Chemosensory Systems

Flavor Perception

Olfaction

Taste

Texture

Temperature

Consistency

Common chemical sense

“heat” of red pepper

“coolness” of menthol

Taste

4+1 Taste Primaries

(Omnivore's Dilemma)

Salty	Safe (approach) [salts]
Sour	Acidic; unripe/poor nutritional value (avoid) [acids]
Sweet	Nutritious (approach) [carbohydrates]
Bitter	Poisonous (avoid) [alkaloids]
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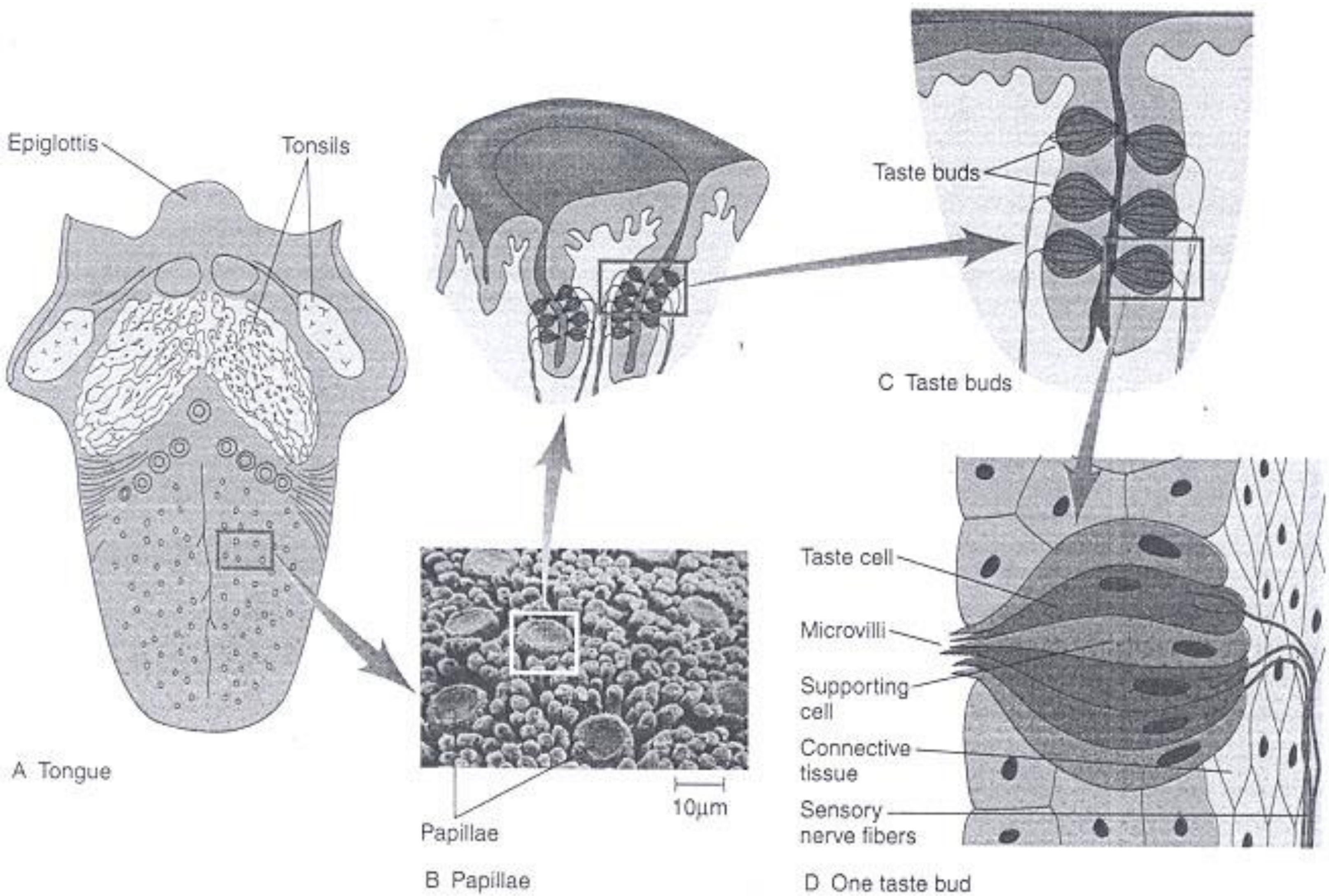
Umami	rich protein sources (hearty; savory) [amino acids]

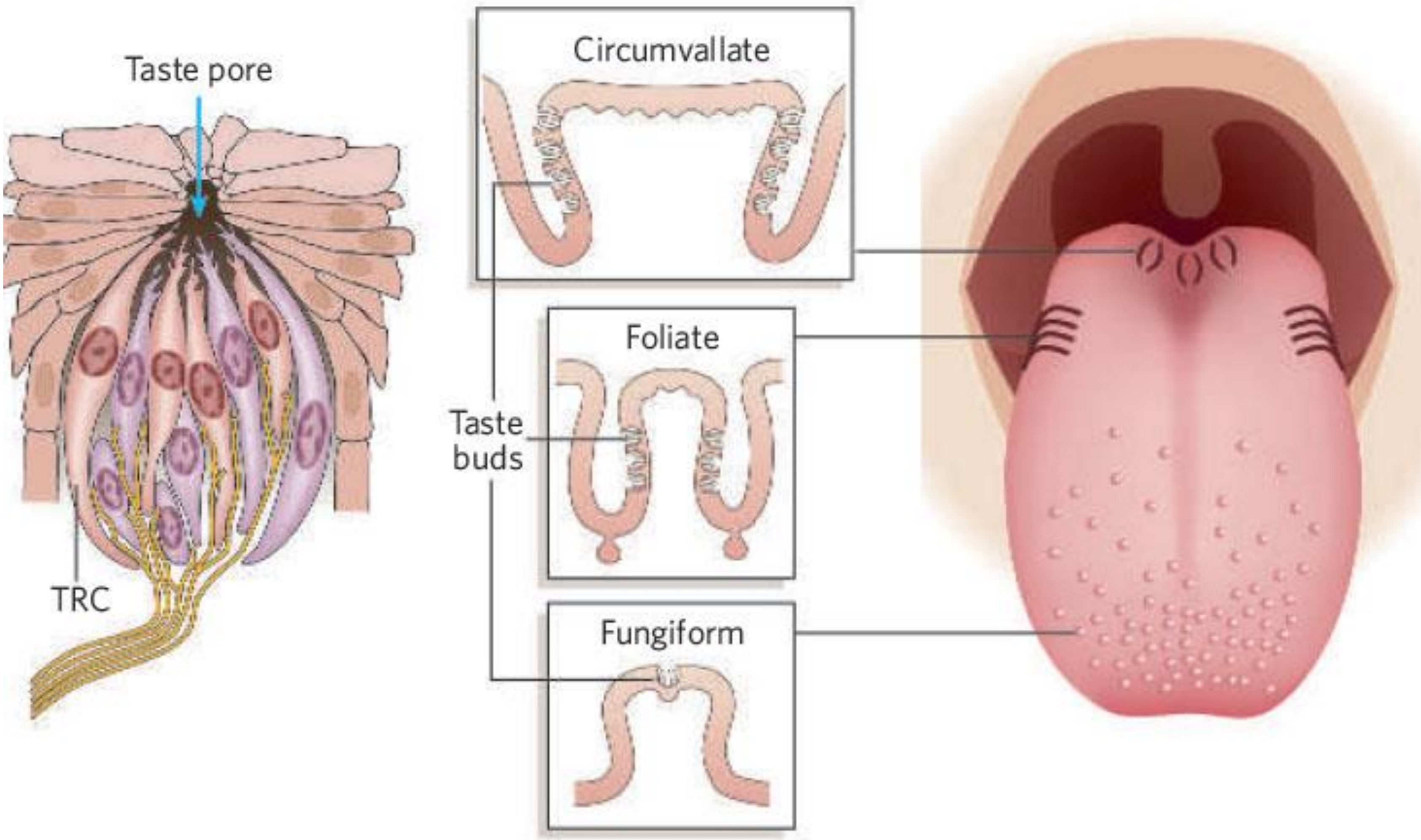
Anatomy of the Tongue

Papillae; Taste buds; Taste receptor cells; Microvilli



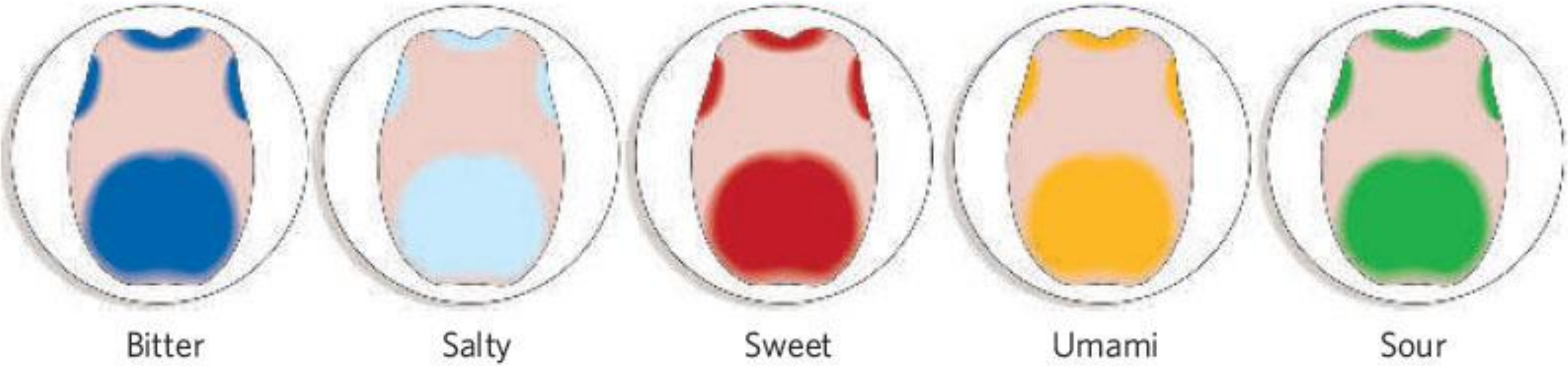
50 TRC's per bud

Types of Papillae



Mean number of taste buds = 4000 (1 log unit of variation within human population)

Taste "Map" Myth Exposed (Almost)



Any region of the tongue with taste buds contains taste cells that will respond to the major taste categories.

Nonetheless, <u>regional variations in sensitivity</u> exist:

sweet + salty preference on anterior-third of tongue;
bitter at the back of the tongue;
sour along back/sides of the tongue

Transduction

Salty

Na+ ions cross microvillus wall at specialized sites; depolarizing cell; action potentials generated

Sour

H+ ions bind to receptor sites; inhibit K+ pumps; cell depolarizes and generates neural "spikes"
[H+] corresponds to acidic strength (i.e., pH)

Transduction

Sweet; Bitter; Umami

G-protein receptor site woven through microvillus wall

Taste molecule interacts with G-protein:

inhibits ionic flow across membrane;

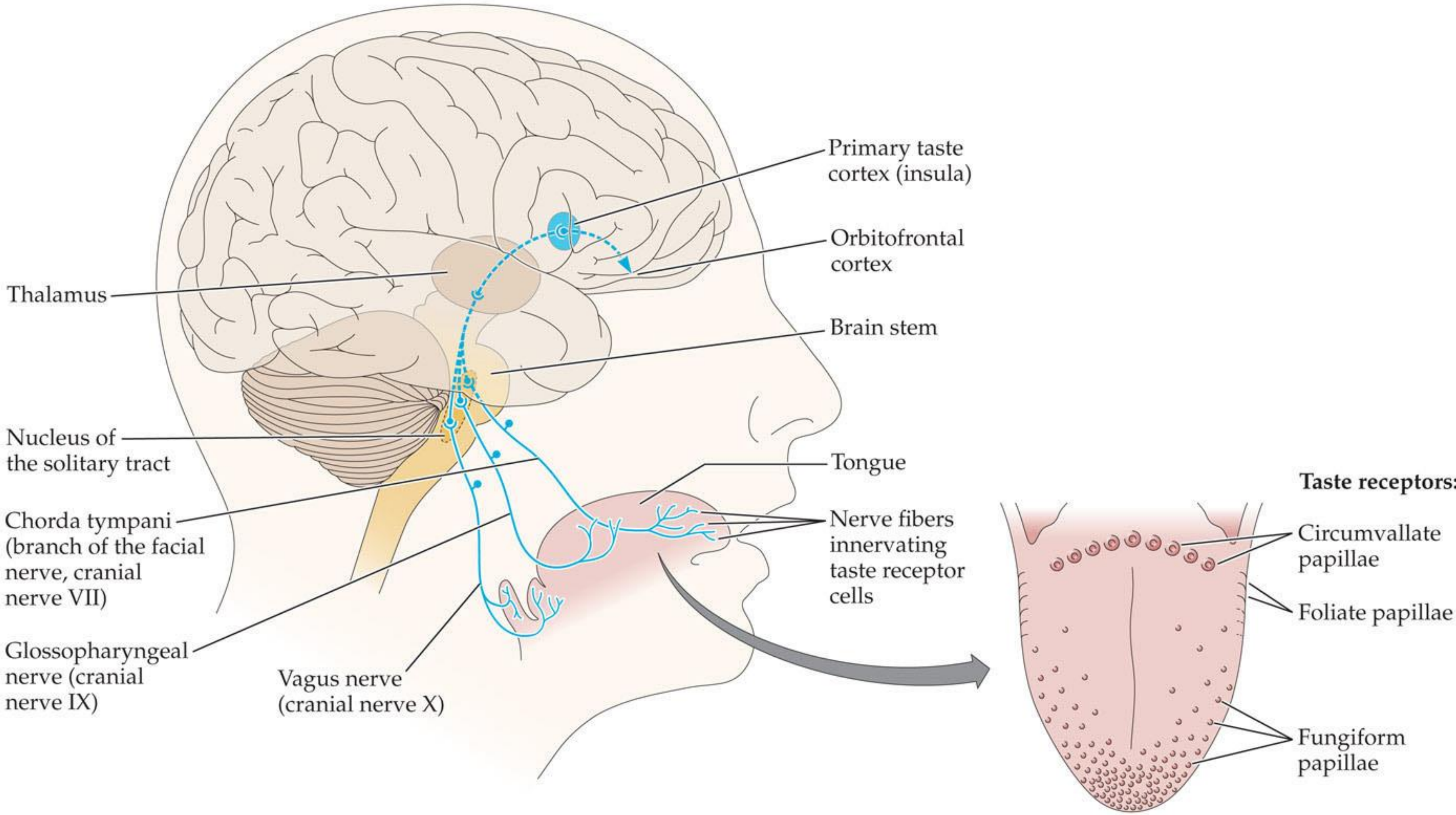
cell depolarizes and starts firing (action potential)

Sensory Coding

- **<u>Intensity</u>**
  Taste cell neurons increase their firing rate with increases in stimulus concentration (mmol)

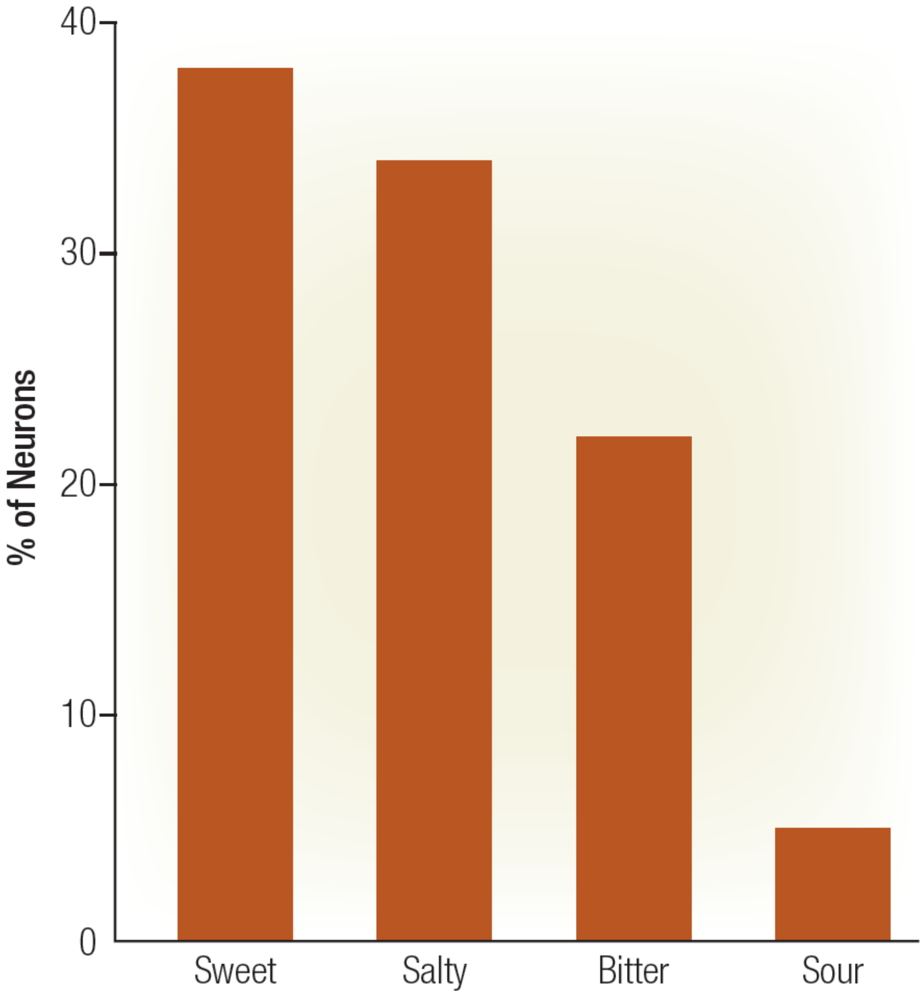
- **<u>Quality</u>**
  Some sort of global cross-fiber "patterning" whose nature <u>remains elusive</u>
  Individual taste receptor cells have transduction sites for multiple taste categories

Innervation of the Taste System



SENSATION & PERCEPTION 4e, **Figure 15.2**

Insular Cortex Taste Cell Tuning

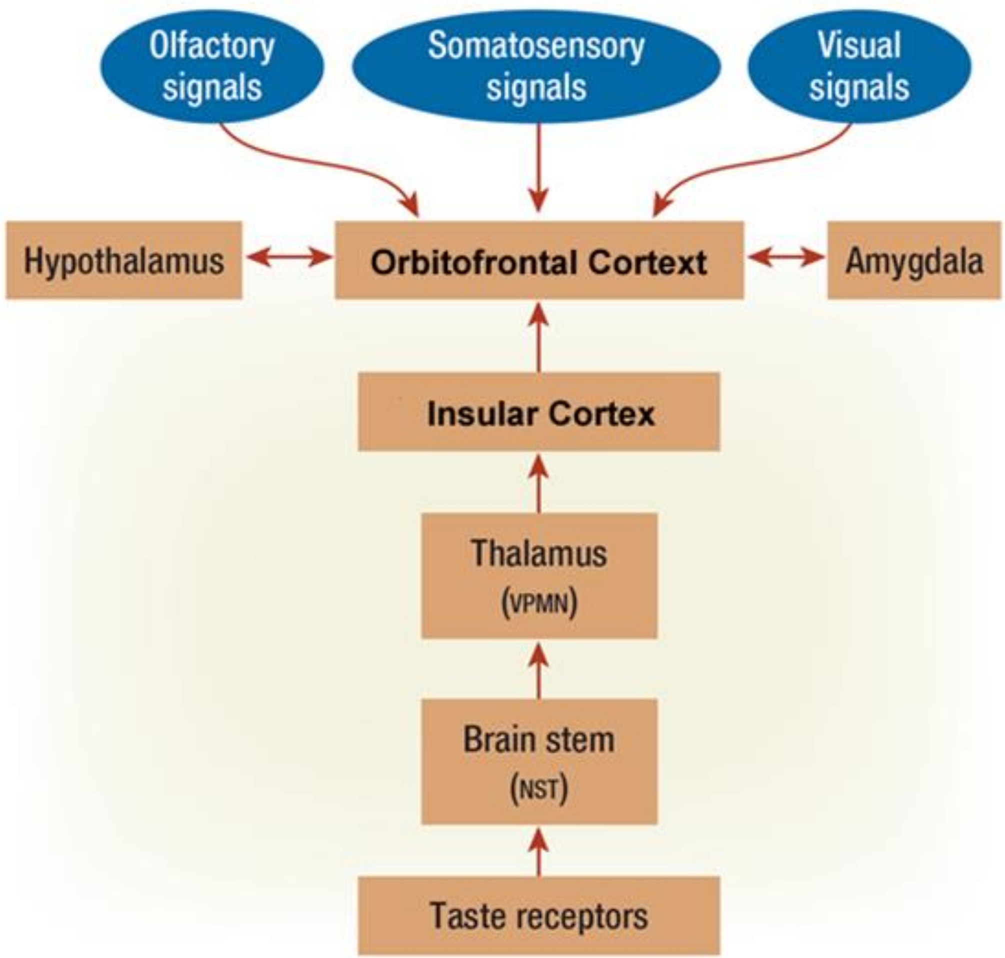


Cortical taste cells show greater category specificity than taste cells on the tongue.

Note the over-representation of cells specifically tuned to the sweet and salty categories.

Orbitofrontal Cortex

(Frontal Cortex Integration of Flavor)



Motivational states (e.g., hunger) do not affect the sensitivity of cells in the primary (insular) cortex.

However, motivational, emotional and learning experiences heavily influence the sensitivities of cells in the orbitofrontal cortex. Site of smell, taste, tactile and temperature components of flavor perception.

Sample Taste Detection Thresholds

(mmol concentrations in water)

Sweet	
Saccharin	0.009
Aspartame (artificial sweetener)	0.02
Sucrose (table sugar)	0.65
Salty	
Calcium chloride	0.008
Sodium chloride	1.0
Potassium chloride	6.3
Sour	
Citric acid	0.07
Acetic acid (vinegar)	0.1
Bitter	
Quinine	0.001
Caffeine	0.05
Urea	15.0
Umami	
Monosodium glutamate	0.05

Great variation in detection thresholds both within and between categories

General Sensitivity Rule-of-thumb:
Bitter > Sour, Salty, Sweet > Umami

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1 mole $C_{12}H_{22}O_{11}$ = 342 grams
0.65 mmol concentration = 0.22 g/L
(i.e., 0.03 ounce in 1 gallon)

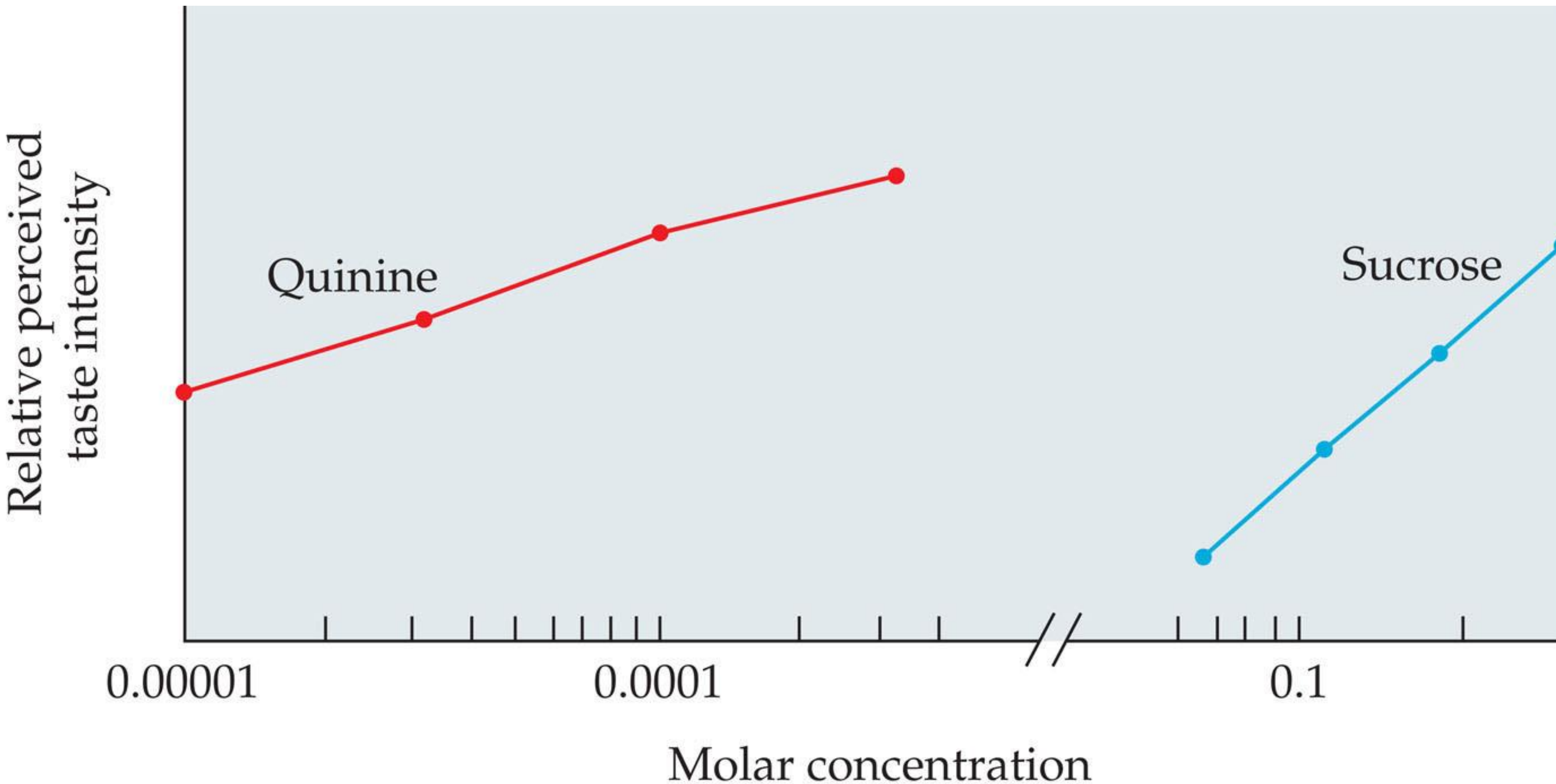
Difference Thresholds

- **JNDs range from 15-25%**
  Difficult to predict based upon molecular properties

- Direct scaling procedures tend to yield power law exponents in the 0.3-0.9 range (sucrose = 0.8) **(slight compressive nonlinearity)** $I = kC^{0.8}$

- Taste is the **least sensitive of the human senses**

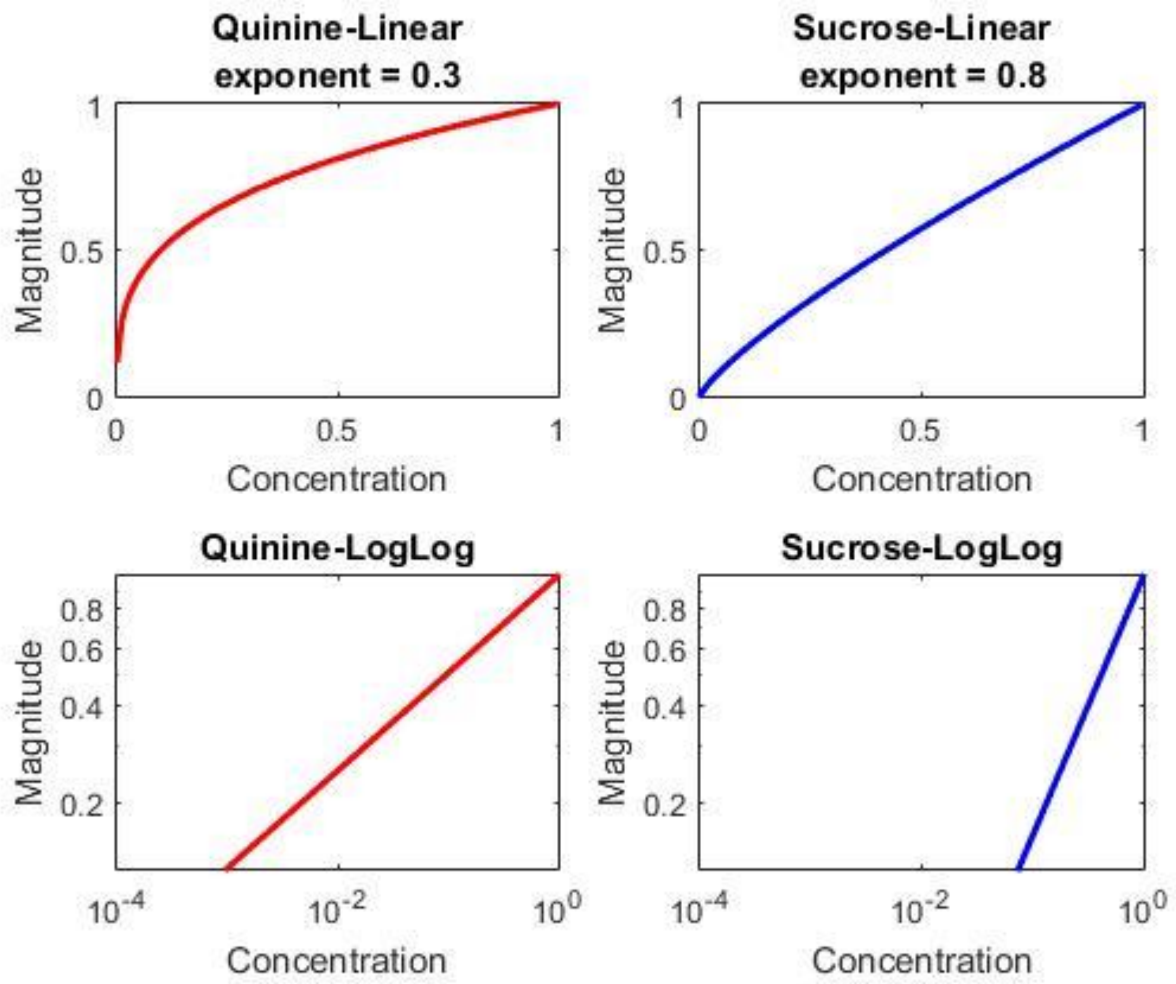
Suprathreshold Taste Functions



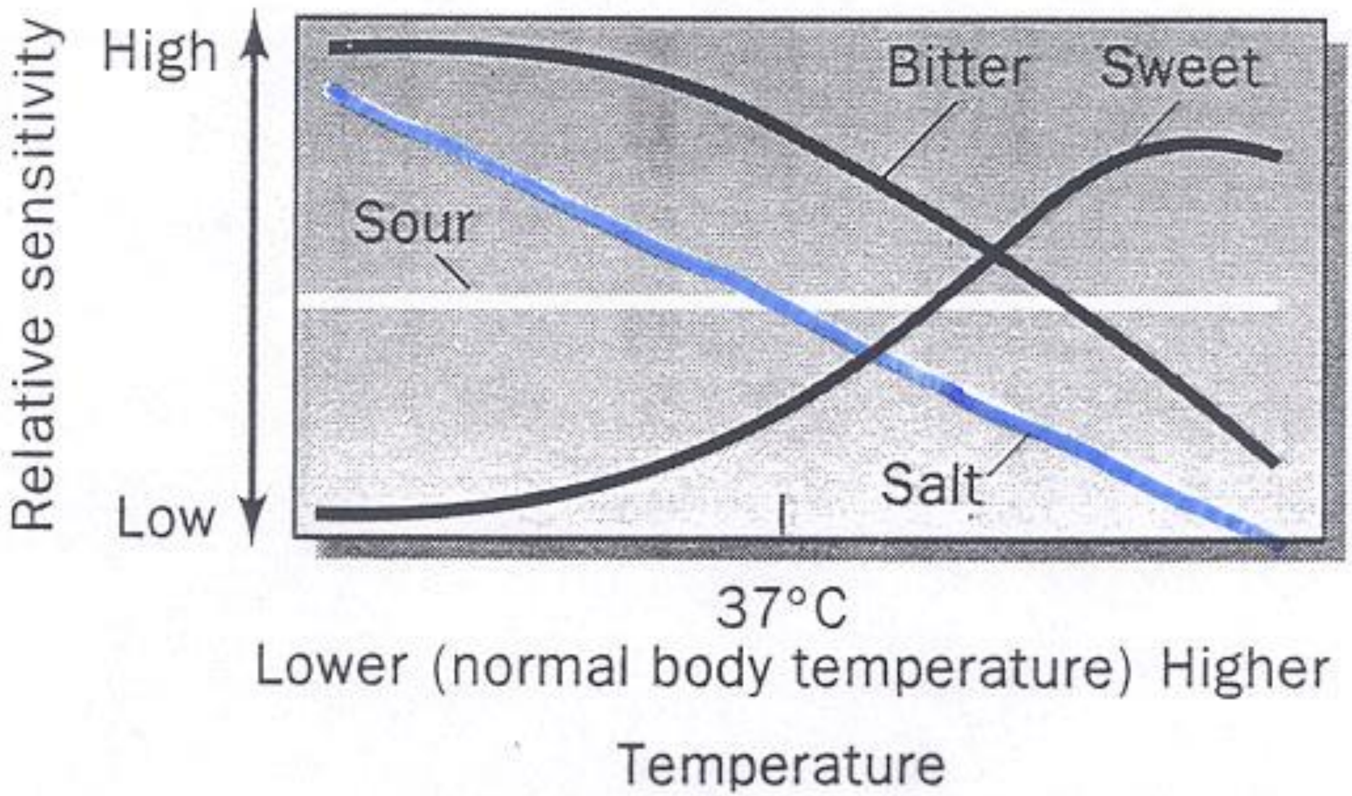
***SENSATION & PERCEPTION 4e*, Figure 15.11**

Stevens' Law: $S = k\ I^n$
Taste of bitter substances grows more slowly (quinine: $n=0.3$) than sweetness (sucrose: $n=0.8$) as stimulus intensity/concentration is increased.

Linear vs Log-Log Functions



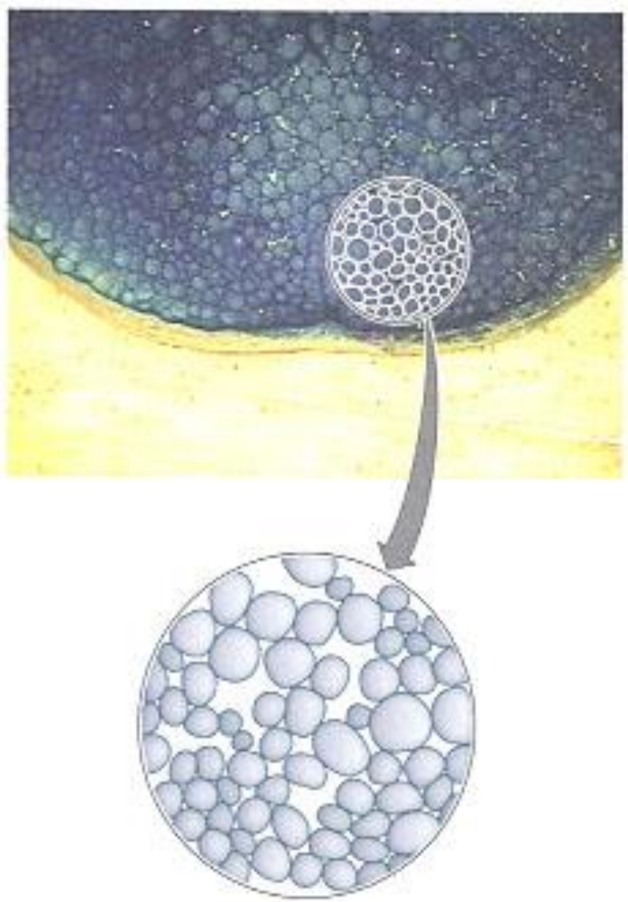
Temperature vs. Sensitivity



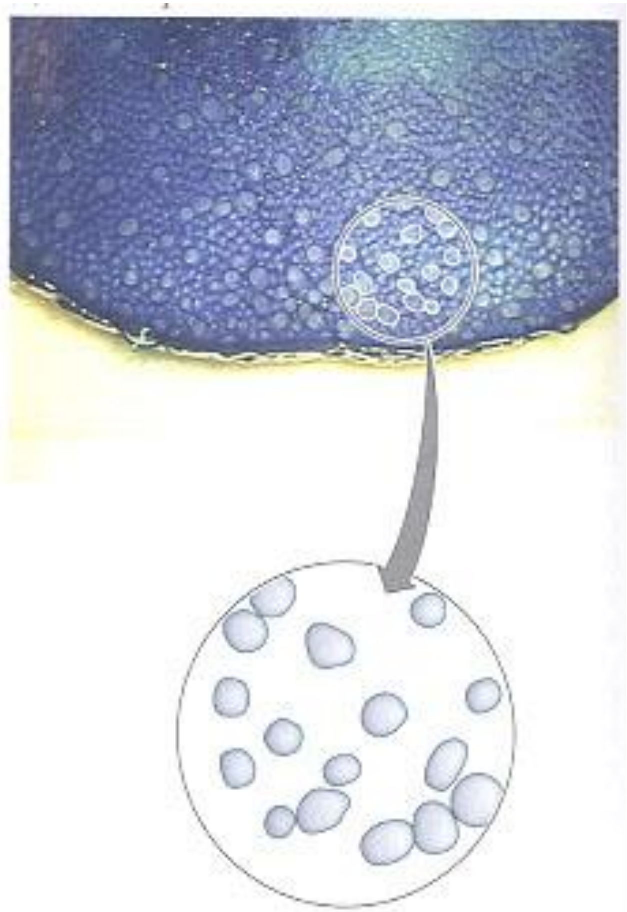
Individual Differences in Taste Bud Count (Fungiform Papillae)

[Taste Lab] (PTC/PROP Tasters)

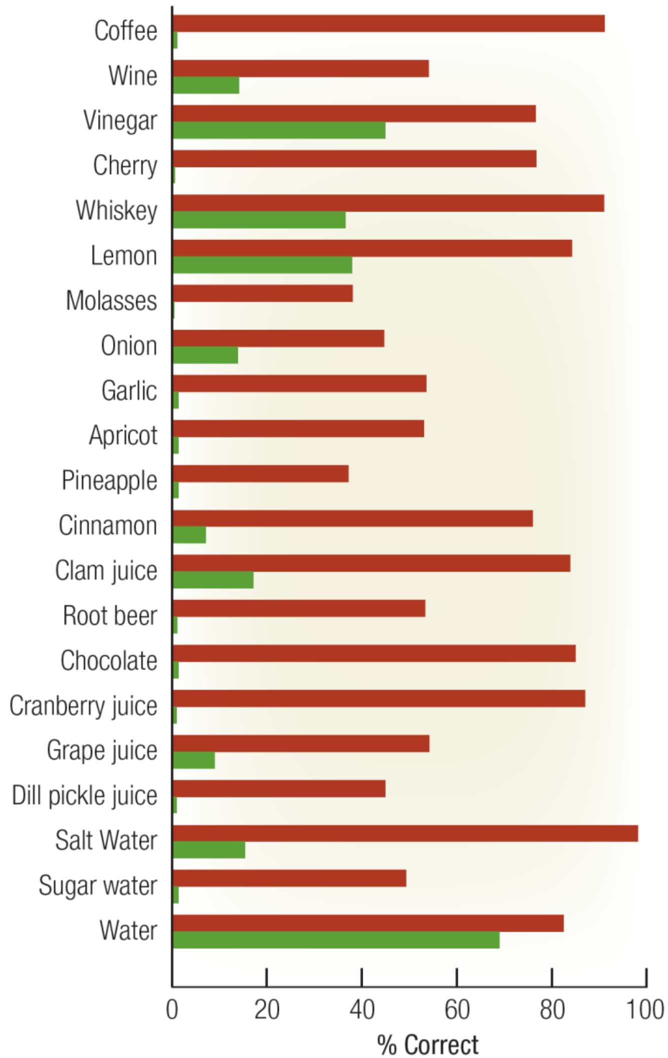
Super-Taster



Normal Taster



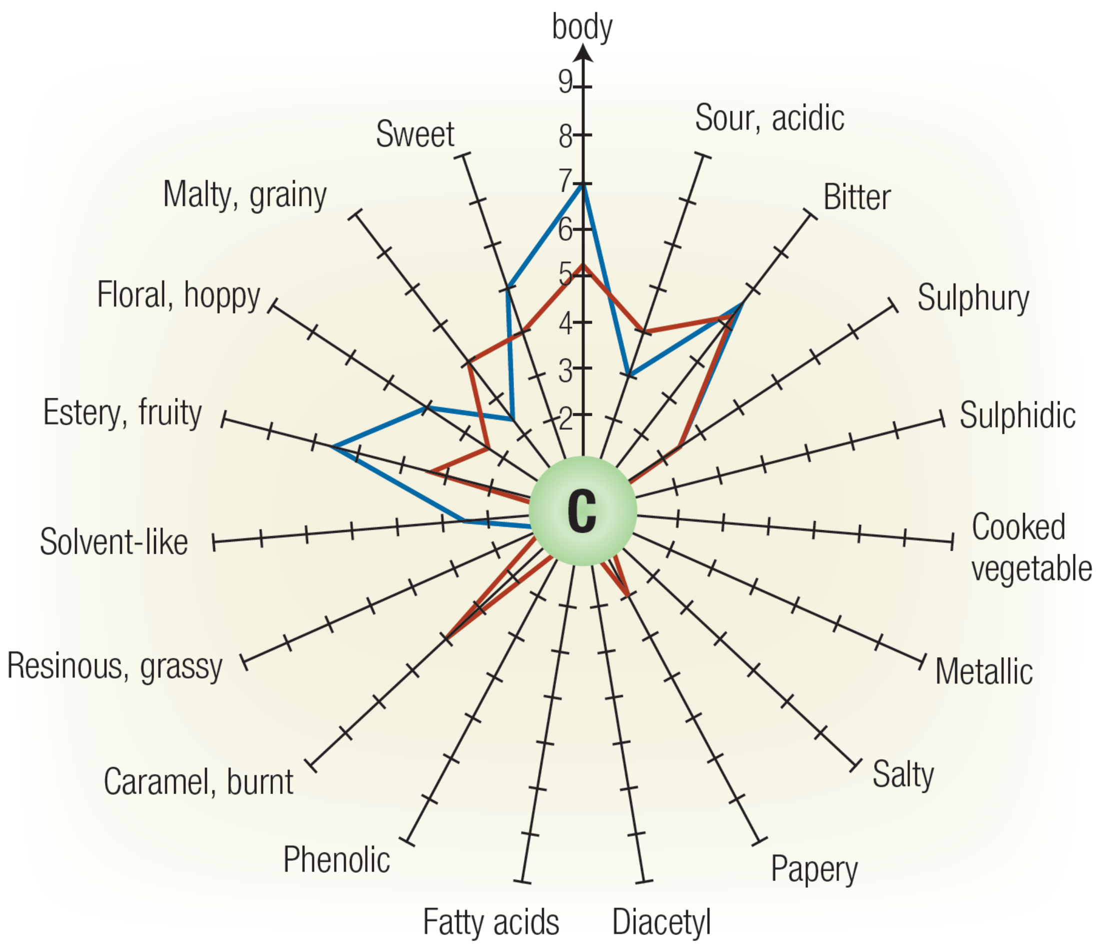
Taste Stimulus Identification
(with and without olfaction)



Identification of stimulus solutions with vs. without wearing a nose plug to attenuate smell cues (taste+smell = RED bars)

Taste, when isolated from olfaction, is a relatively impoverished sensory input

Domain-Specific Scaling Procedures



Qualitative Scale Used by "Expert Panel" for evaluation of beer

Although the search for a general-purpose model for representing the qualitative dimensions of taste has yet to be successful....

Task-specific scales based upon well-defined sensory descriptors have proved to yield reliable results for quality control of foods and beverages.

Much training is required before reliability is achieved.

Olfactory System

Flavor Perception

Olfaction

Taste

Texture

Temperature

Consistency

Common chemical sense

- “heat” of red pepper
- “coolness” of menthol

Adaptive Advantages of Olfaction

- Locate & track food/prey at a distance
- Long-distance warning beyond line-of-sight and in the dark
- Sexual attraction
  (Are there human pheromones?)
- Hedonic reward system
  Gastronomic delights; Fine wine; etc.

Stimulus Requirements

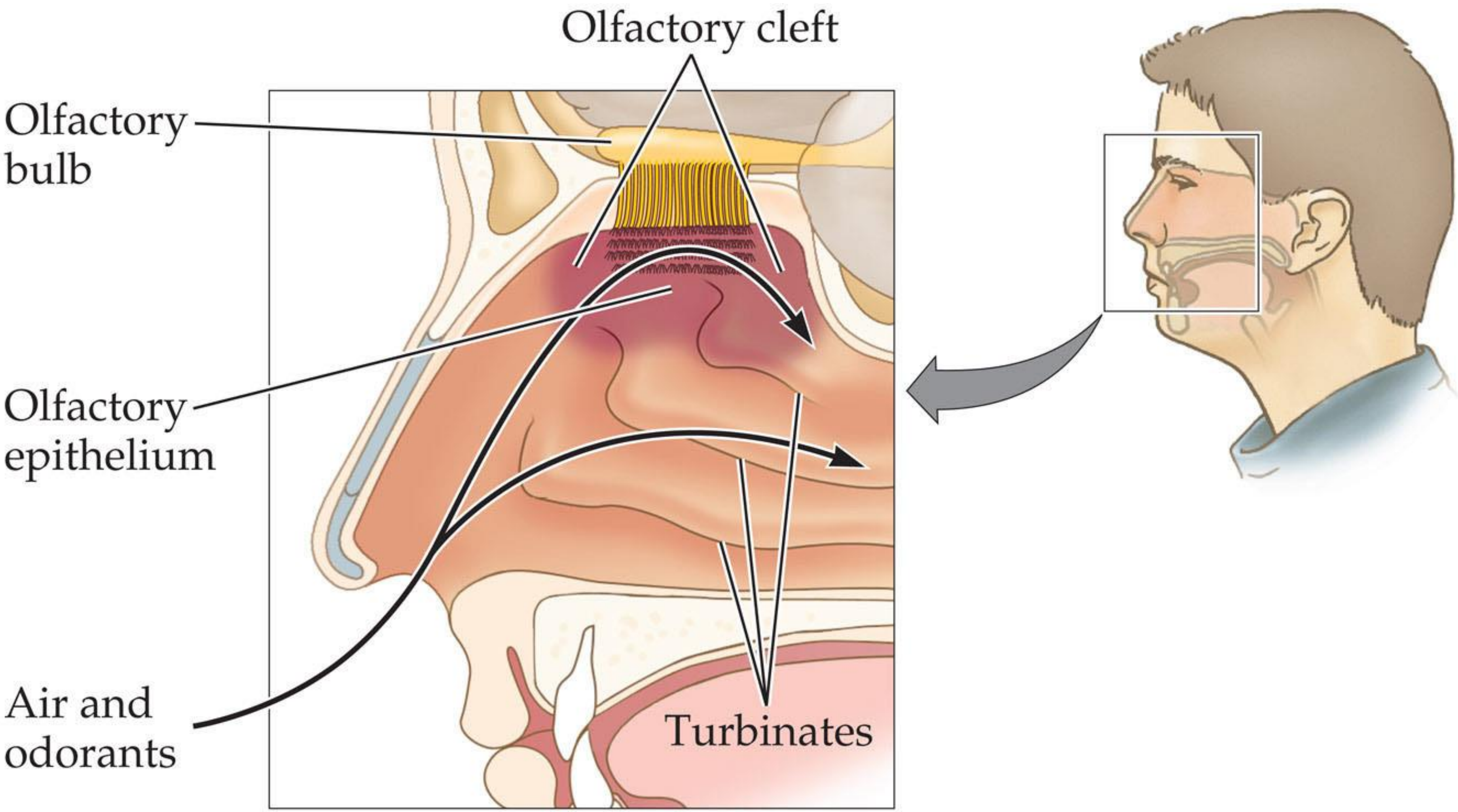
Airborne molecules (vaporous)

Fat soluble (diffusion across mucosa)

No established geometric relationship between molecular geometry and scent category (but L- vs. D- isomer findings)

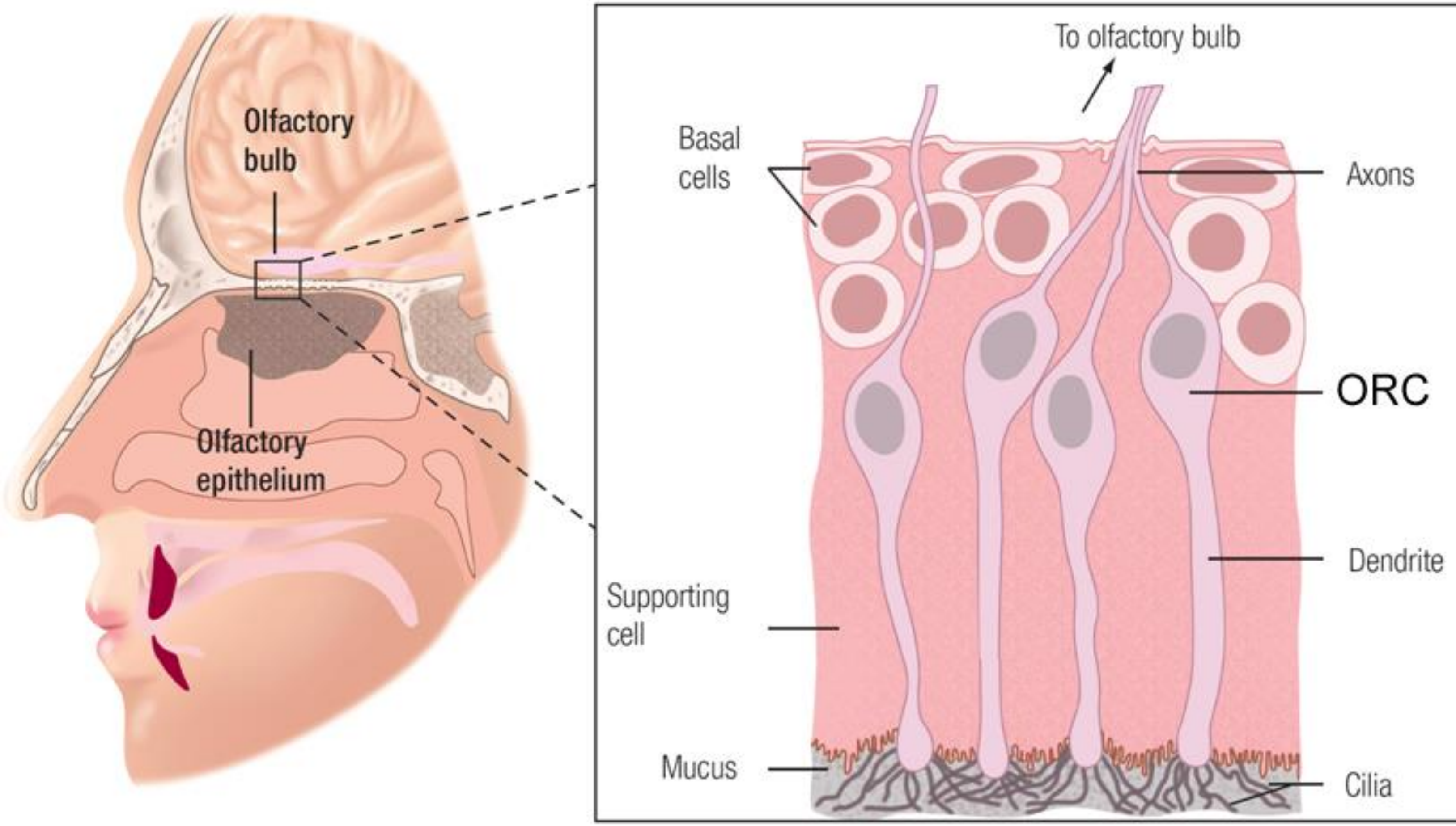
(“Shape Theory” dominates but yet to be proven)
(Luca Turin’s provocative “molecular vibration theory”)

Gross Anatomy



SENSATION & PERCEPTION 4e, Figure 14.2

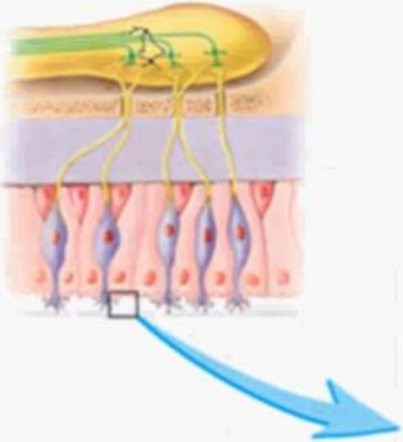
Olfactory Epithelium

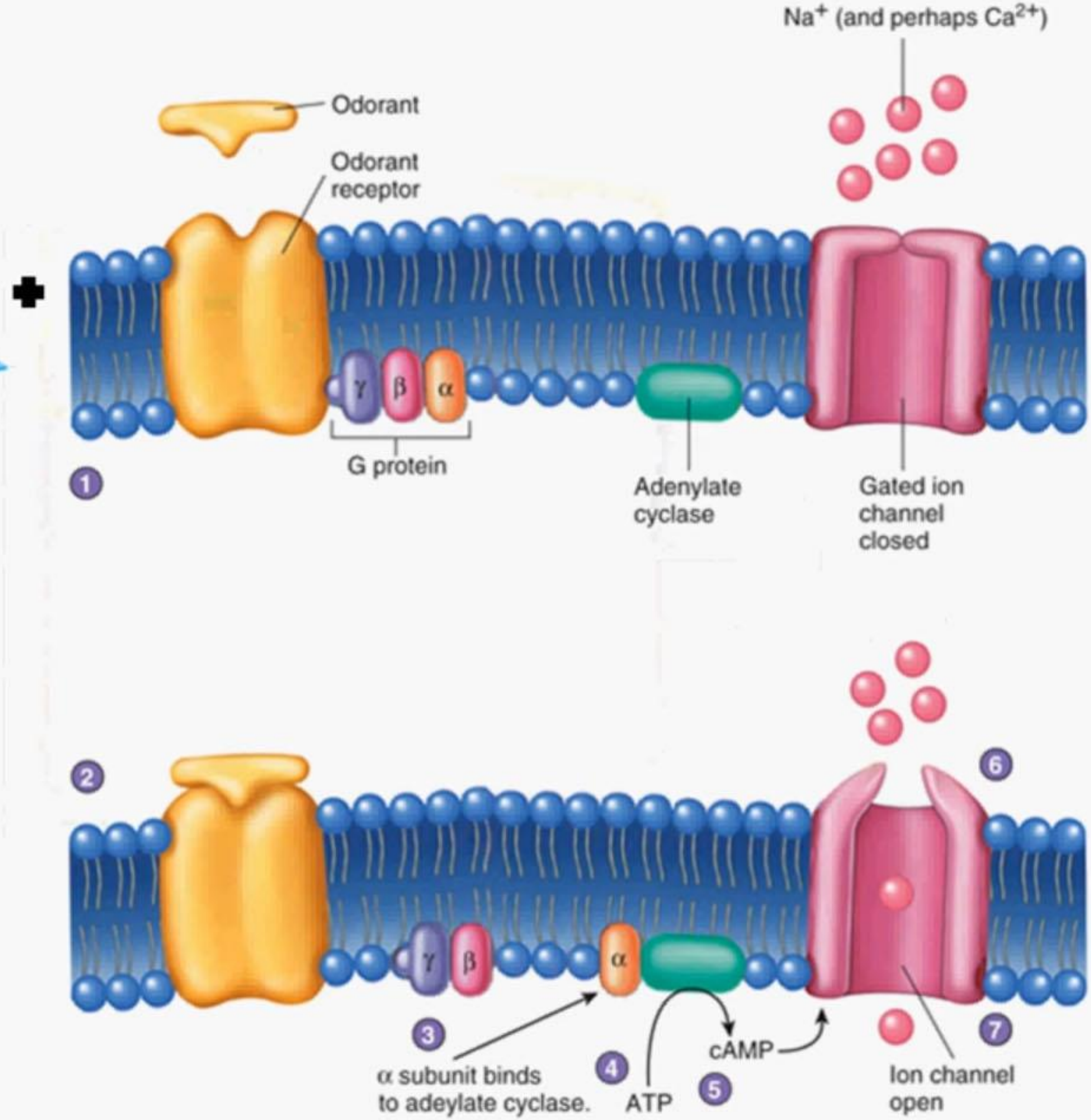


ORC = olfactory receptor cell

ORCs replaced about every 30 days in rodent models
…but what about humans?

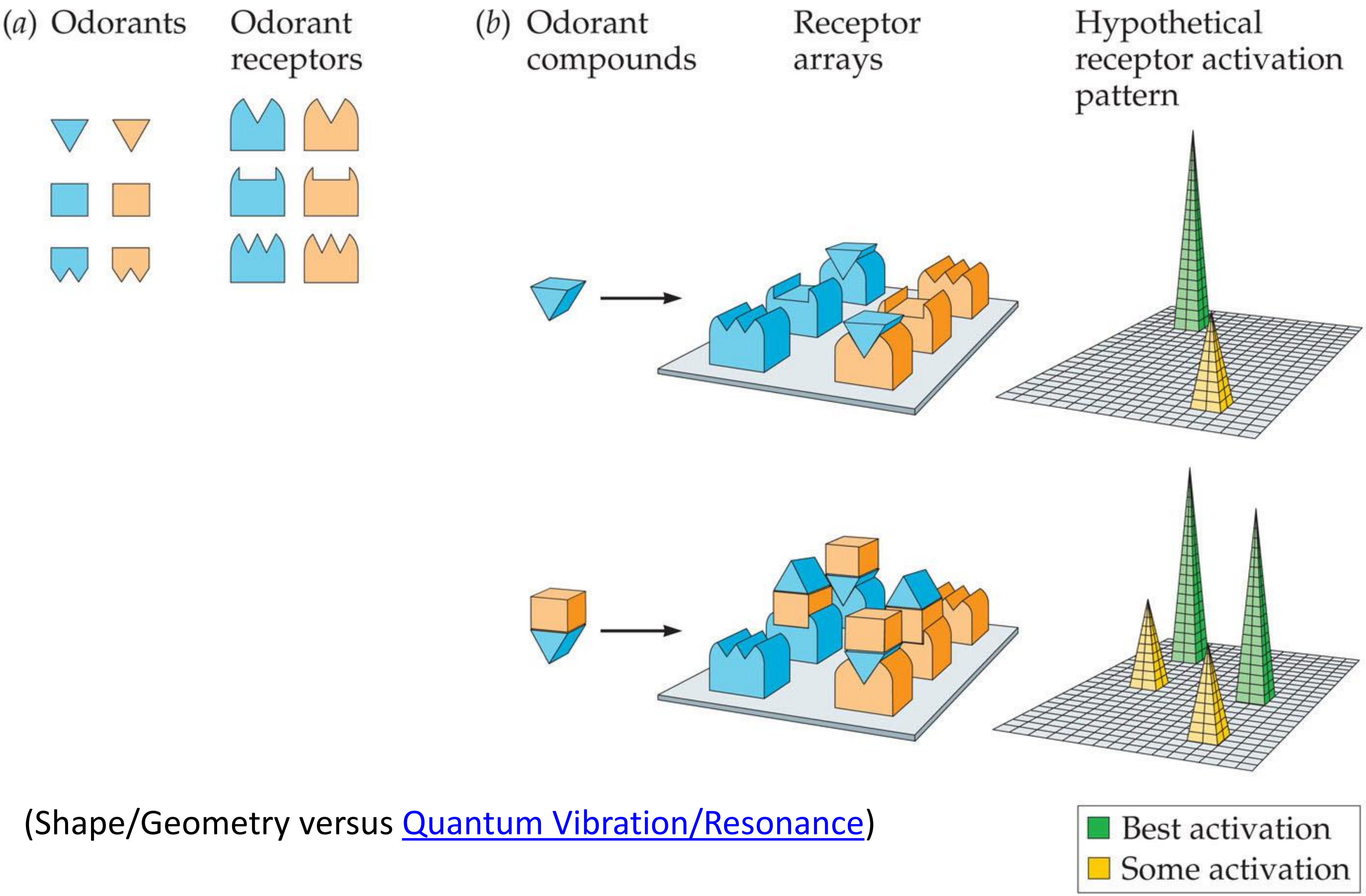
AROMATIC MOLECULES BIND TO RECEPTORS ON THE MEMBRANES OF OLFACTORY HAIR CELLS LEADING TO DEPOLARIZATION





1. The cell membrane of an olfactory hair, unstimulated. The gated ion channel is closed.
2. An odorant binds to a specific odorant receptor.
3. The associated G protein is activated.
4. The α subunit of the G protein binds to and activates adenylate cyclase.
5. Adenylate cyclase catalyzes the conversion of ATP to cyclic AMP (cAMP).
6. cAMP opens ion channels, such as Na^{+} and Ca^{2+} channels.
7. Ions entering the olfactory hair cause depolarization of the neuron.

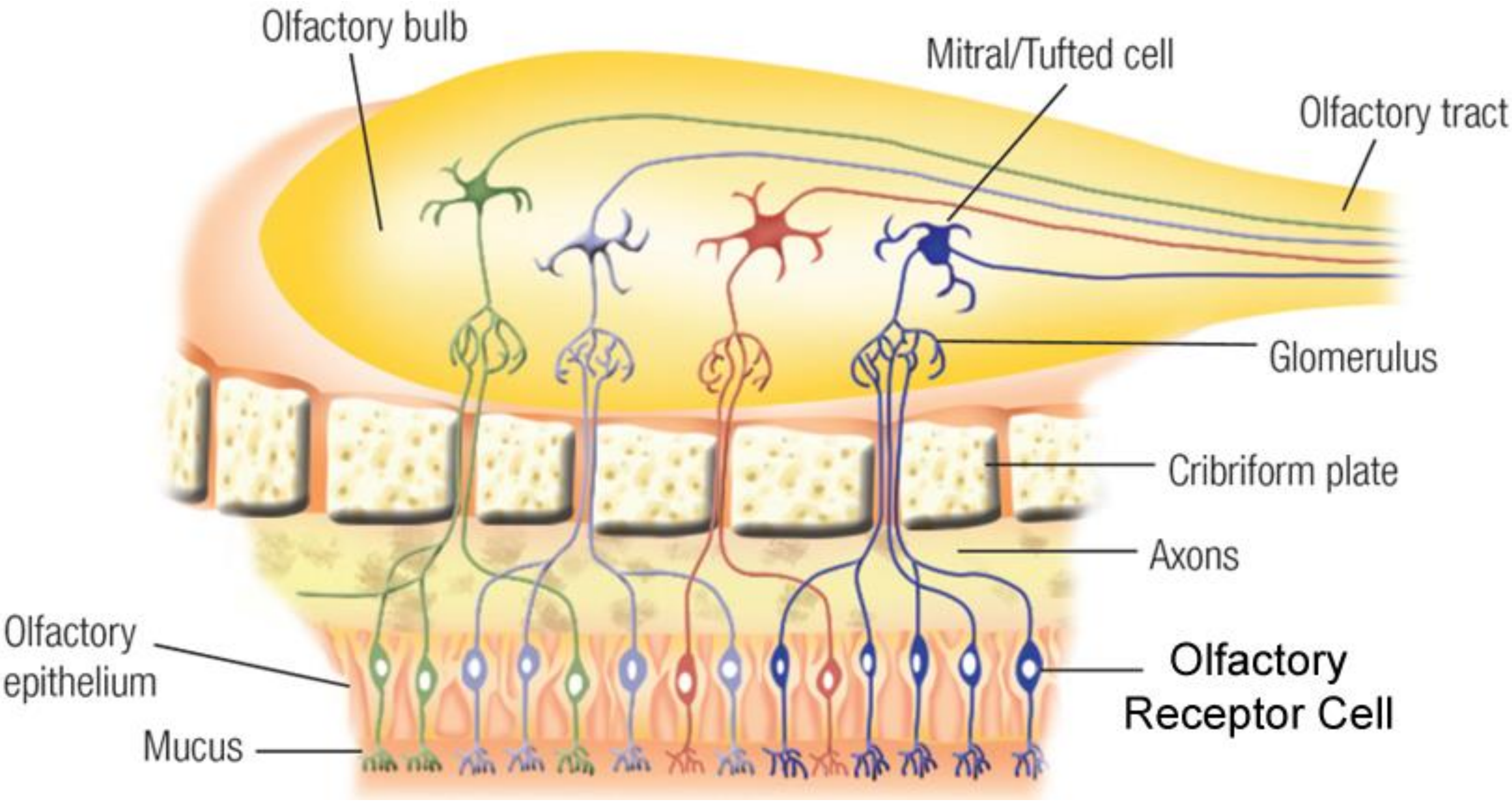
Shape Theory of Odor Specificity



(Shape/Geometry versus [Quantum Vibration/Resonance](#))

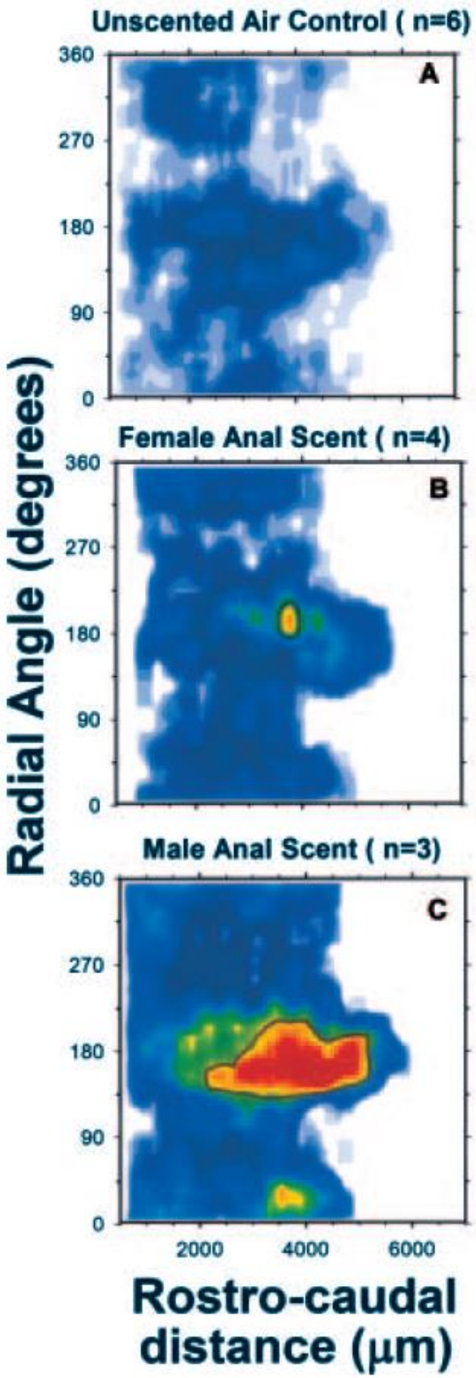
SENSATION & PERCEPTION 4e, Figure 14.9

Olfactory Bulb



5-10 Million ORCs in olfactory epithelium (100X more in Bloodhound)
1000 olfactory proteins/receptor types (5% of genome in rat; **Axel & Buck**)
350-400 olfactory proteins in humans (1% of genome)
1:1:1 rule: 1 ORC -> expressing 1 OR protein -> 1 ORP-specific glomerulus

“Odor Maps”

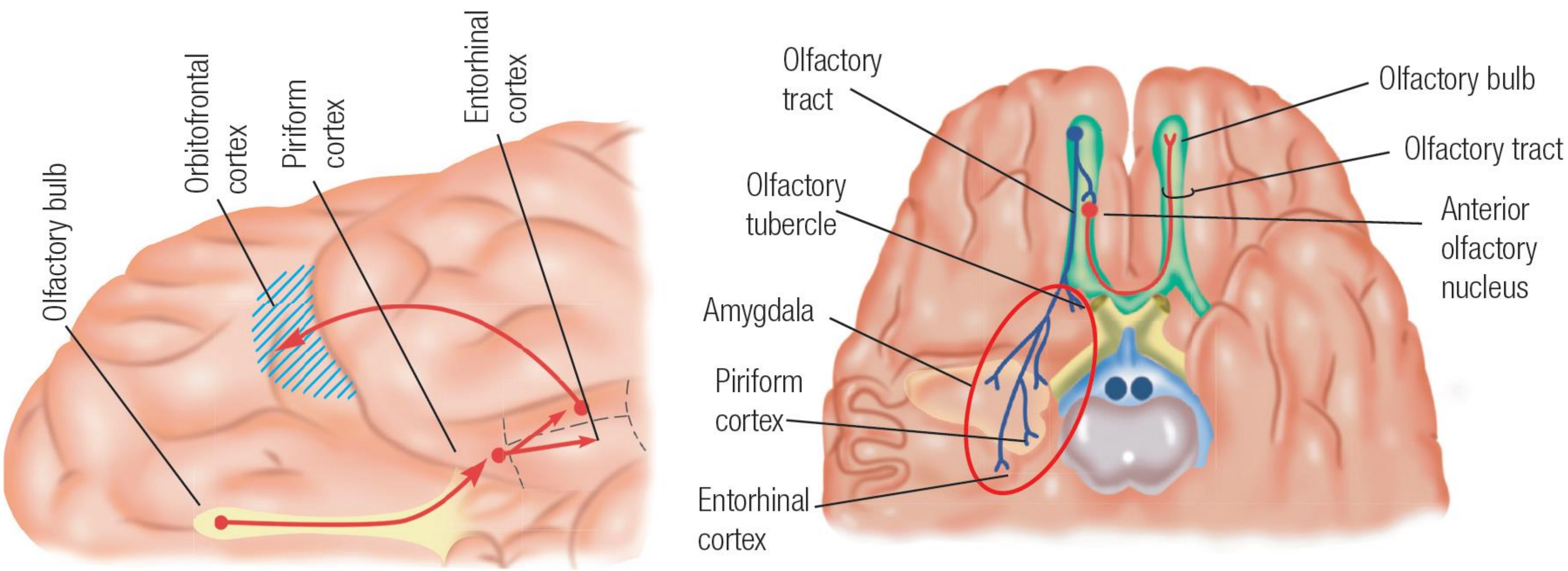


Pattern of glomeruli activation in oestrous female ferrets after exposure to control, female and male scent markings

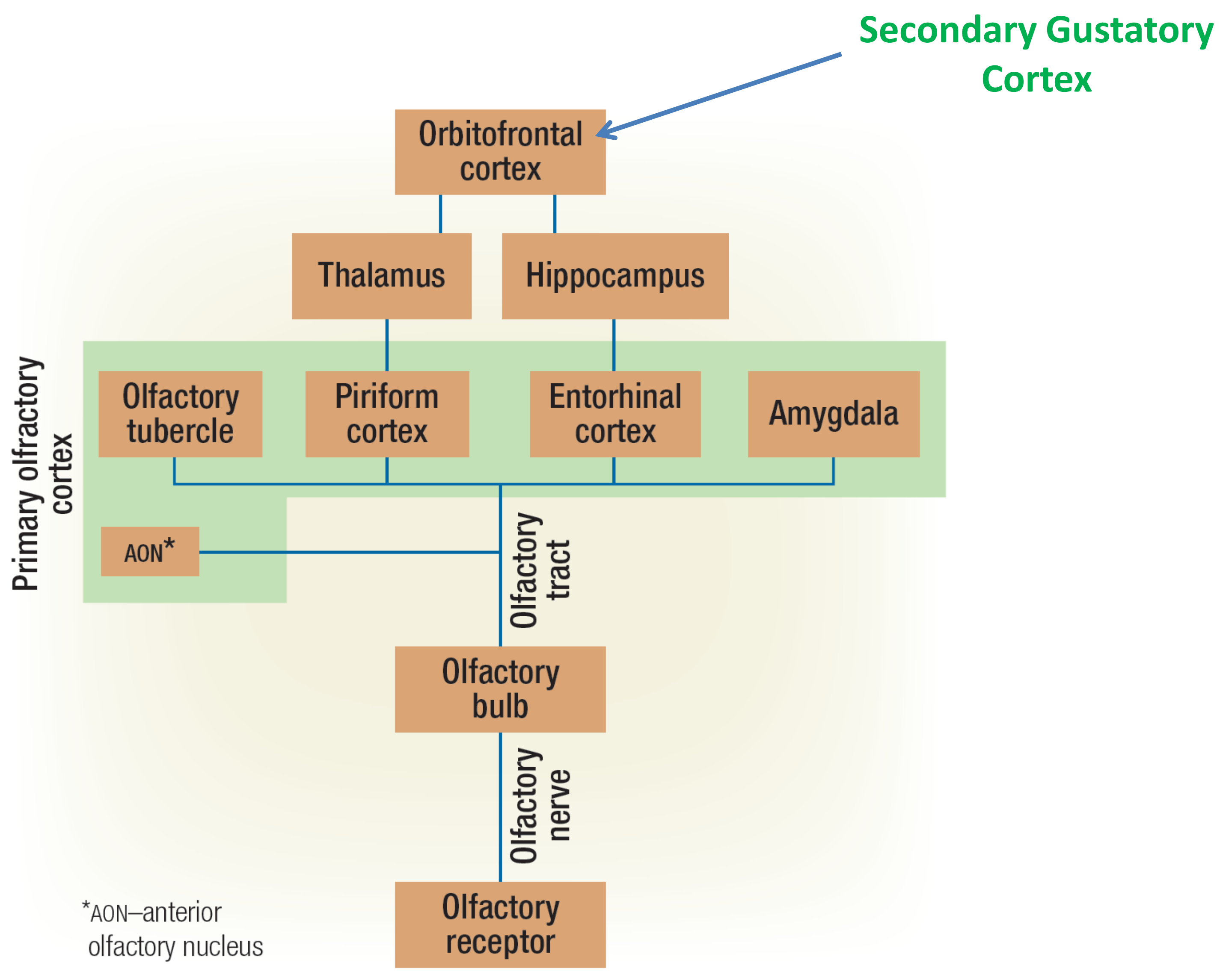
Woodley & Baun (2004)
European J. Neuroscience

[Glomeruli Activation Movie]

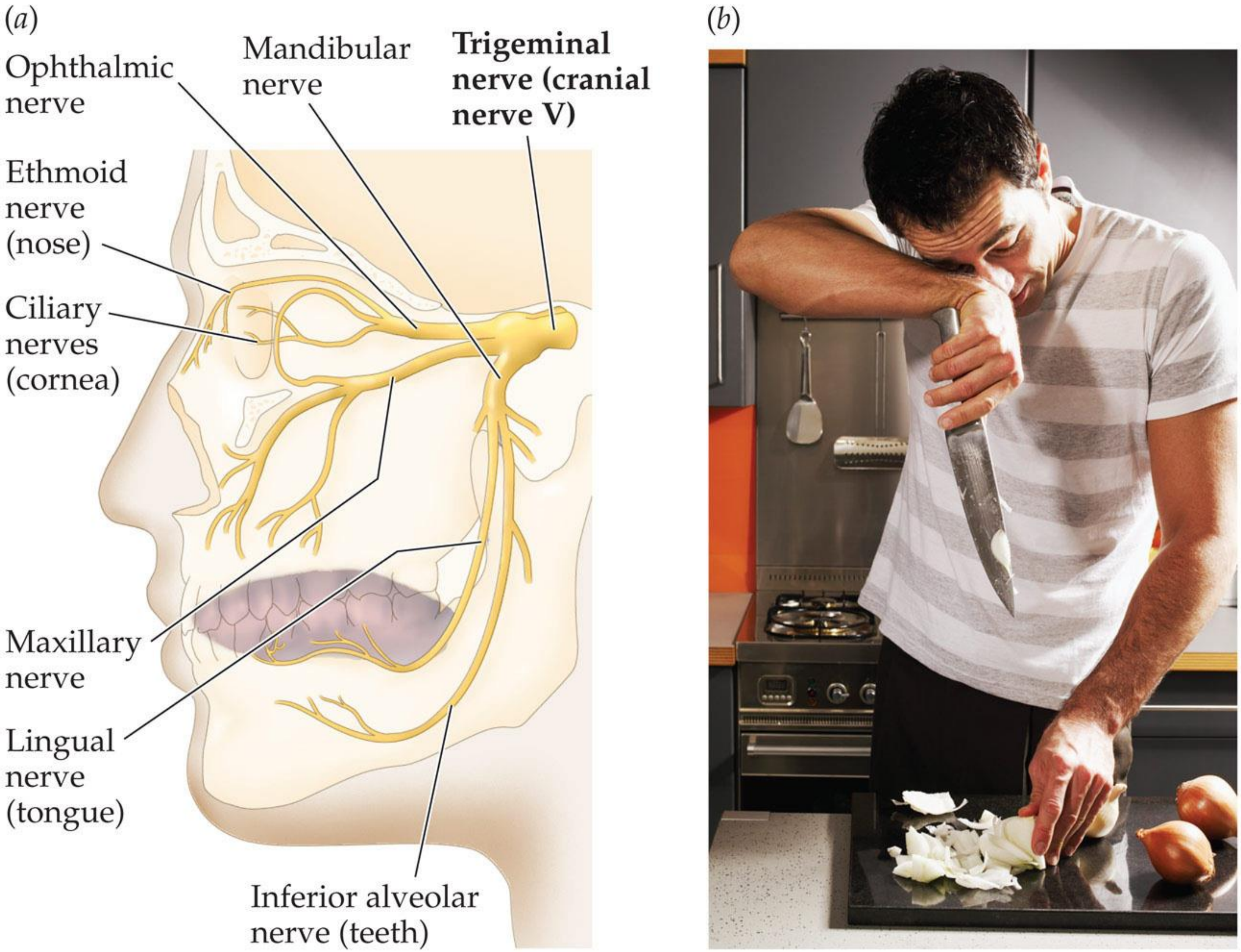
Ascending Pathways



Ascending Pathway Schematic



Trigeminal Nerve Stimulation



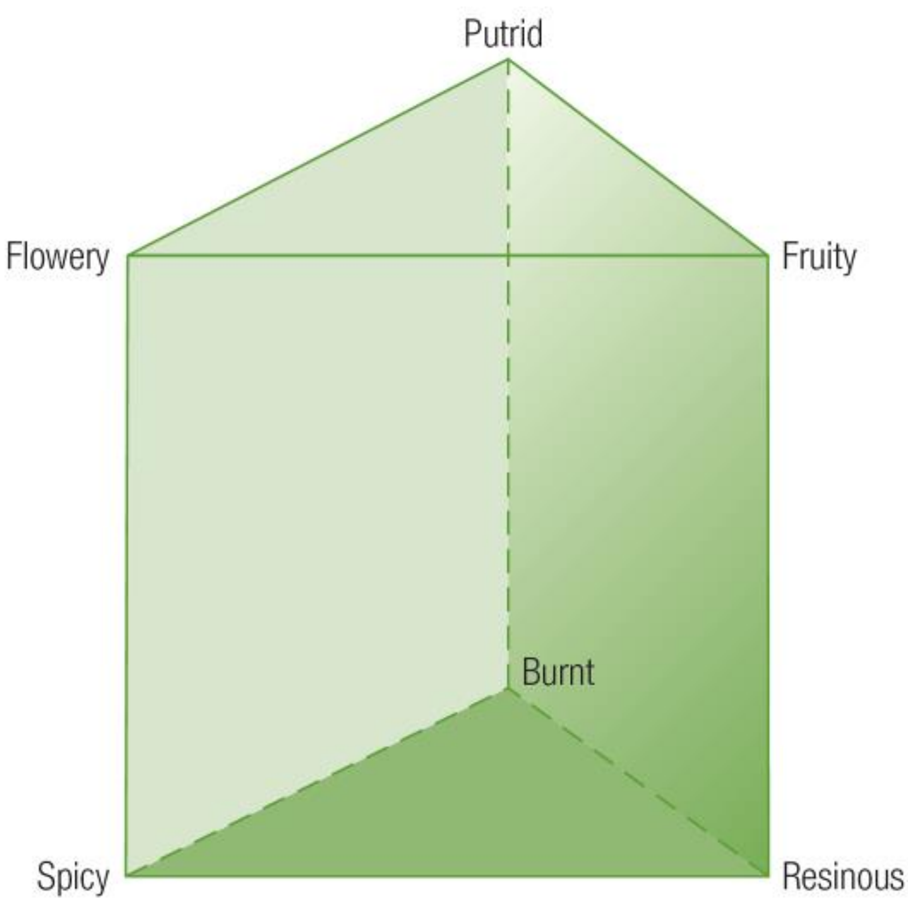
SENSATION & PERCEPTION 4e, Figure 14.8

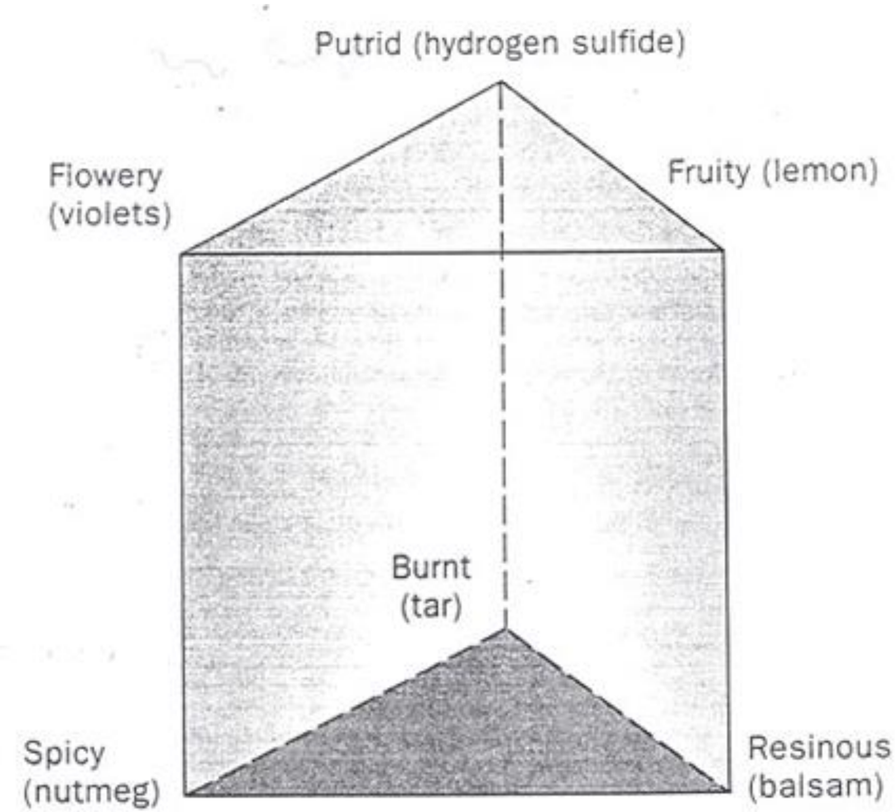
Onions -> tears
Pepper -> sneeze
Smelling salts:
arousal

Olfactory Models and Psychophysics

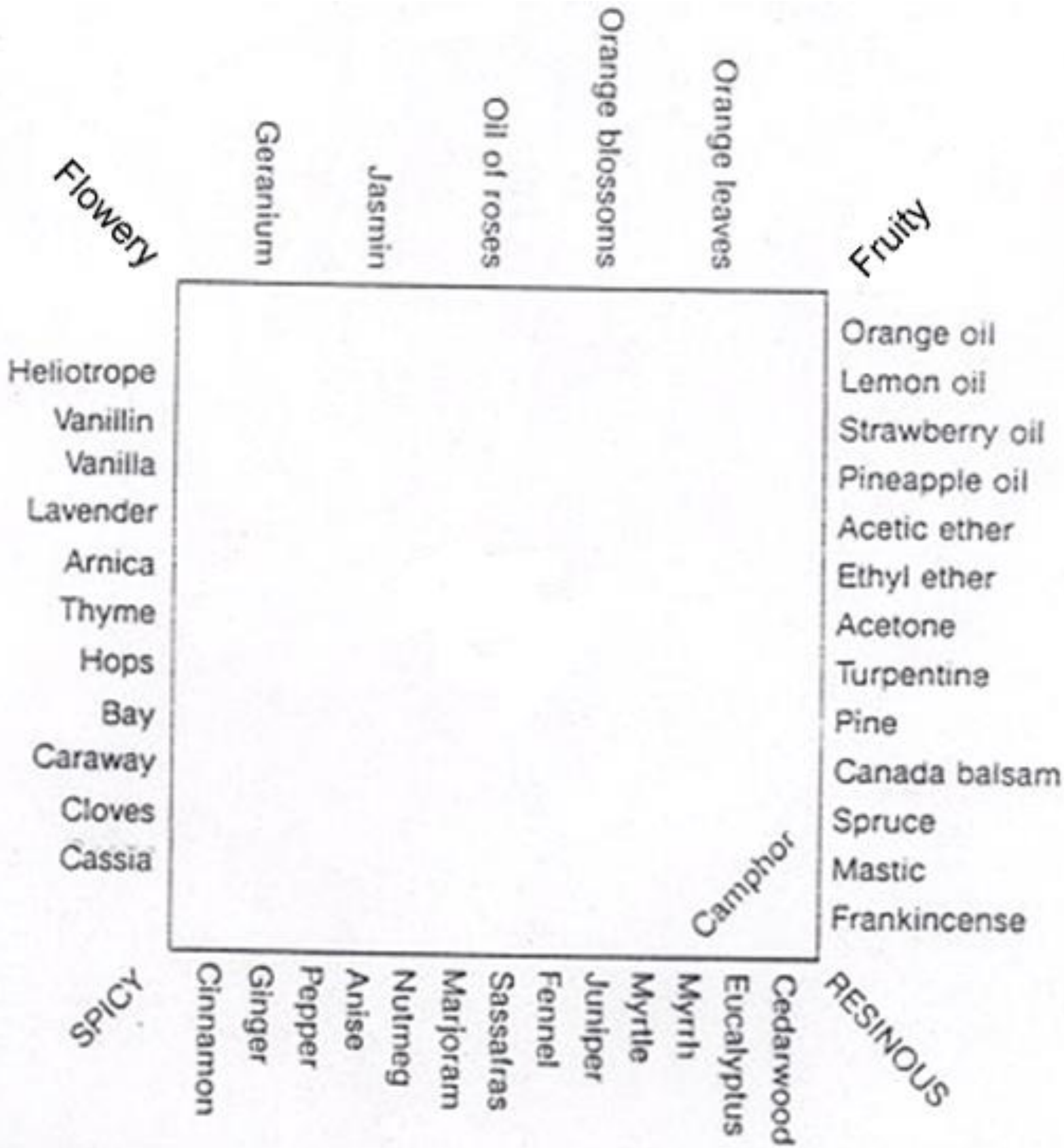
Henning's Smell Prism

(6 primaries odors + geometry)

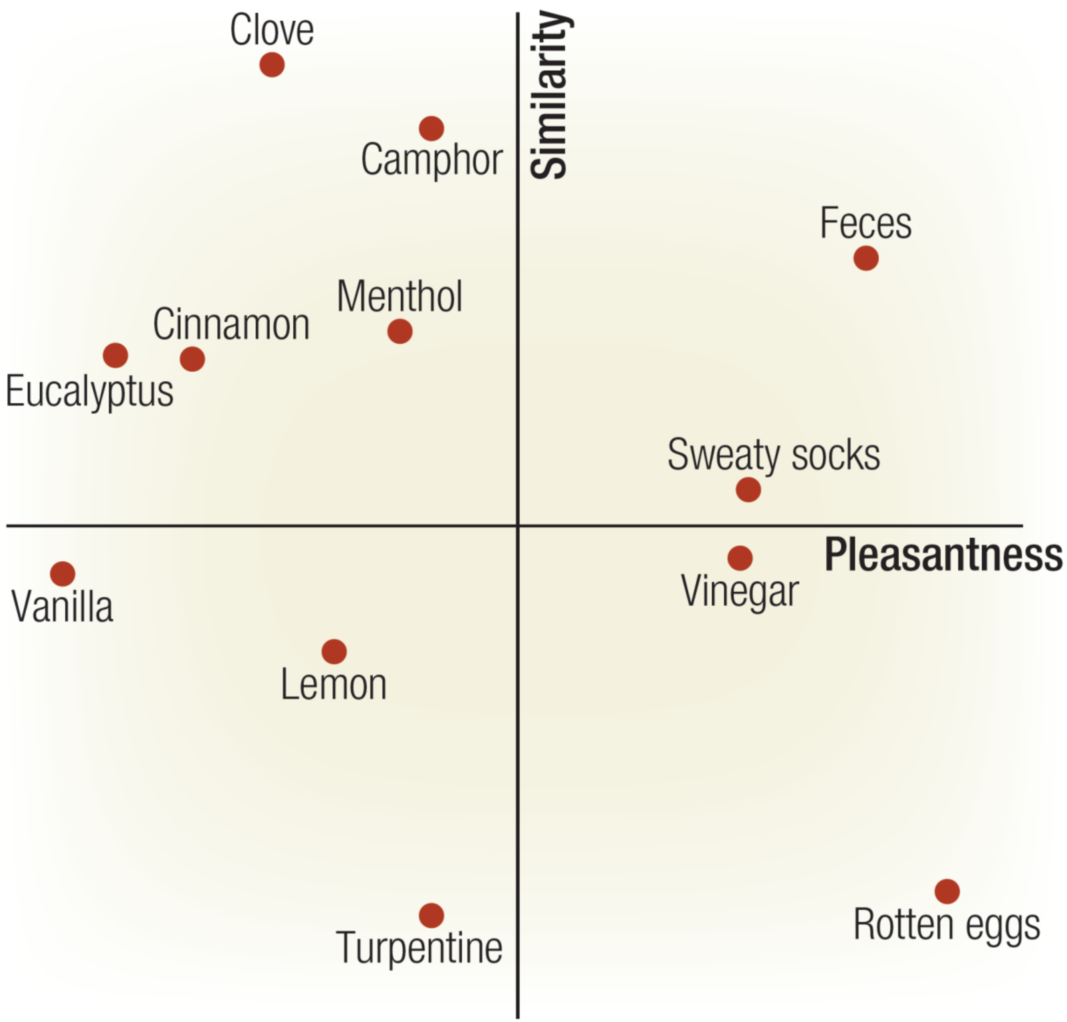




One Face of the Henning Smell Prism



MultiDimensional Scaling Approach



Highly Diverse Smell Thresholds

(micrograms/Liter or PPB)

Musk	0.00007
Lemon	0.003
Vanilla	0.002
Rotten eggs	0.2
Bitter almond	3.0
Perspiration	9.0
Banana	39.0
Wintergreen	100.0

PPTrillion

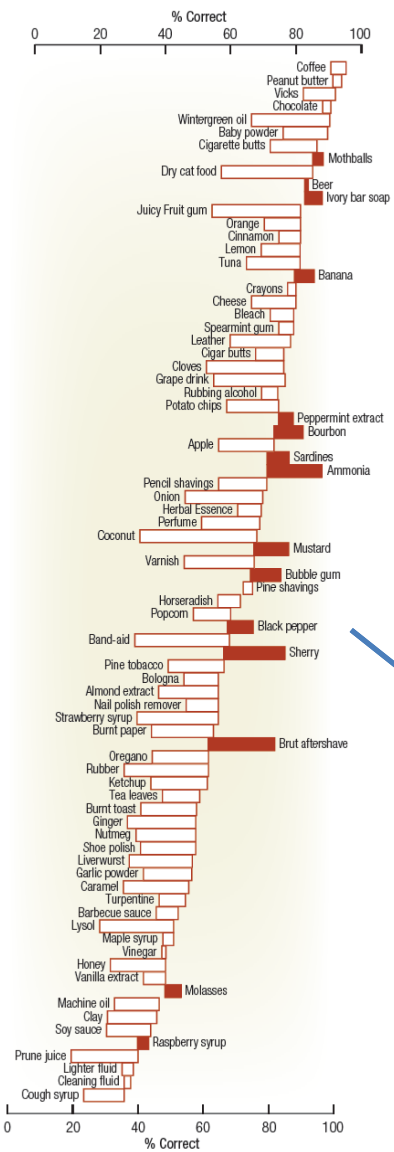
Million-fold difference between most and least sensitive thresholds.

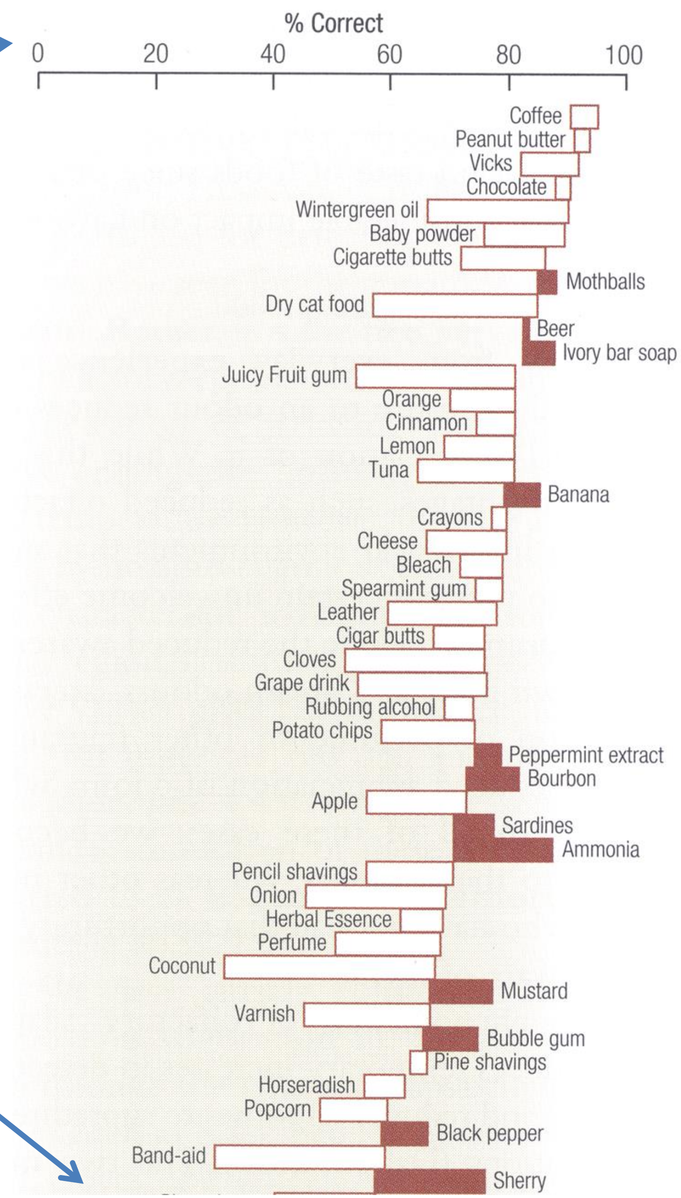
Olfactory Sensitivity

- Absolute thresholds vary by 6 log units across known stimulus set
- JND = 7%
  More sensitive than taste
  Implications for odor localization
- Females generally demonstrate superior detection and discrimination

% Identification of Common Odors

(Females > Males except dark bars)





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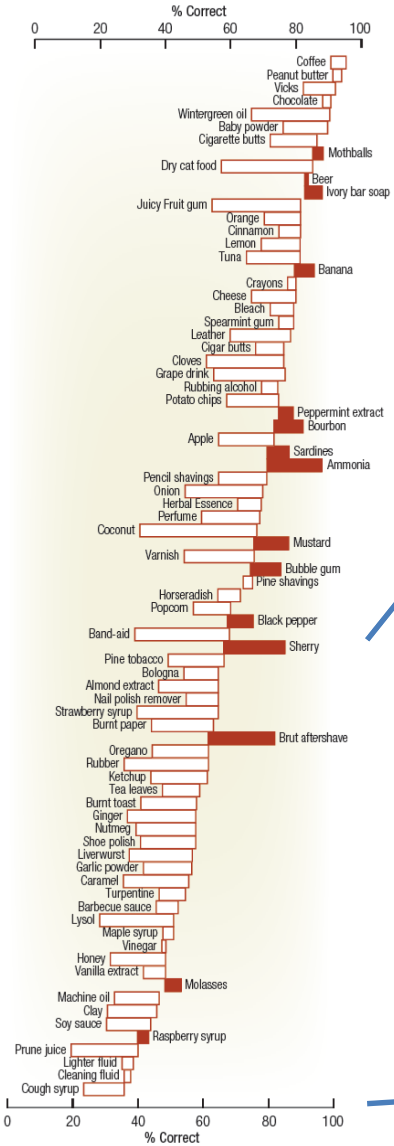
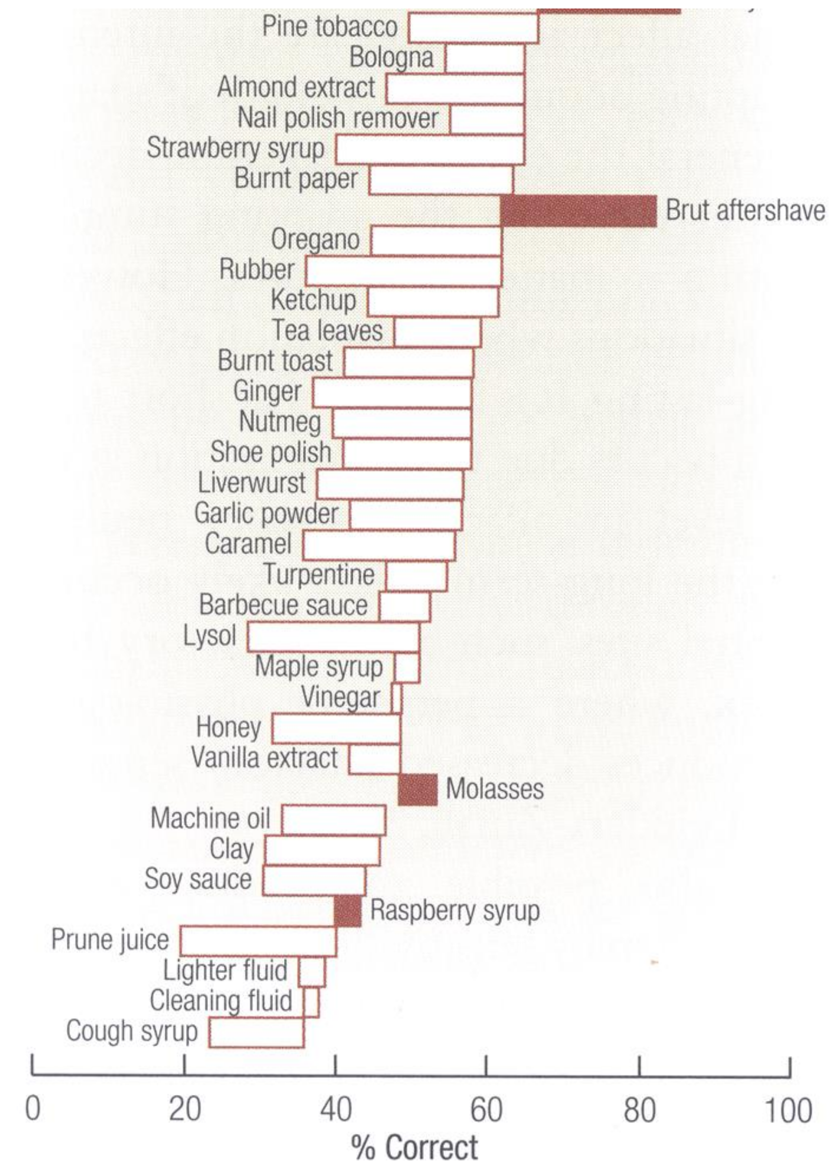
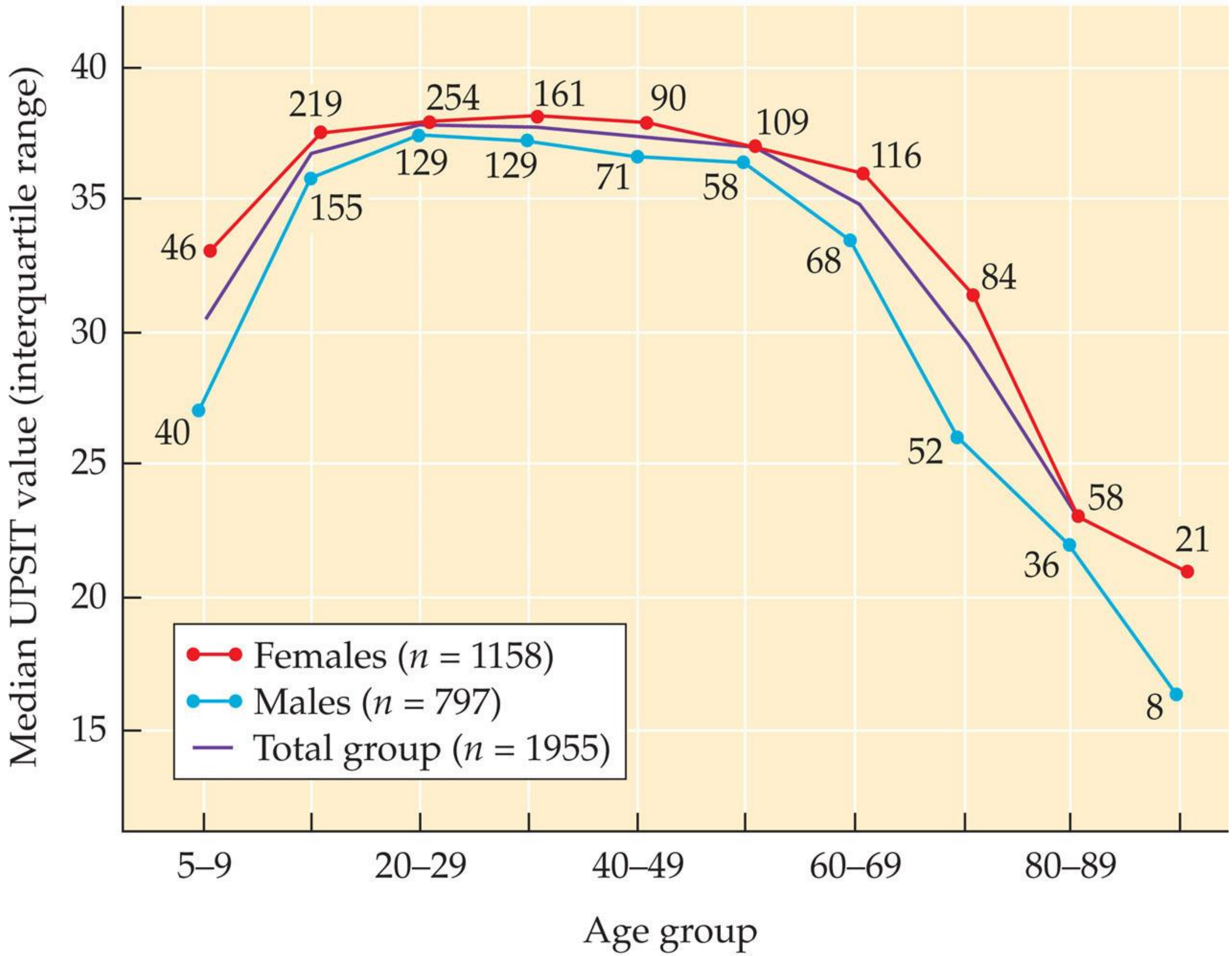




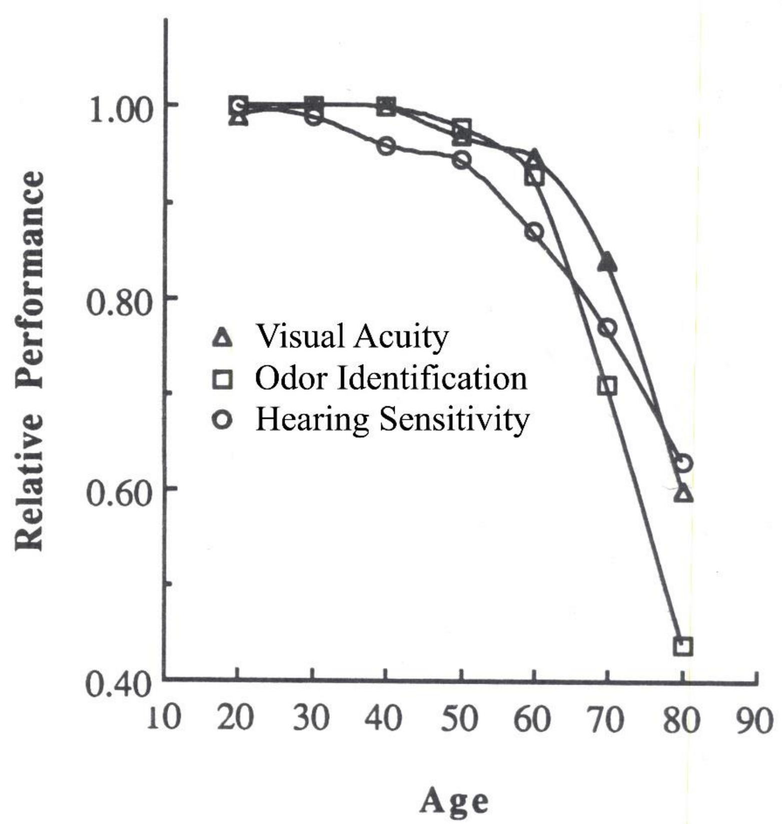
Aging and Odor Identification

(National Geographic Scratch n' Sniff Test)



SENSATION & PERCEPTION 4e, **Figure 14.14**

Visual, Auditory & Olfactory Aging



Source: Schieber (1992)

Some Intriguing Findings

- Wallace (1977)
  80-90% accurate gender identification upon "blind" sniff of the hand
- Russell (1977)
  22-of-29 college students could discriminate their own sweaty T-shirt from 2 distractors
- Human "pheromones"? (vestigial VNO)
- McClintock Effect
  (slippery phenomenon…i.e., unreliable effect)

Odor Identification Test

Answers

1	Lemon
4	Pineapple
12	Strawberry
27	Honey
30	Green Pepper
36	Licorice
40	Vanilla
43	Black Pepper
47	Butter
54	“Smokey”