm: Stimulus is not present and observer responds “Yes.”
- Correct rejection: Stimulus is not present and observer responds “No.”

Thresholds and the Dawn of Psychophysics

Many real-world problems can be conceptualized as a search for a signal amidst noise.

FIGURE 1.10 Mammograms, X-rays of the breast, are used to screen women for breast cancer



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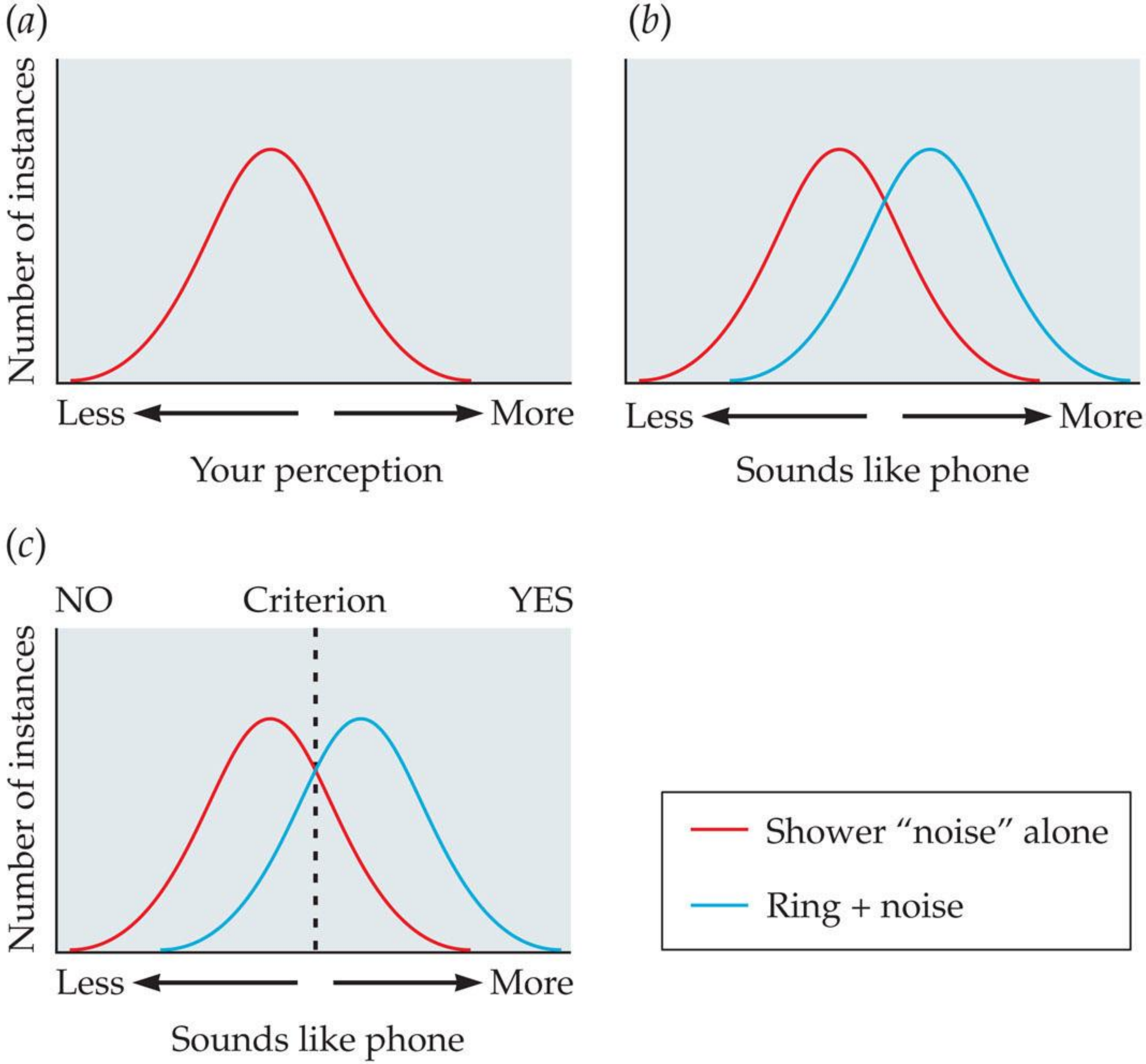
Signal detection theory makes a distinction between an observers' ability to perceive a signal and their willingness to report it. These are two separate concepts:

- Sensitivity
- Criterion

Thresholds and the Dawn of Psychophysics

- Sensitivity: A value that defines the ease with which an observer can tell the difference between the presence and absence of a stimulus or the difference between stimulus 1 and stimulus 2.
- Criterion: An internal threshold that is set by the observer.
  - If the internal response is above criterion, the observer gives one response.
  - Below criterion, the observer gives another response.

Figure 1.11 Detecting a stimulus using signal detection theory (SDT) (Part 1)



SENSATION & PERCEPTION 4e, **Figure 1.11 (Part 1)**

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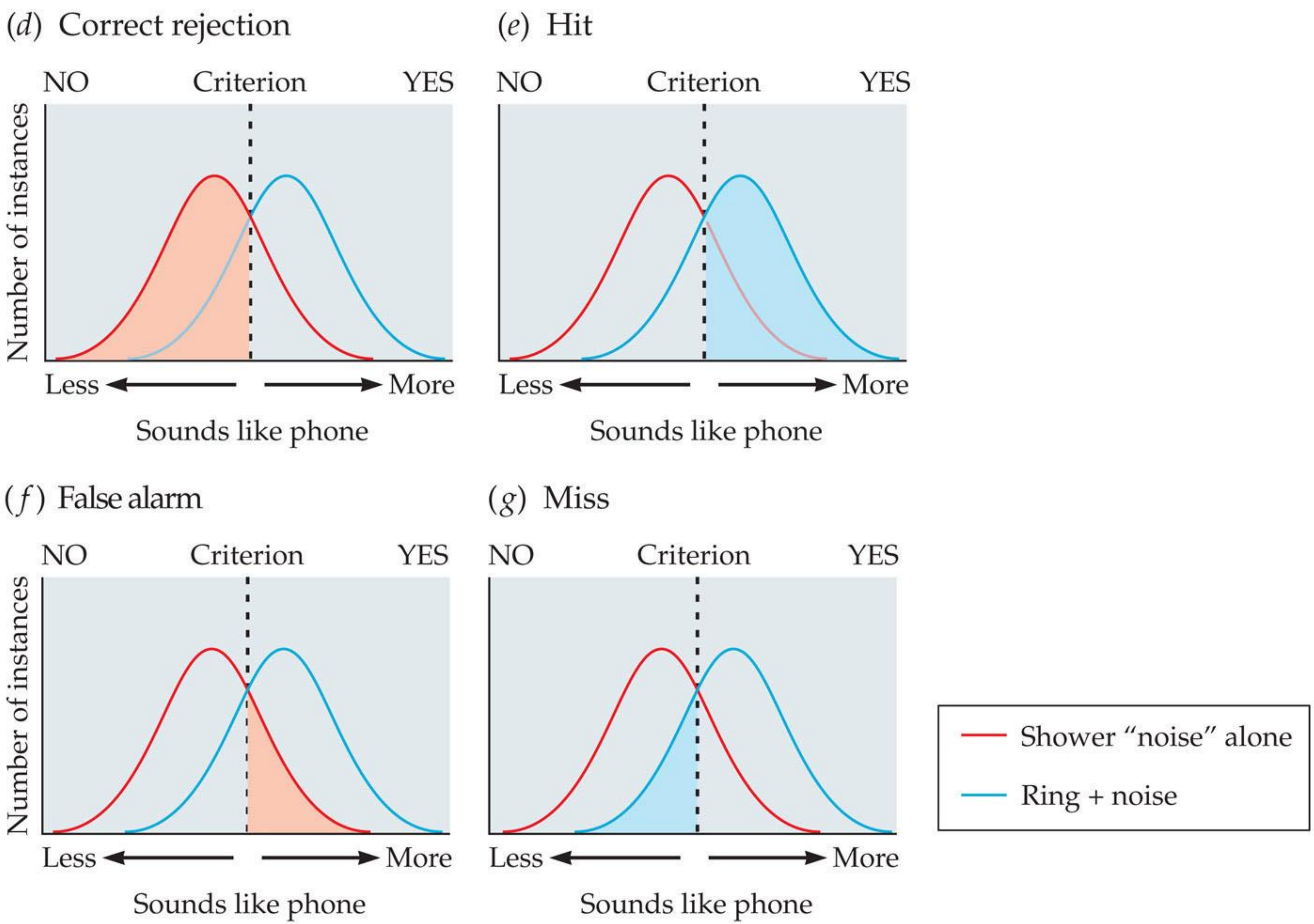
Figure 1.11 Detecting a stimulus using signal detection theory (SDT) (Part 2)



SENSATION & PERCEPTION 4e, Figure 1.11 (Part 2)

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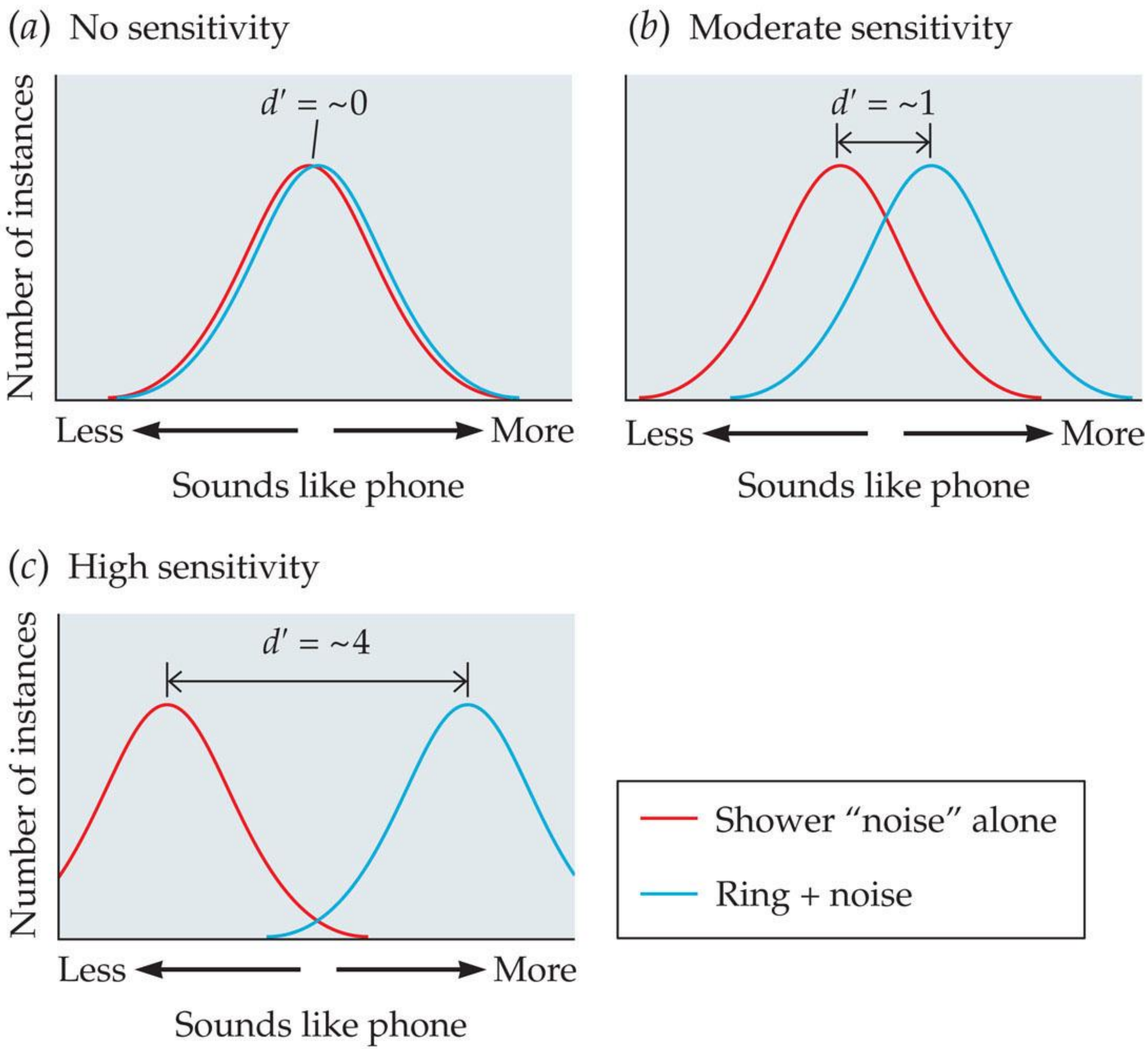
Figure 1.12 Your sensitivity to a stimulus is illustrated by the separation between the distributions of your response to noise alone and to signal plus noise



SENSATION & PERCEPTION 4e, Figure 1.12

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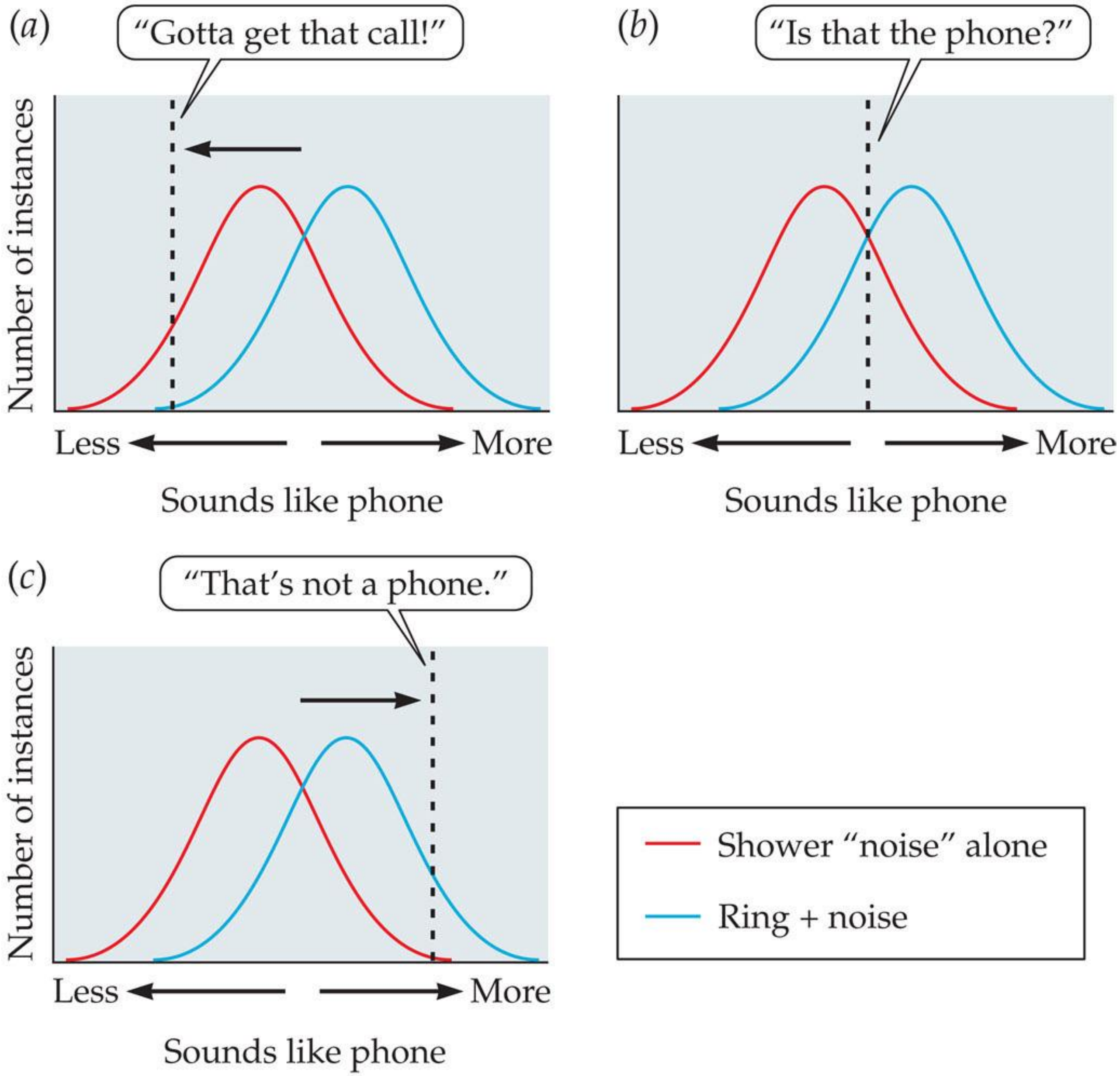
Figure 1.13 For a fixed *d′*, all you can do is change the pattern of your errors by shifting the response criterion



SENSATION & PERCEPTION 4e, Figure 1.13
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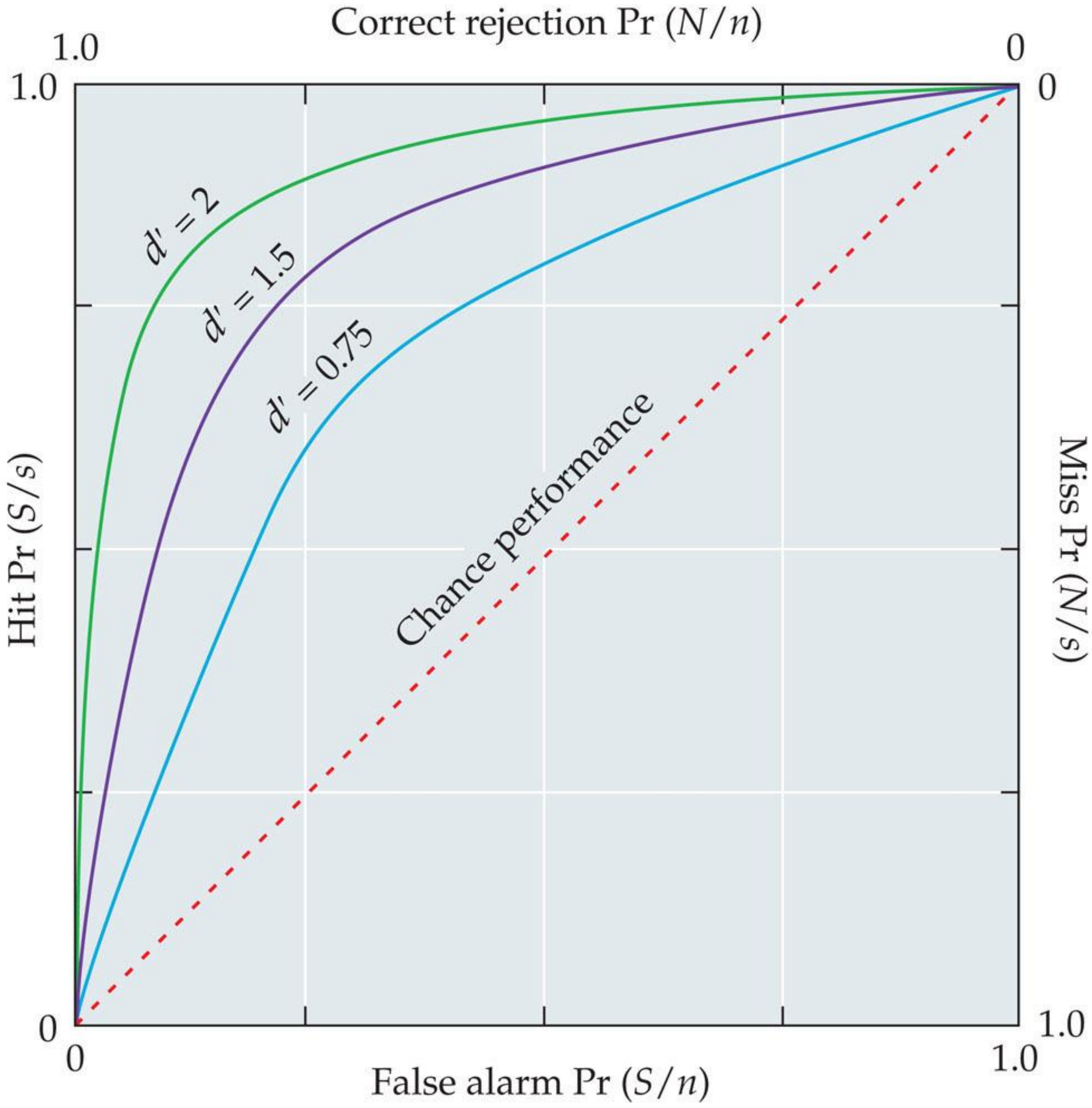
Receiver operating characteristic (ROC): In studies of signal detection, the graphical plot of the hit rate as a function of the false alarm rate.

- Chance performance will fall along the diagonal.
- Good performance (high sensitivity) “bows out” towards the upper left corner.

Plotting the ROC curve allows one to predict the proportion of hits for a given proportion of false alarms, and vice-versa.

- Changes in criteria move performance along a curve but do not change the shape of the curve.

Figure 1.14 Theoretical receiver operating characteristic (ROC) curves for different values of *d′*



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Joseph Fourier (1768–1830) developed another useful tool for analyzing signals.

- Fourier analysis: A mathematical procedure by which any signal can be separated into component sine waves at different frequencies; combining these component sine waves will reproduce the original signal.

Thresholds and the Dawn of Psychophysics

- Sine wave
  - In hearing, a waveform for which variation as a function of time is a sine function; also called a “pure tone”
  - In vision, a pattern for which variation in a property, like brightness or color as a function of space, is a sine function

Why sine waves?

- Many stimuli can be broken down into a series of sine wave components using Fourier analysis.
  - Any sound, including music and speech
  - Any complex image, including photographs, movies, objects, and scenes
  - Any movement, including head and limb movements

Why sine waves? (*continued*)

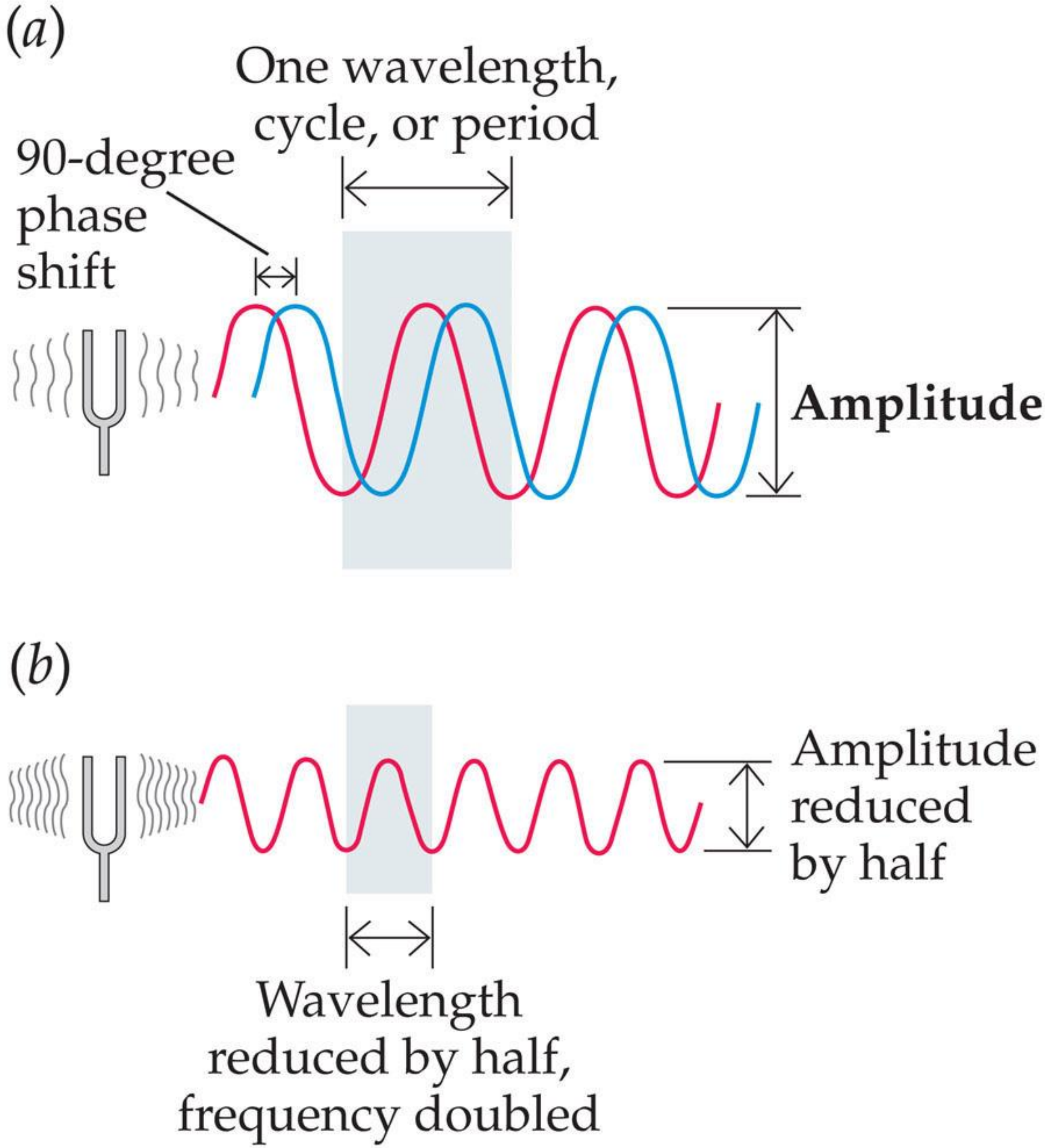
- Also, our brains seem to analyze stimuli in terms of their sine wave components!
  - Vision
  - Audition

Properties of sine waves

- Period or wavelength: The time or space required for one cycle of a repeating waveform.
- Phase:
  - In vision, the relative position of a grating
  - In hearing, the relative timing of a sine wave
- Amplitude: The height of a sine wave, from peak to trough, indicating the amount of energy in the signal.

Sounds can be described as changes in pressure over time.

Tuning forks produce pure tones, which change pressure over time according to the sine function.



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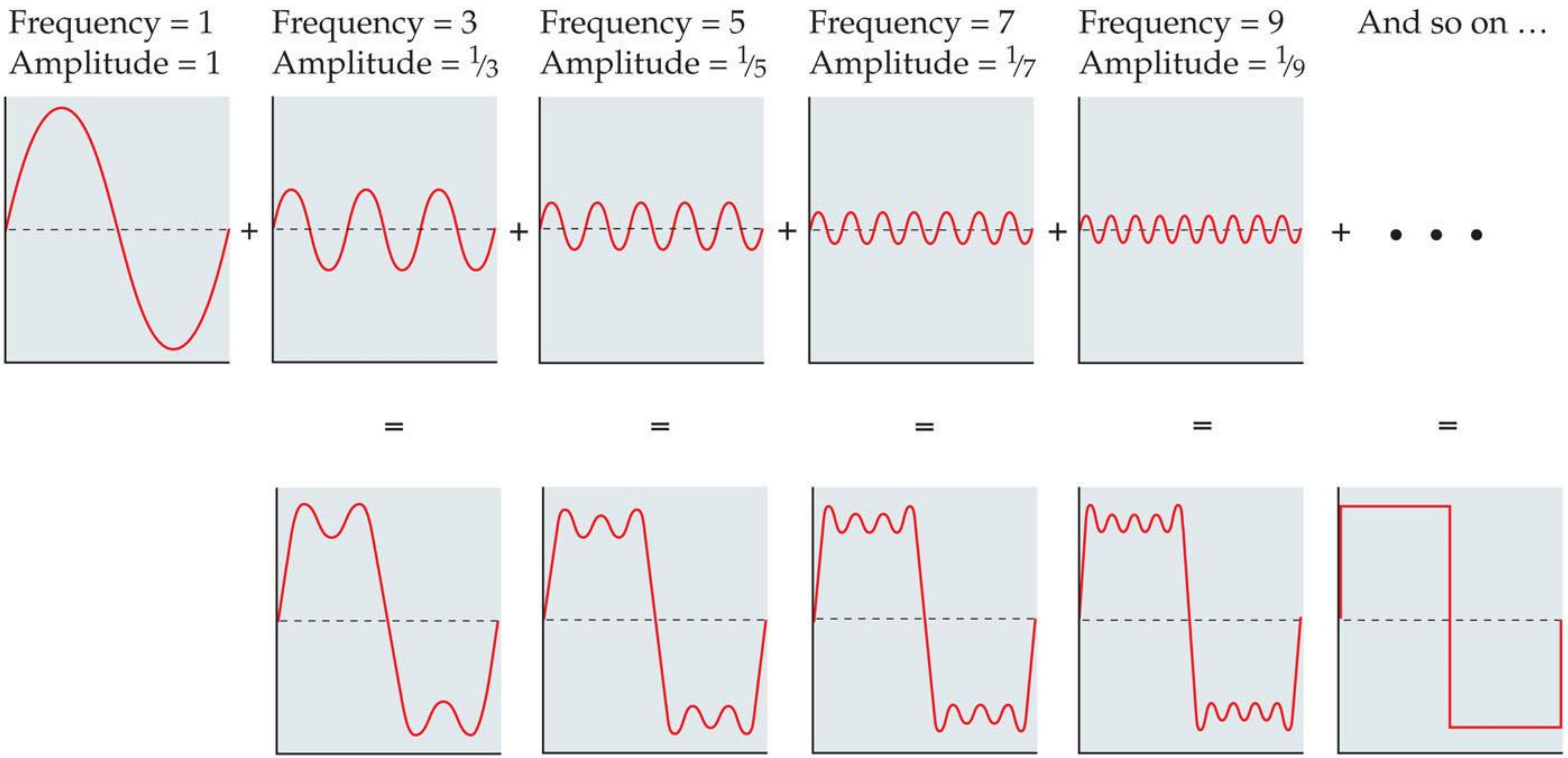
Thresholds and the Dawn of Psychophysics

Even something as complicated and artificial as a square wave can be reproduced by adding the correct sine waves together.

Figure 1.17 Every complex sound wave can be analyzed as a combination of sine waves, each with its own frequency, amplitude, and phase



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http://www.businessinsider.com/7-gifs-trigonometry-sine-cosine-2013-5

https://commons.wikimedia.org/wiki/File:Fourier_series_square_wave_circles_animation.gif

Thresholds and the Dawn of Psychophysics

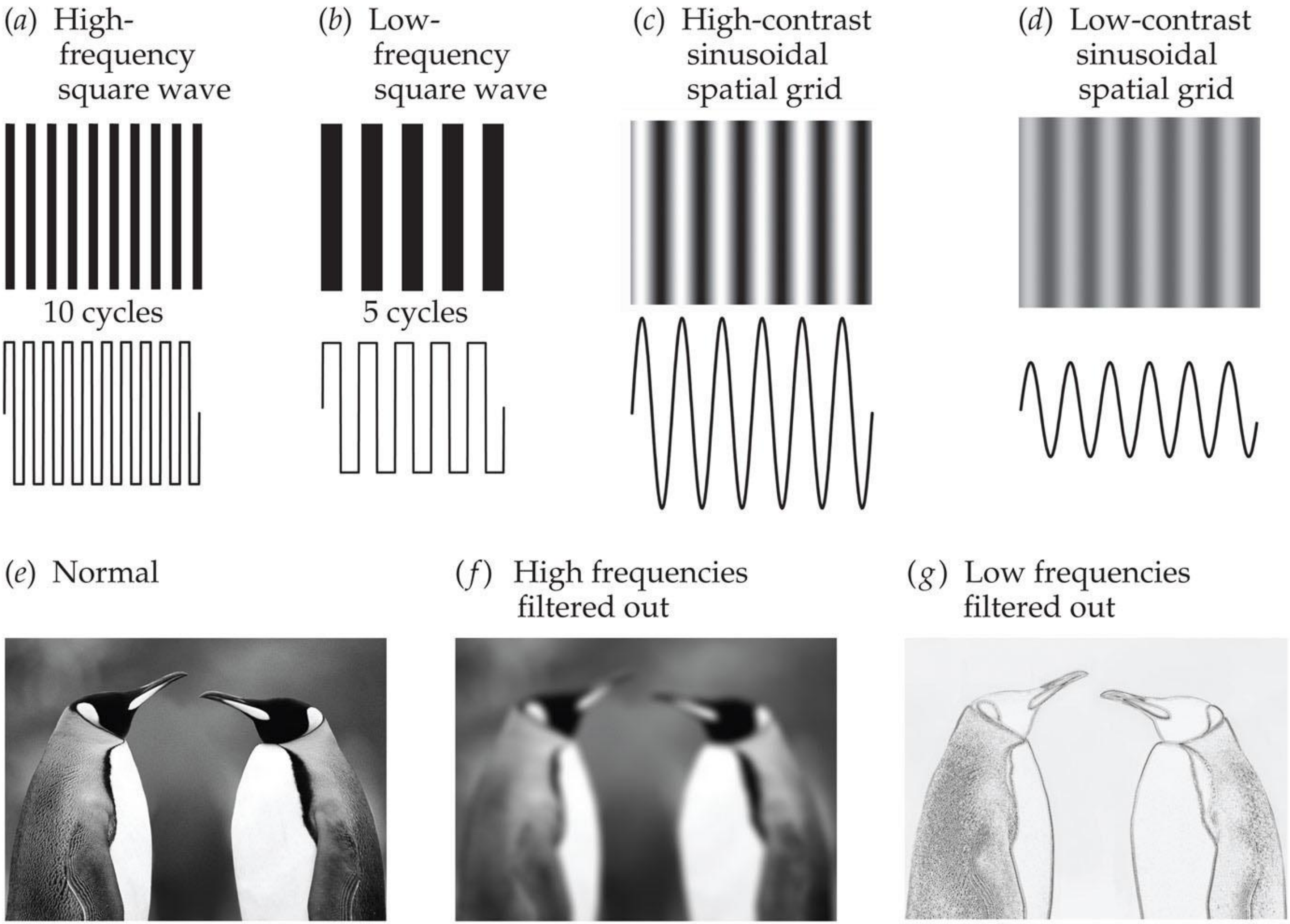
Images can be described as changes in light and dark across space. In the case of sine waves, these would look like bars of light and dark—gratings.

Thresholds and the Dawn of Psychophysics

Imagining a 360° circle around your head, your visual field is about 170° wide. Your thumbnail at arms' length is about 1°. This is called "visual angle."

- Spatial frequency: The number of cycles of a grating per degree of visual angle.
- Cycles per degree: The number of pairs of dark and bright bars per degree of visual angle.

Figure 1.18 Spatial frequency



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Doctrine of specific nerve energies: A doctrine formulated by Johannes Müller (1801–1858) stating that the nature of a sensation depends on which sensory fibers are stimulated, not on how the fibers are stimulated.

Figure 1.19 Johannes Müller formulated the doctrine of specific nerve energies

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Cranial nerves: Twelve pairs of nerves (one for each side of the body) that originate in the brain stem and reach sense organs and muscles through openings in the skull.

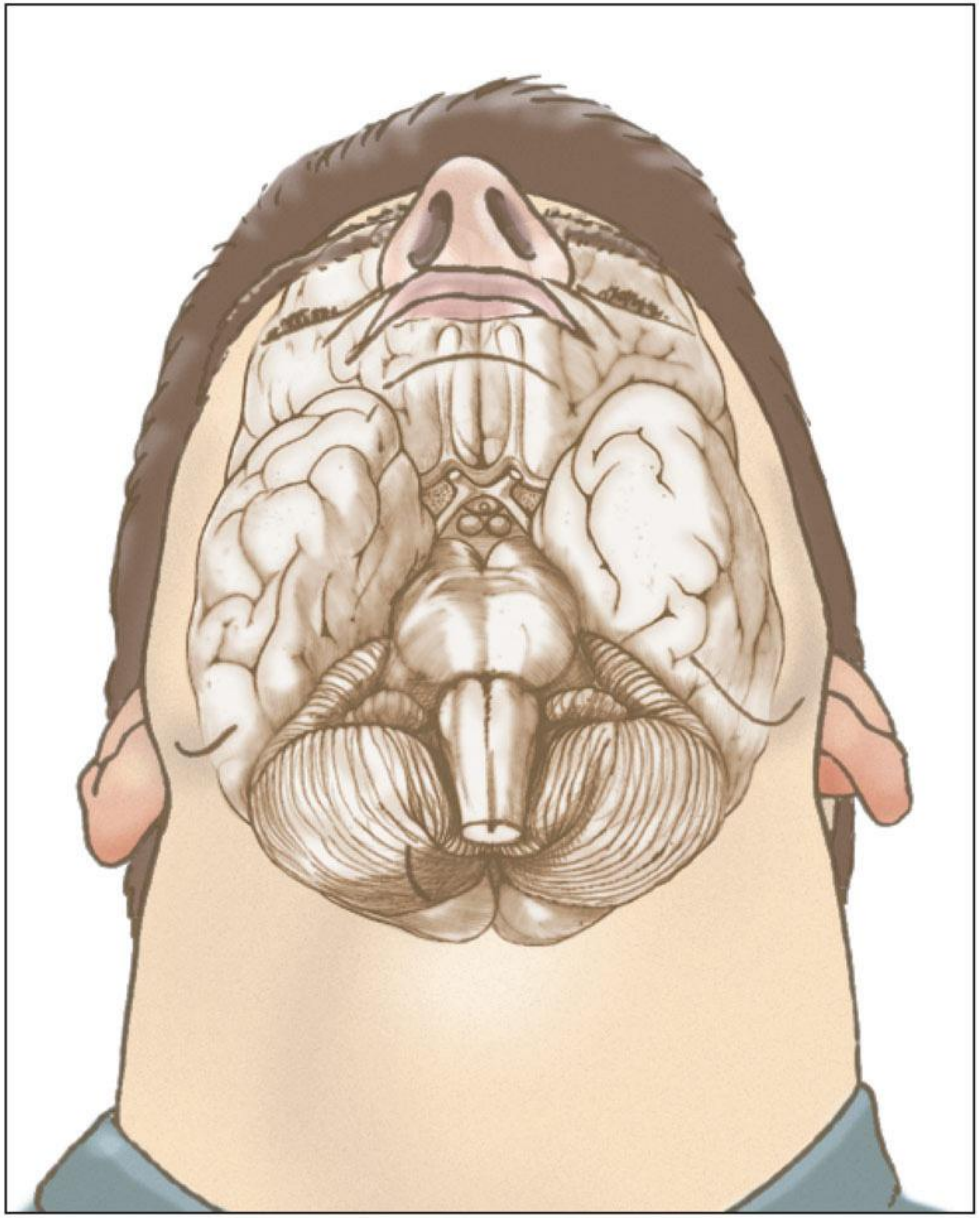
Sensory information

- Olfactory (I) nerves
- Optic (II) nerves
- Auditory (VIII) nerves

Muscles that move the eyes

- Oculomotor (III)
- Trochlear (IV) nerves
- Abducens (VI) nerves

Figure 1.20 Twelve pairs of cranial nerves pass through small openings in the bone at the base of the skull (Part 1)



SENSATION & PERCEPTION 4e, **Figure 1.20 (Part 1)**

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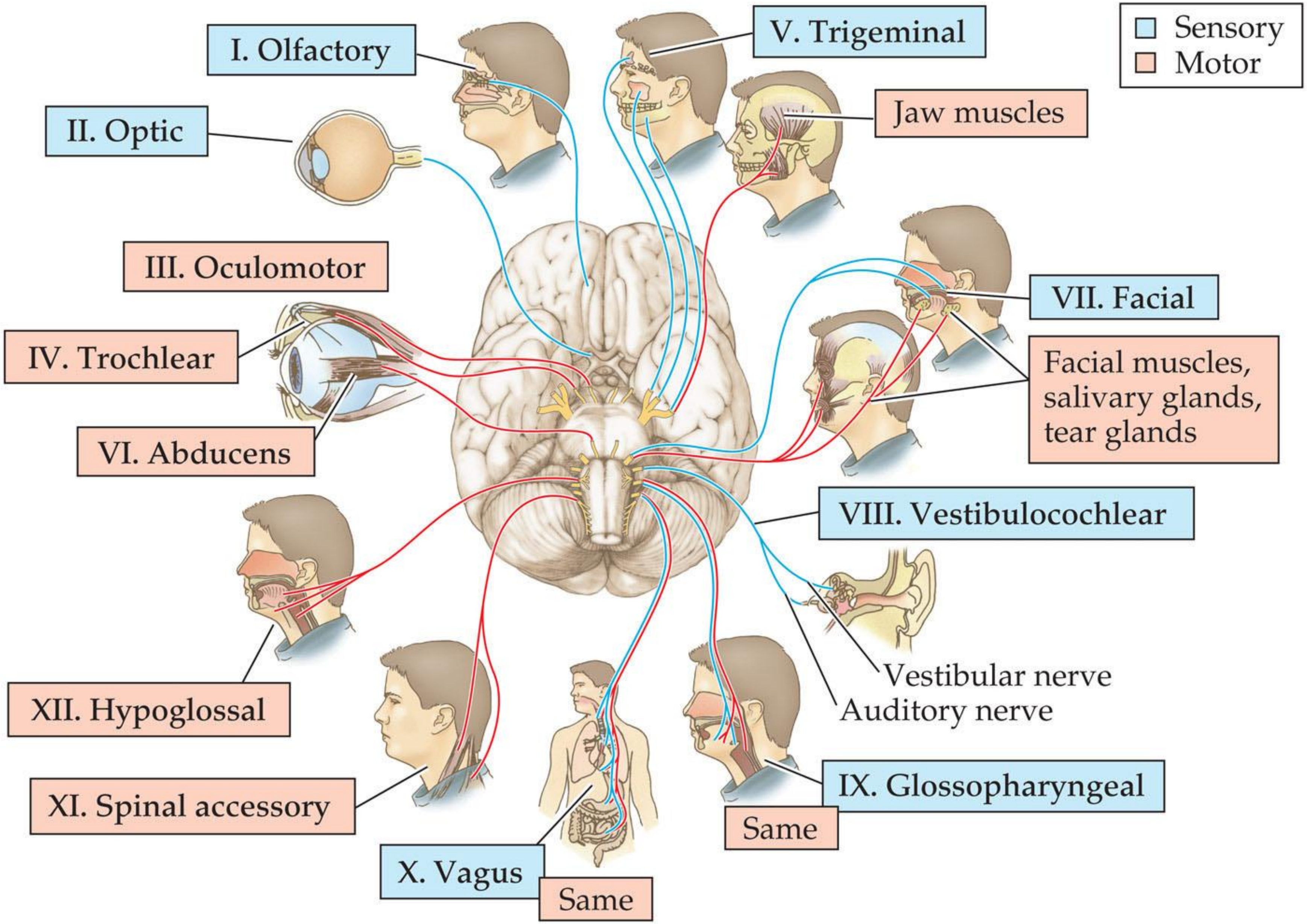
Figure 1.20 Twelve pairs of cranial nerves pass through small openings in the bone at the base of the skull (Part 2)



SENSATION & PERCEPTION 4e, Figure 1.20 (Part 2)

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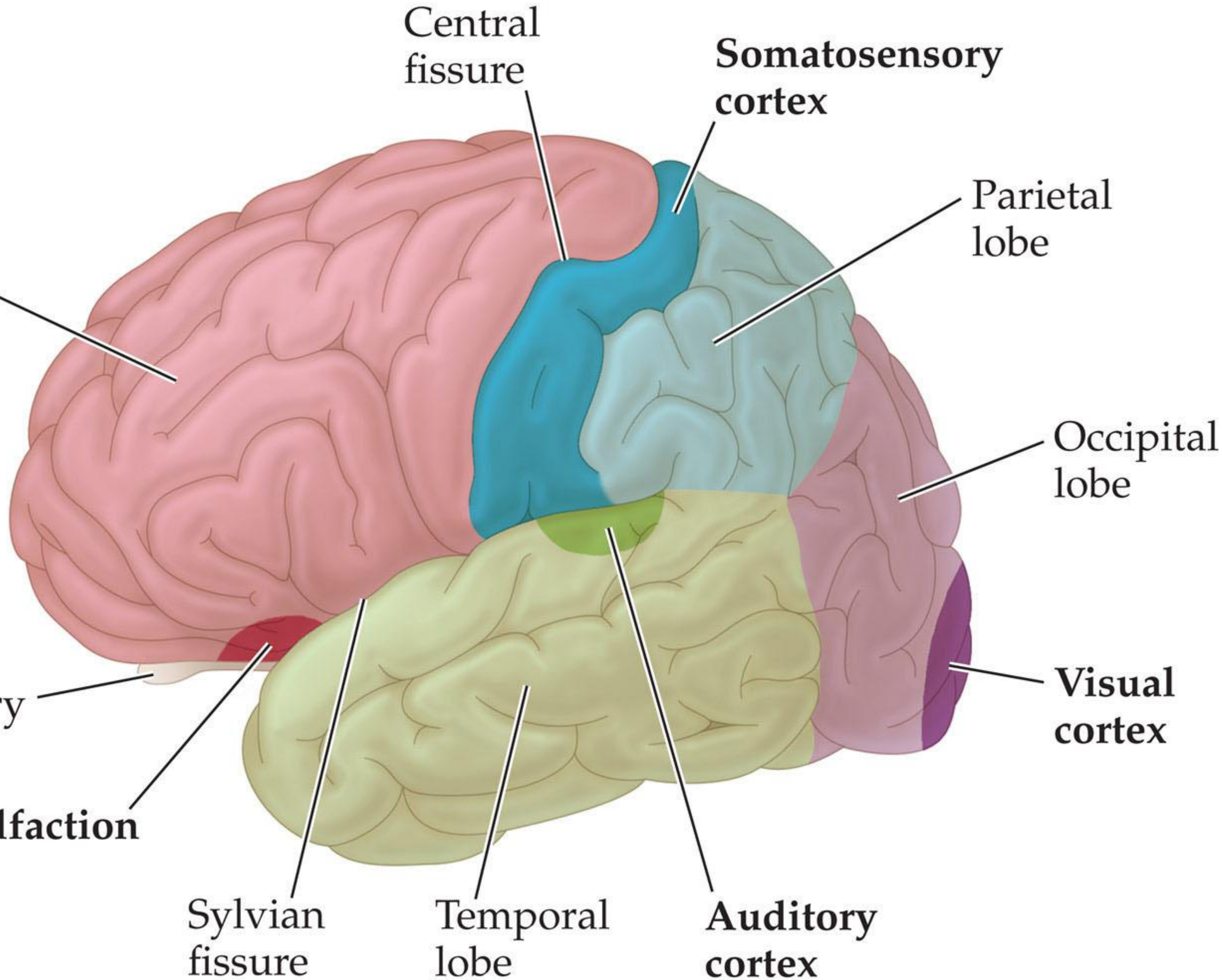
Just as different nerves are dedicated to specific sensory and motor tasks, different areas of the cortex are also dedicated to specific sensory and motor tasks.

However, there are some areas of the brain that are polysensory, meaning that information from several senses is combined.

Figure 1.21 Cortex of the human brain



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Hermann von Helmholtz (1821–1894)

- Invented the ophthalmoscope
- Wrote *On the Sensations of Tone* (1863), one of the first studies of auditory perception
- Argued that behavior could be explained by only physical forces (materialism)
  - To prove this, he measured the speed of the neural impulse and proved that neurons obey the laws of physics and chemistry.

Figure 1.22 Hermann von Helmholtz was one of the greatest scientists of all time

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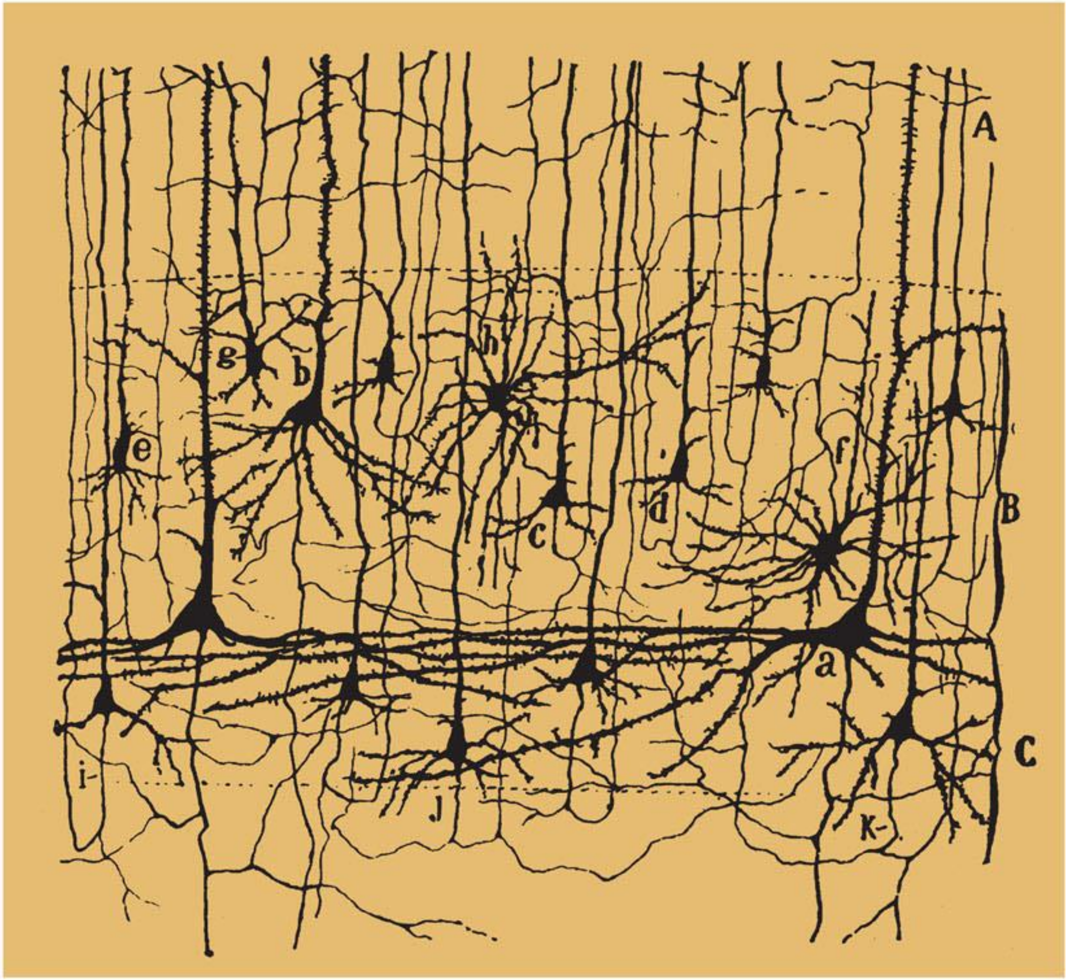
Santiago Ramón y Cajal (1852–1934)

- Created incredibly detailed drawings of neurons and neural structures
- Was the first person to discover the synapse
- Won the Nobel Prize in Medicine for his contributions

Figure 1.23 (*a*) Santiago Ramón y Cajal. (*b*) Ramón y Cajal created these drawings of brain neurons

(*a*)

(*b*)



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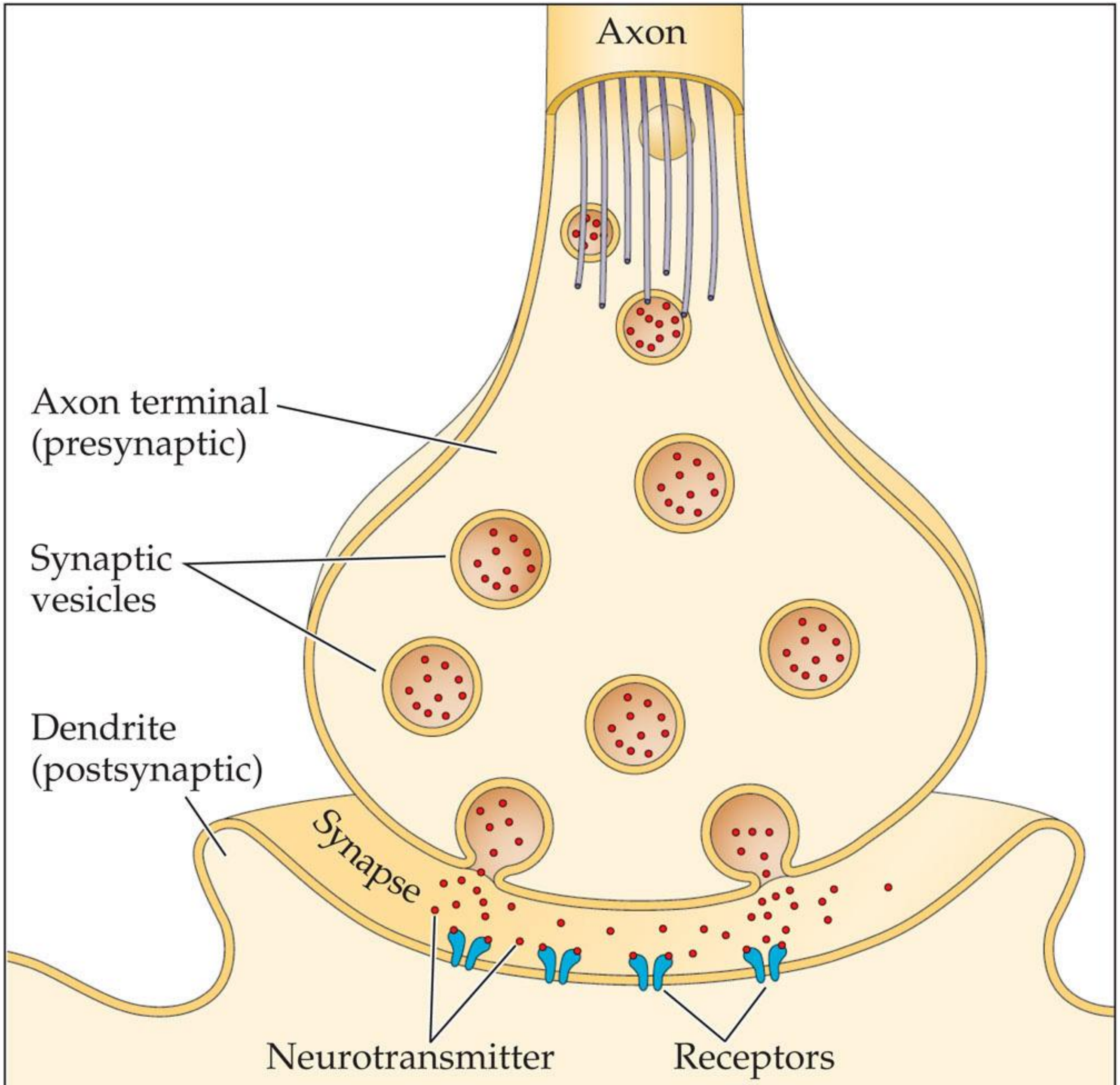
Synapse: The junction between neurons that permits information transfer.

Neurotransmitter: A chemical substance used in neuronal communication at synapses.

Figure 1.25 A synapse



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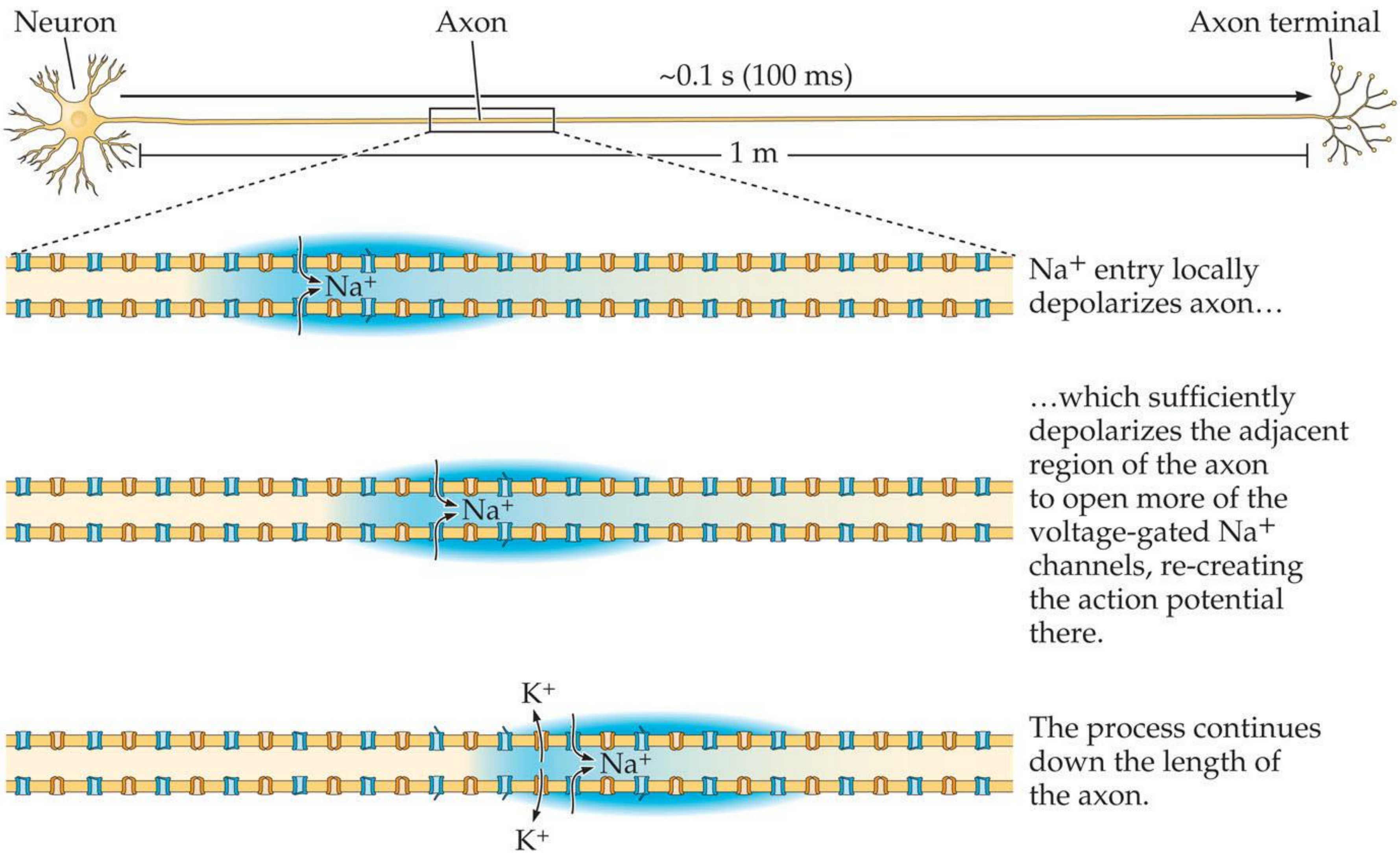
Neurons fire in an all-or-none fashion for each spike, and the number of spikes per second indicates how excited the neuron is.

Each action potential starts near the cell body of a neuron and propagates down the axon towards the axon terminal.

- Electrochemical process involving Na^+ and K^+ ions moving in and out of the neuron

Entire populations of neurons work in concert to process information.

Figure 1.28 An action potential of a neuron is created when the membrane of the neuron permits sodium ions to rush into the cell, thus increasing the voltage



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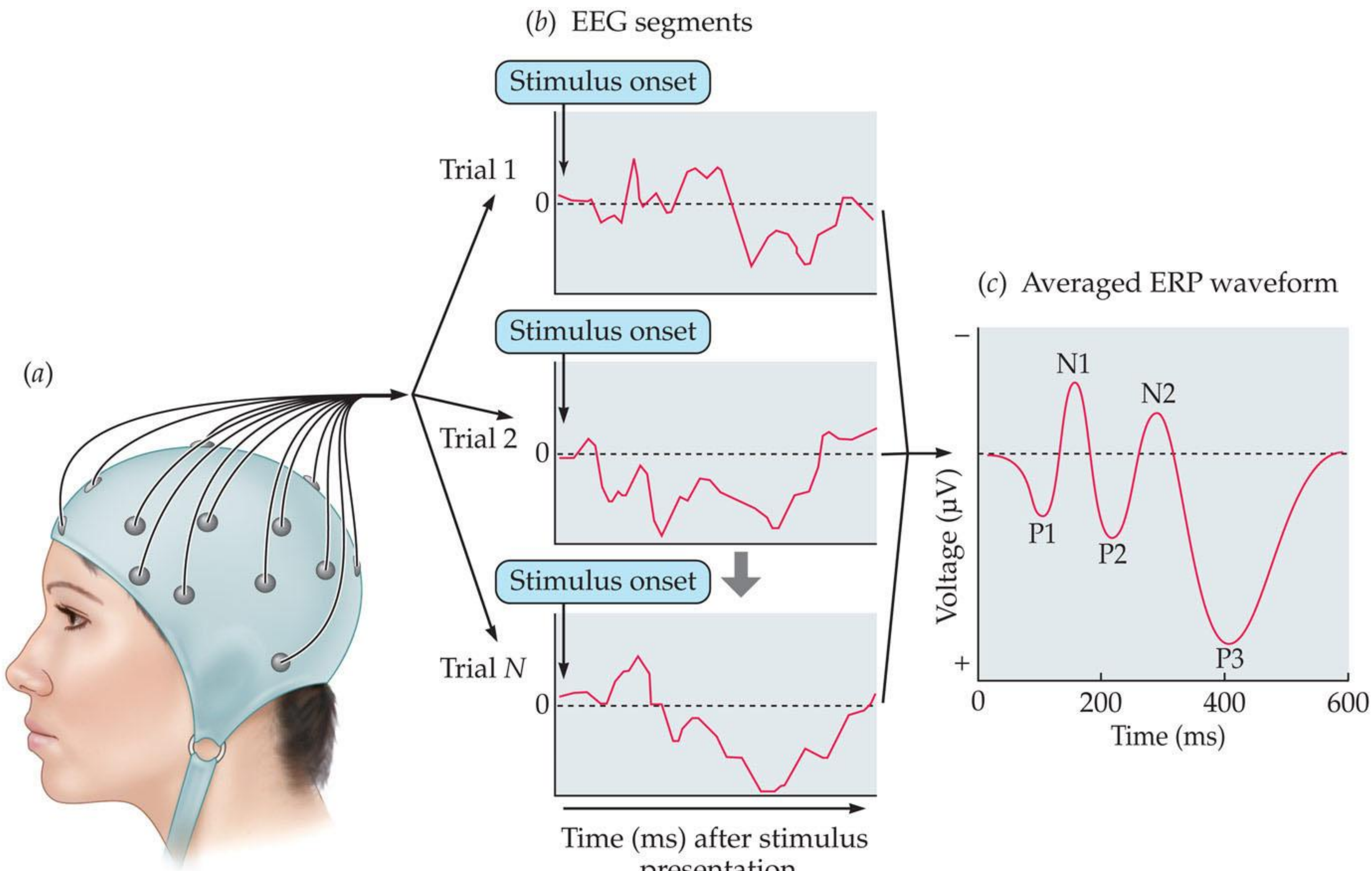
Modern brain imaging technologies

- Electroencephalography (EEG): A technique that, using many electrodes on the scalp, measures electrical activity from populations of many neurons in the brain.
- Event-related potential (ERP): A measure of electrical activity from a subpopulation of neurons in response to particular stimuli that requires averaging many EEG recordings.

Figure 1.31 Electroencephalography (Part 1)



SENSATION & PERCEPTION 4e, **Figure 1.31 (Part 1)**

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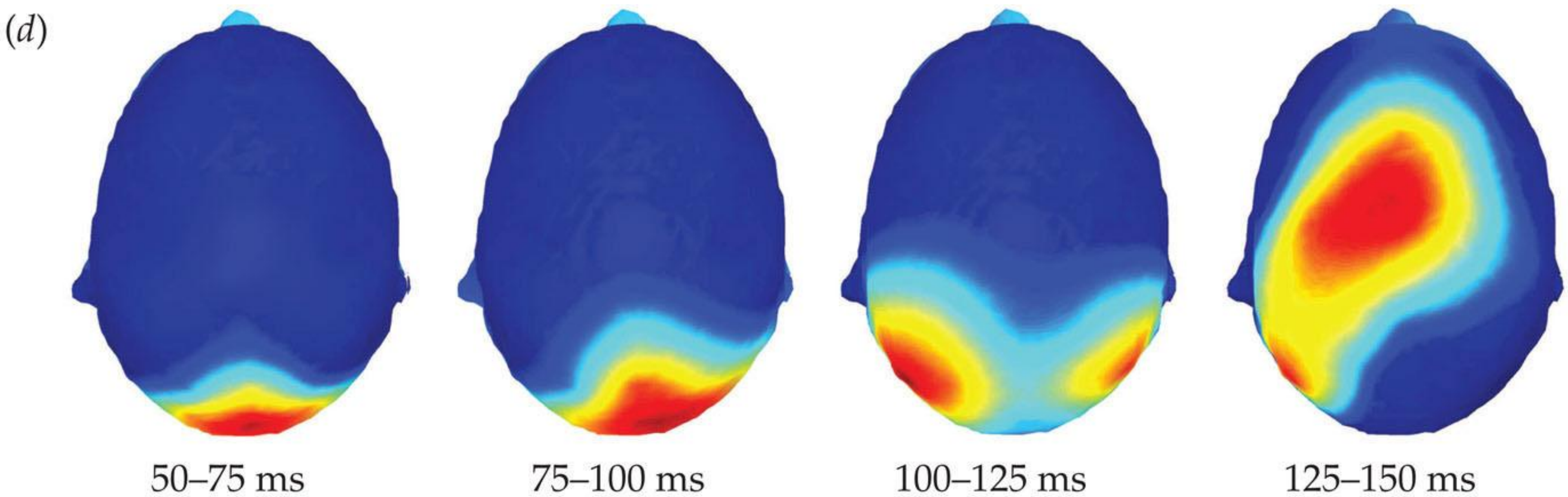
Figure 1.31 Electroencephalography (Part 2)



SENSATION & PERCEPTION 4e, Figure 1.31 (Part 2)

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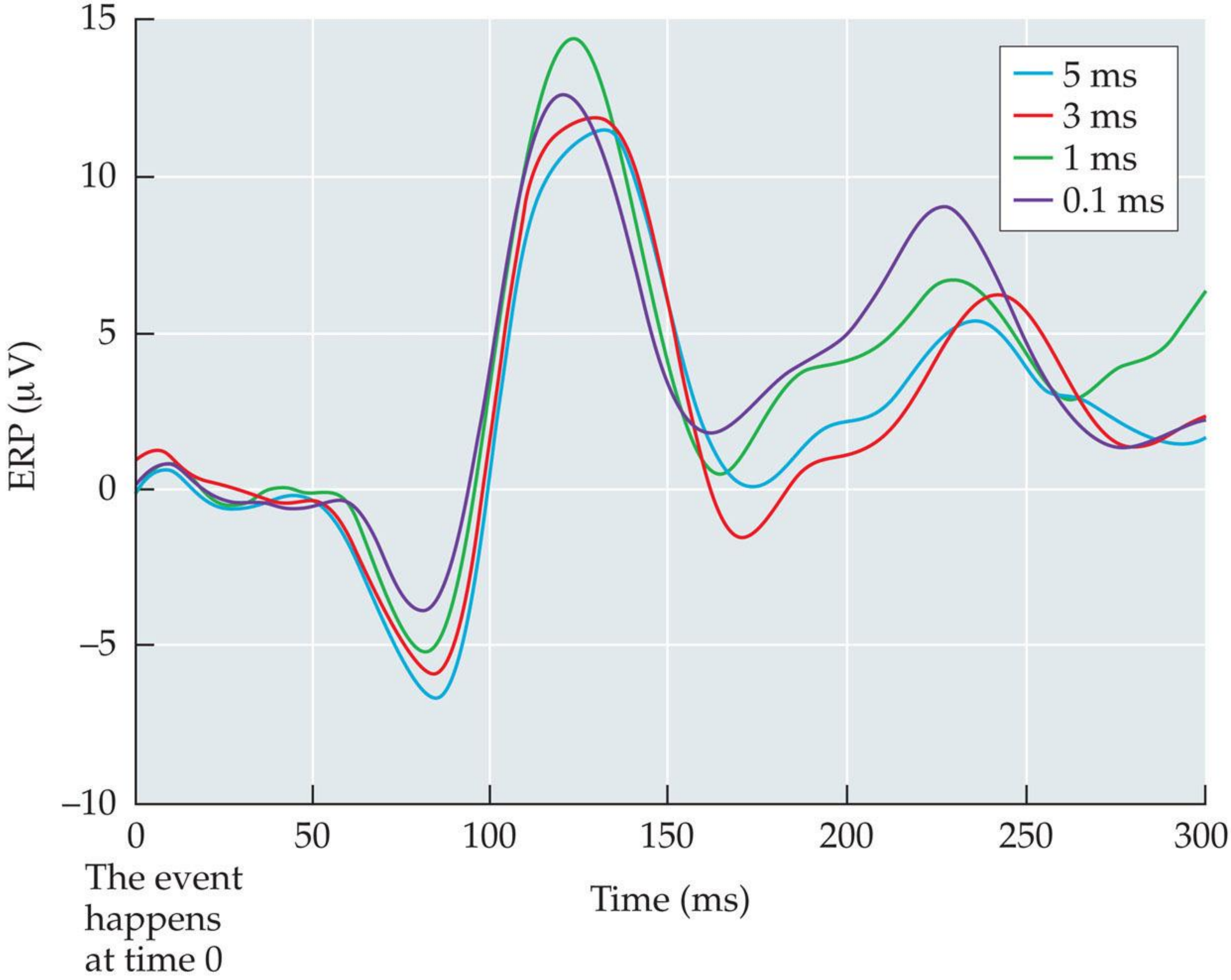
Figure 1.32 Event-related potentials produced in response to very brief flashes of light



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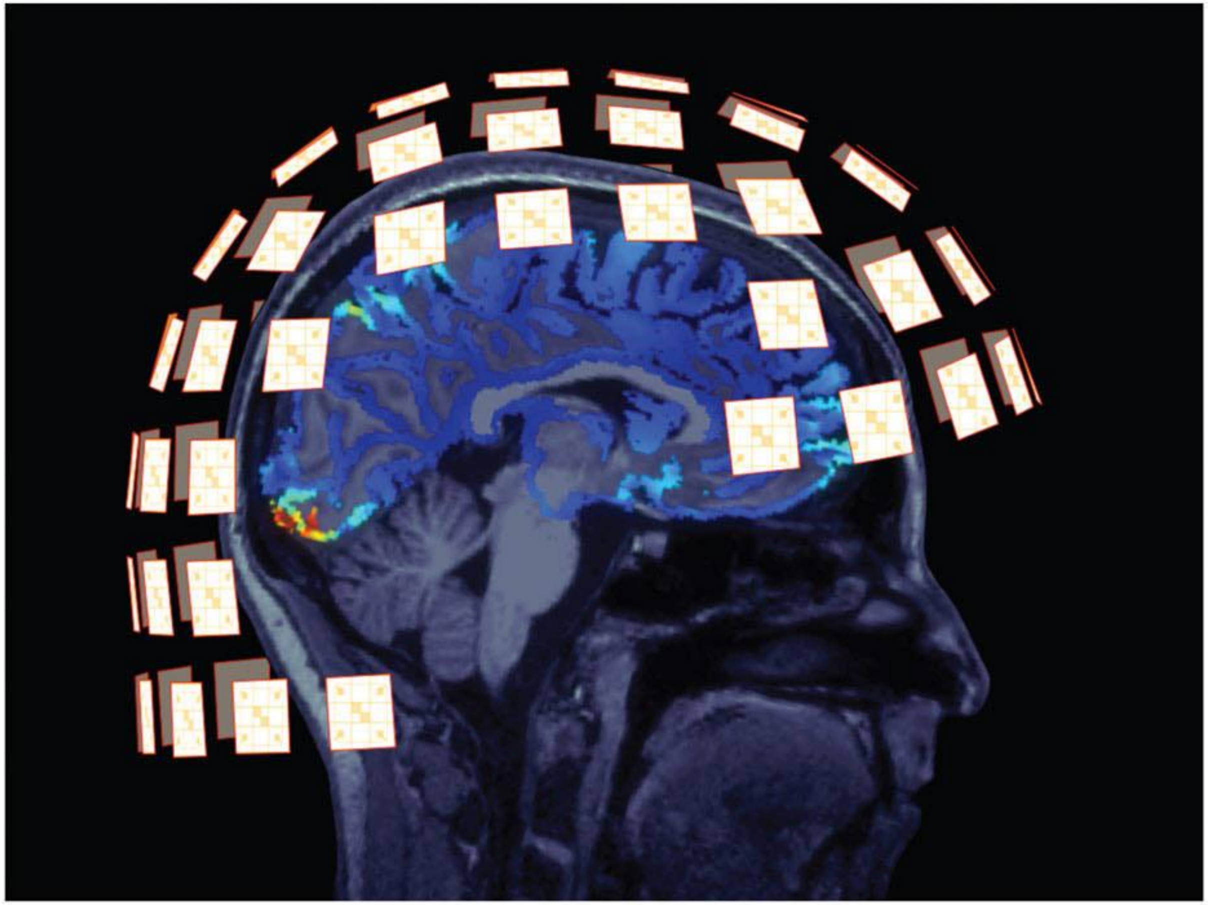
Modern brain imaging technologies (*continued*)

- Magnetoencephalography (MEG): A technique, similar to EEG, that measures changes in magnetic activity across populations of many neurons in the brain
  - MEG has the same high temporal resolution as EEG, but it has better spatial resolution.

Figure 1.33 Magnetoencephalography (MEG)

(*a*) An MEG machine

(*b*) Reconstruction of brain responses to a visual stimulus



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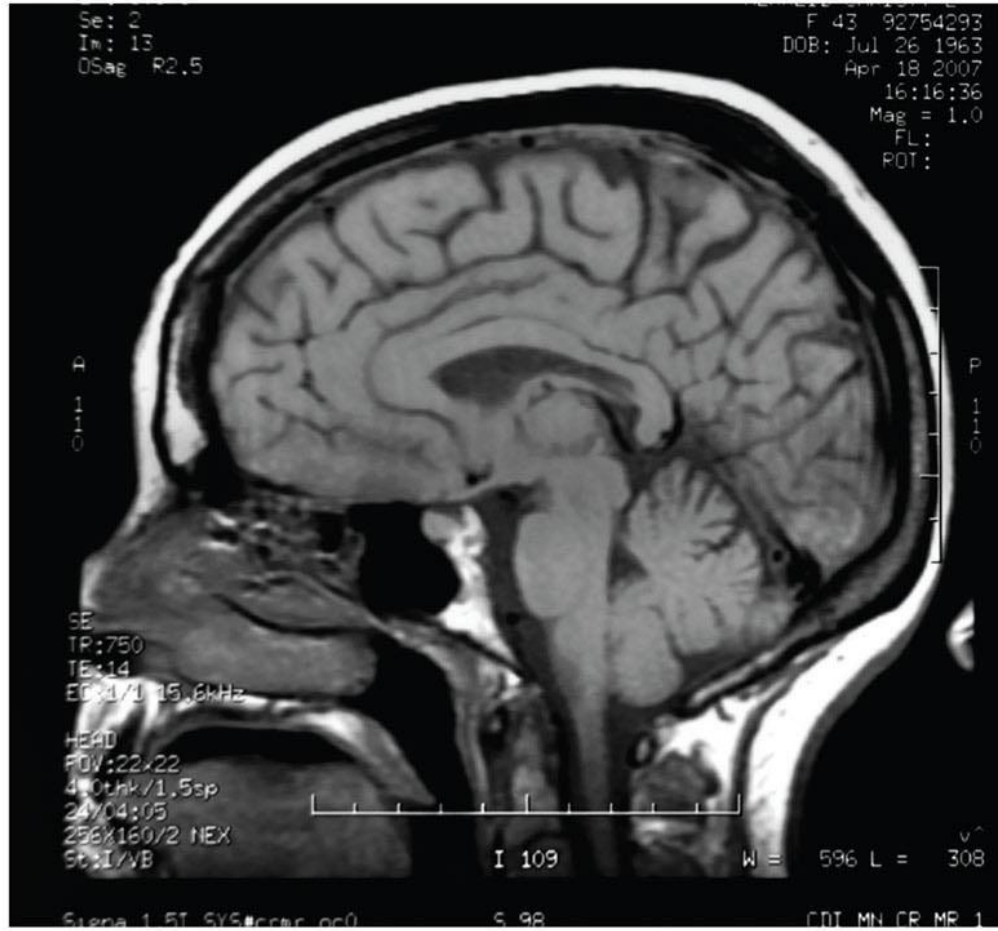
Modern brain imaging technologies (*continued*)

- Computerized tomography (CT): An imaging technology that uses X-rays to create images of slices through volumes of material (e.g., the human body).
- Magnetic resonance imaging (MRI): An imaging technology that uses the responses of atoms to strong magnetic fields to form images of structures like the brain.

Figure 1.35 CT and MRI

(*a*) CT

(*b*) MRI



SENSATION & PERCEPTION 4e, Figure 1.35

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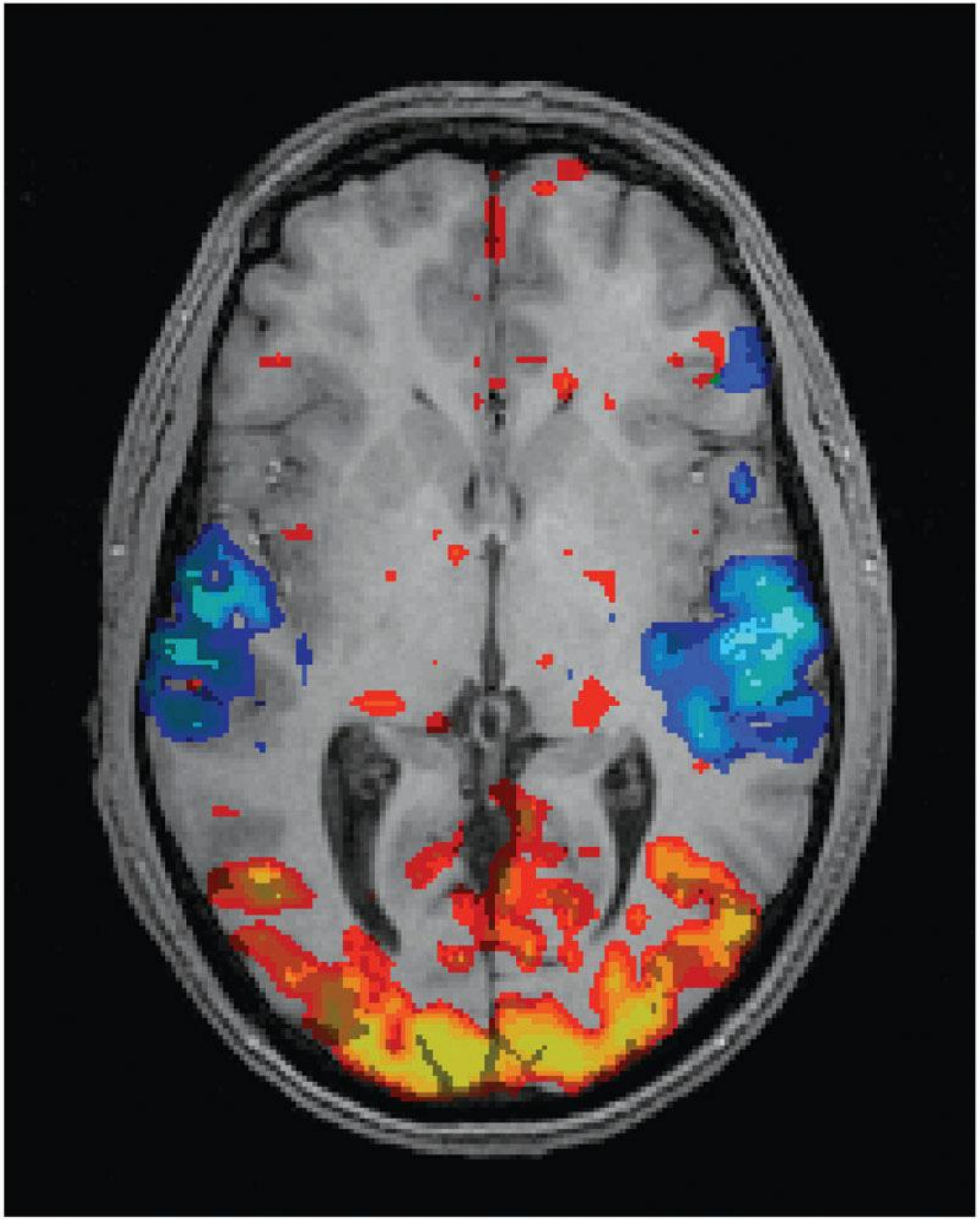
Modern brain imaging technologies (*continued*)

- Functional magnetic resonance imaging (fMRI): Variant of MRI. Measures localized patterns of brain activity. Activated neurons provoke increased blood flow, which can be quantified by measuring changes of oxygenated and deoxygenated blood to strong magnetic fields.

Modern brain imaging technologies (*continued*)

- Blood oxygen level-dependent (BOLD) signal: The ratio of oxygenated to deoxygenated hemoglobin that permits the localization of brain neurons that are most involved in a task.

Figure 1.36 Functional MRI



SENSATION & PERCEPTION 4e, **Figure 1.36**

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Modern brain imaging technologies (continued)

- Positron emission tomography (PET): An imaging technology that allows us to define locations in the brain where neurons are especially active by measuring the metabolism of brain cells using safe radioactive isotopes.