Molecular Literacy for All

CO_2 to $C_6H_{12}O_6$: Photosynthesis

Boiling water, which tops out at 212°F (100°C) at sea level, isn't hot enough. That's why a boiled steak turns gray instead of dark brown, exciting the palate of exactly no one.

ILLINOIS
Beckman Institute for Advanced Science & Technology

Jeff Moore (email: jsmoore@Illinois.edu)

Session 7 Today's Outline

Making Sugar

- RuBisCO
- Calvin Cycle
- Photorespiration

Making Bread

- Composition of a Wheat Berry
- Gluten Formation
- Maillard Reaction

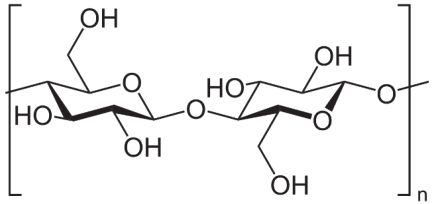
Taste & Smell

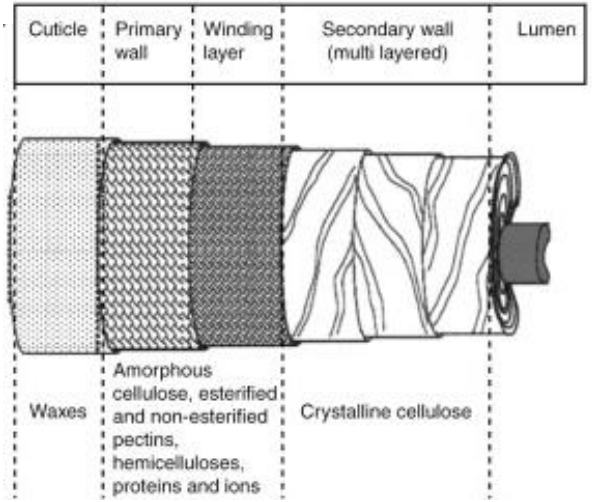
- Taste receptors
- Signal Transduction
- Three Theories of Smell

Jose Intro – Loves Chemistry & Loves Language

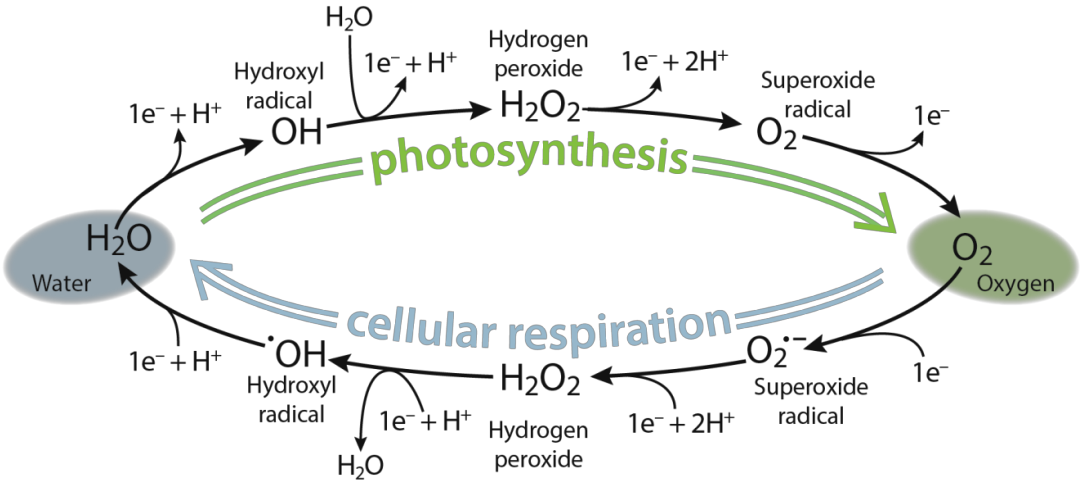
English	Spanish	Greek	Arabic
glucose	glucosa		

Cotton Composition

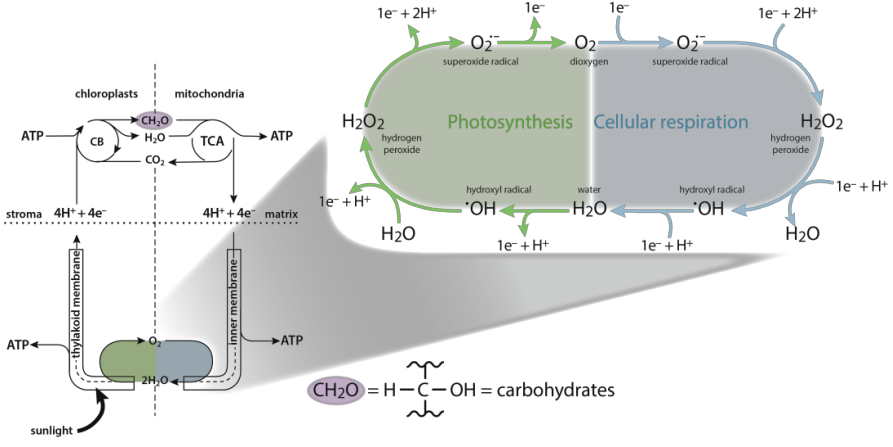


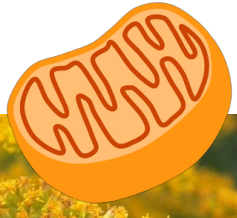


The Jekyll and Hyde of dioxygen

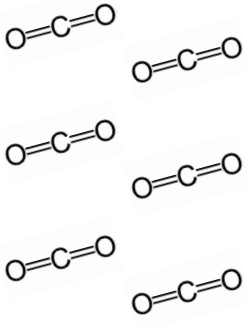


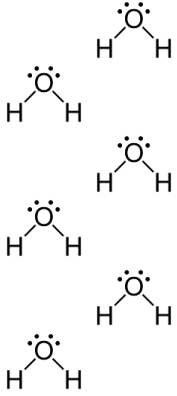
Science 07 May 1954: Vol. 119, Issue 3097, pp. 623-626
DOI: 10.1126/science.119.3097.623

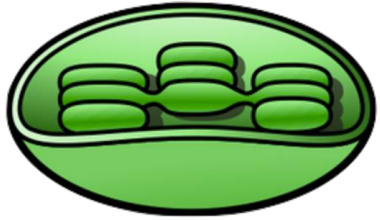

chloroplasts
mitochondria
ATP
CB
TCA
ATP
CH_2O
H_2O
CO_2
stroma
$4H^+ + 4e^-$
$4H^+ + 4e^-$
matrix
thylakoid membrane
inner membrane
ATP
ATP
O_2
$2H_2O$
sunlight
$1e^- + 2H^+$
$1e^-$
$1e^-$
$1e^- + 2H^+$
$O_2^{\cdot-}$
superoxide radical
O_2
dioxygen
$O_2^{\cdot-}$
superoxide radical
H_2O_2
hydrogen peroxide
Photosynthesis
Cellular respiration
H_2O_2
hydrogen peroxide
$1e^- + H^+$
hydroxyl radical
$^{\cdot}OH$
water
H_2O
hydroxyl radical
$^{\cdot}OH$
$1e^- + H^+$
H_2O
$1e^- + H^+$
$1e^- + H^+$
H_2O
CH_2O = H — C — OH = carbohydrates

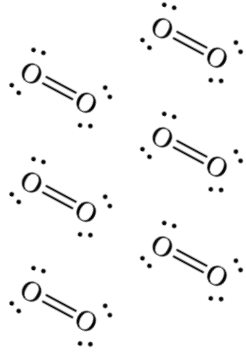


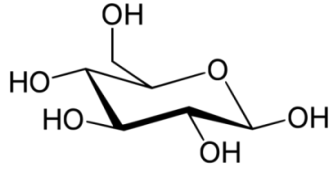
Carbon fixation











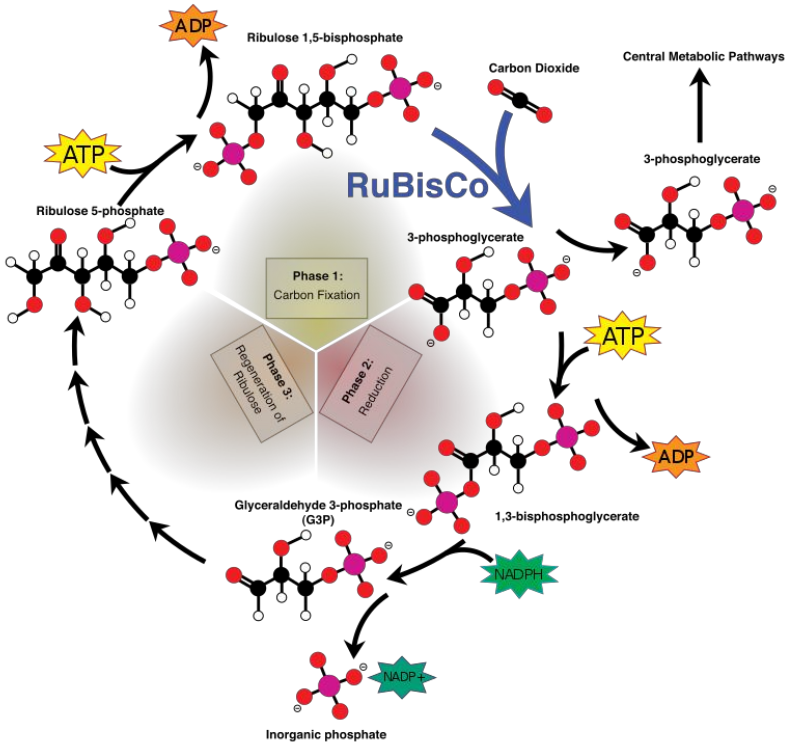
when you are far more vital to life on earth but the mitochondria gets all the glory

Calvin Cycle

To create 1 surplus G3P requires 3 carbons, and therefore 3 turns of the Calvin cycle. To make one glucose molecule (which can be created from 2 G3P molecules) would require 6 turns of the Calvin cycle.

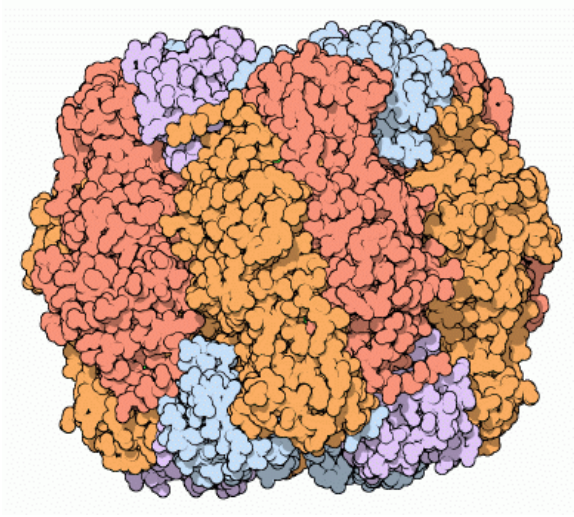
There are 11 reactions involved in this cycle, several of which models have identified as limiting steps that are negatively impacted by the changing climate.

RIPE is working on increasing the efficiency of plants to regenerate sugars.

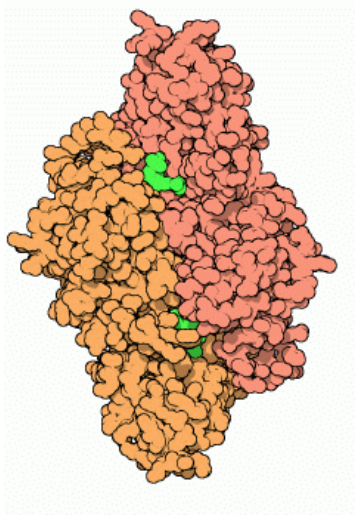


RIPE Realizing Increased Photosynthetic Efficiency

RuBisCO

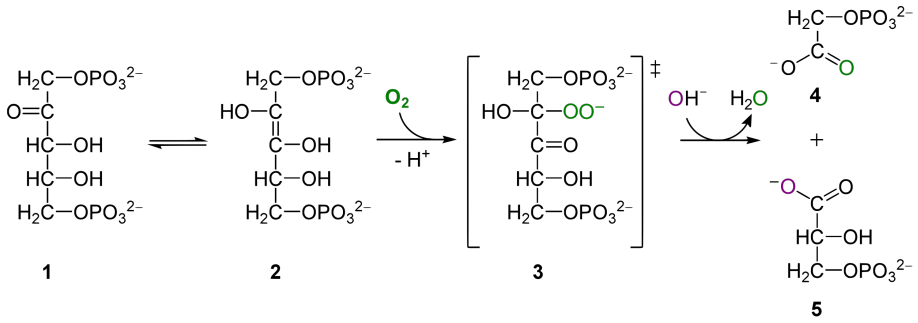


16mer RuBiSCO from spinach.



Dimer RuBISCO from photosynthetic bacteria.

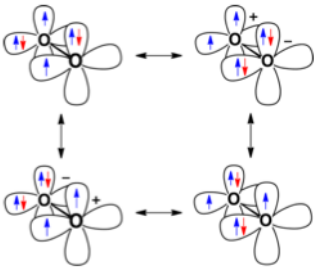
https://pdb101.rcsb.org/motm/11



Why did nature choose oxygen?

Table 1. Enthalpies of Reaction, $\Delta H(298.15\ K)$ in kcal/mol, Obtained from Experimental Heats of Formation, $\Delta_f H°(298.15\ K)$, and from G4 Calculations

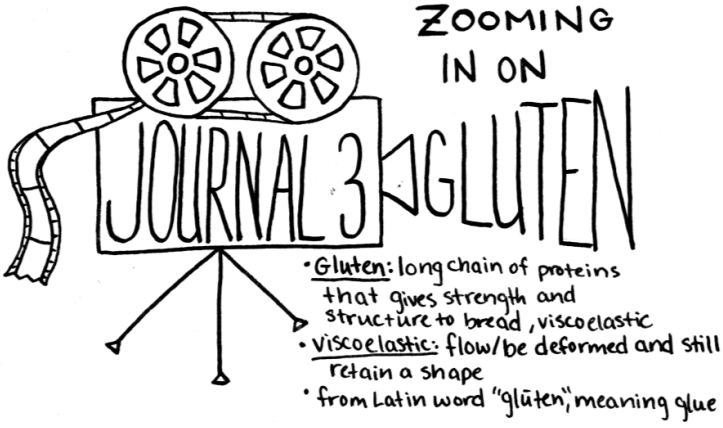
reaction label	reaction	$\Delta H(298.15\ K)$ G4 value	$\Delta H(298.15\ K)$ ATcT value
A	$^{\bullet}OH + H_2O_2 \rightarrow H_2O + {}^{\bullet}OOH$	−31.6	−31.0
B	$^{\bullet}OH + {}^{\bullet}OOH \rightarrow H_2O + {}^{\bullet}OO^{\bullet}$	−69.0	−69.2
C	$2\ {}^{\bullet}OOH \rightarrow HOOH + {}^{\bullet}OO^{\bullet}$	−37.4	−38.2
D	$2\ {}^{\bullet}OH + HOOH \rightarrow 2H_2O + {}^{\bullet}OO^{\bullet}$	−100.6	−100.2
E	$3\ {}^{\bullet}OO^{\bullet} \rightarrow O_6$ (cyclic)	+79.4	
F	$4\ {}^{\bullet}OO^{\bullet} \rightarrow O_8$ (cyclic)	+94.6	
G	$2\ {}^{\bullet}OOH \rightarrow HOOOOH$	−15.4	
H	$^{\bullet}SH + H_2S_2 \rightarrow H_2S + {}^{\bullet}SSH$	−17.5	
I	$^{\bullet}SH + {}^{\bullet}SSH \rightarrow H_2S + {}^{\bullet}SS^{\bullet}$	−33.4	
J	$2\ {}^{\bullet}SSH \rightarrow HSSH + {}^{\bullet}SS^{\bullet}$	−15.9	
K	$2\ {}^{\bullet}SH + HSSH \rightarrow 2H_2S + {}^{\bullet}SS^{\bullet}$	−50.9	
L	$3\ {}^{\bullet}SS^{\bullet} \rightarrow S_6$ (cyclic)	−70.8	
M	$4\ {}^{\bullet}SS^{\bullet} \rightarrow S_8$ (cyclic)	−103.0	
N	$2\ {}^{\bullet}SSH \rightarrow HSSSSH$	−41.2	

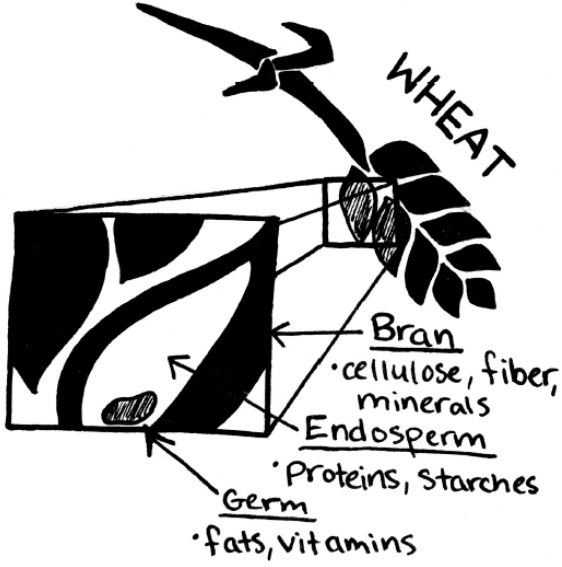


reaction label	reaction	$\Delta H(298.15\ K)$ G4 value	$\Delta H(298.15\ K)$ ATcT value
O	$H_2 + {}^{\bullet}OO^{\bullet} \rightarrow HOOH$	−31.6	−32.4
P	$H_2 + HOOH \rightarrow 2H_2O$	−83.3	−83.2
Q	$2H_2 + {}^{\bullet}OO^{\bullet} \rightarrow 2H_2O$	−114.9	−115.6
R	$H_2O_2 \rightarrow 2\ {}^{\bullet}OH$	48.9	49.4

J. Am. Chem. Soc. 2017, 139, 26, 9010–9018

What is in the wheat berry?





Nerija Cuplinskas

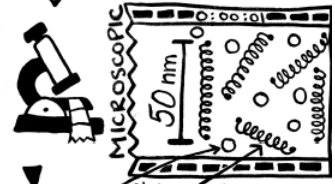
Prof. Gabe Rudebusch

- dry, free flowing flour
- water added to form sticky dough

ZOOM

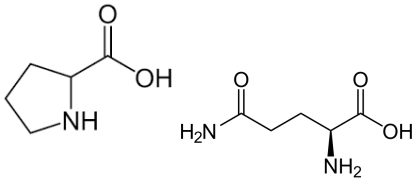
- flour granules contain starches and protein building blocks for gluten formation

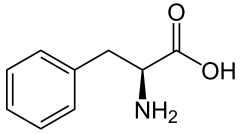
ZOOM



- glutenins: long, coil-like proteins with cysteine rich termini responsible for the structural properties of gluten
- gliadins: monomeric, help dough act like fluid

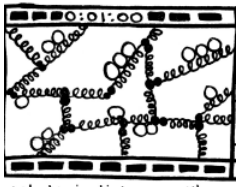
The trigger for those with Celiac disease





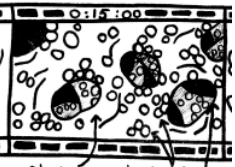
- soft sticky, elastic dough

- gluten begins to form with wetting and oxygenation

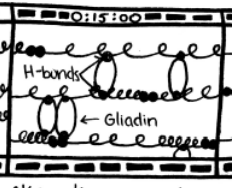


- glutenin links up with disulfide and dityrosine bonds to make long strands into a weblike network

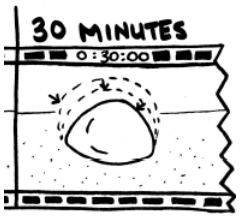
- Shapes dough into a shiny, smooth ball by kneading



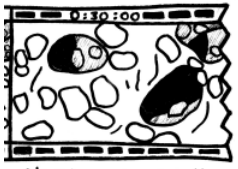
- gluten and starch divided by CO_2 gas bubbles during fermentation



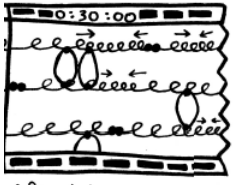
- Kneading orientates the chains
- coils straighten out
- encourages side-by-side bonding through H-bonds



- dough ball retains shape
- shrinks back a bit
- begins to rise

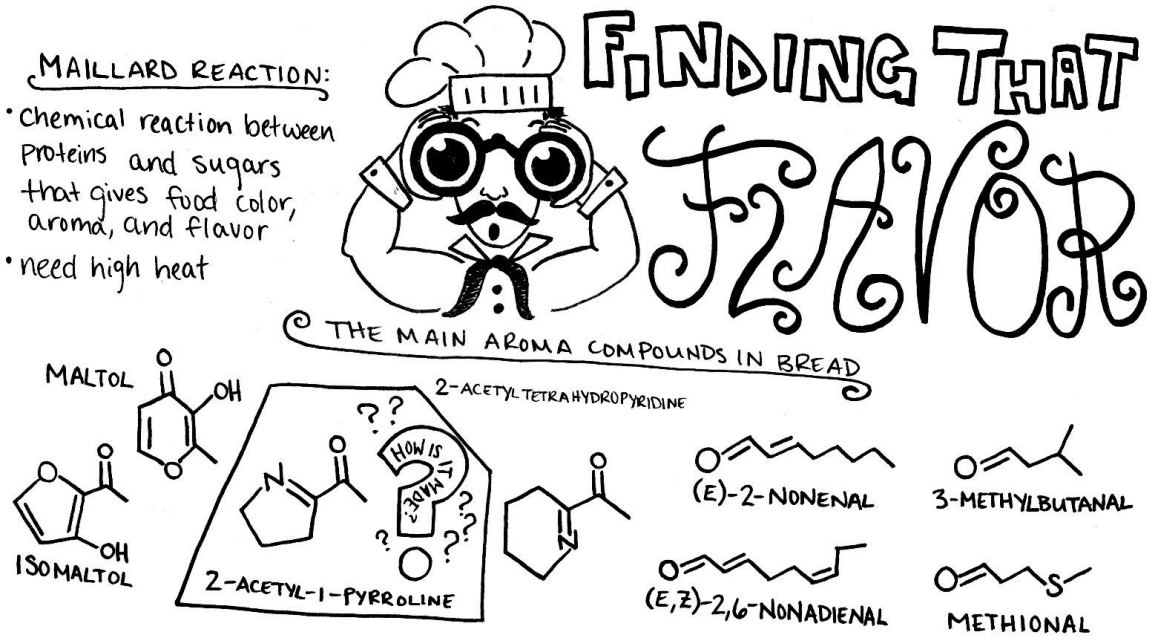


- starch grains swell while absorbing water
- gas bubbles expand

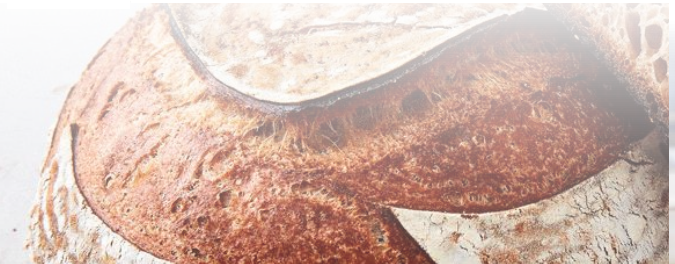


- final dough has viscoelastic properties

NL 2018

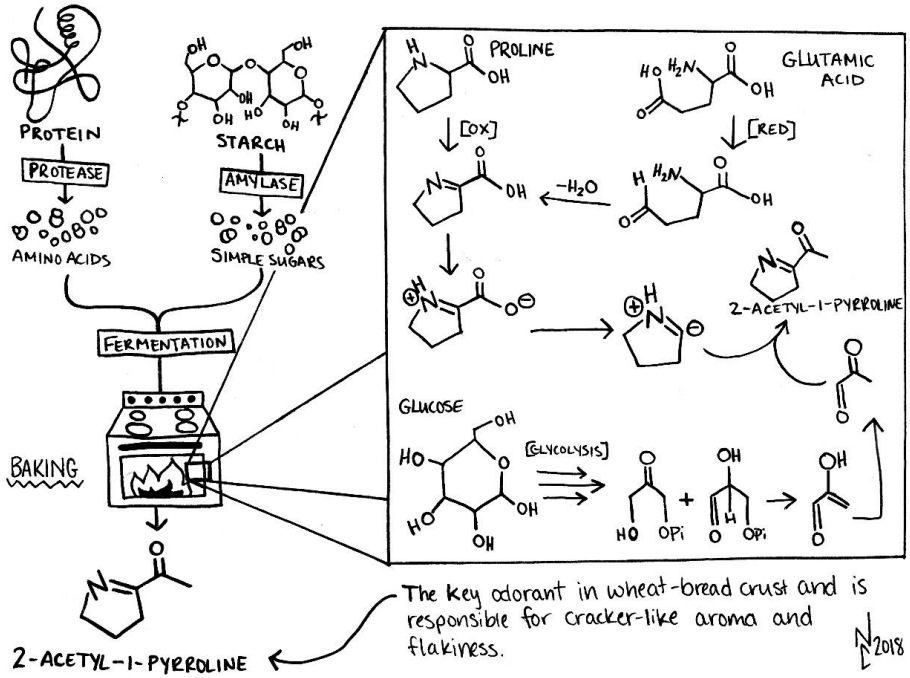


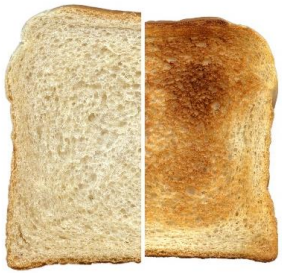
"[…] we have evolved to respond to two important signals when encountering food. The first is a "nutrition" signal that tells us the food will deliver a hefty dose of easily digestible calories, vitamins, and minerals. The second is a "general harmlessness" signal that tells us the food won't kill us. The Maillard reaction is evolution's way of combining these two signals into one super-signal, specific to the roasty or browned flavors of cooked food."



https://www.seriouseats.com/2017/04/what-is-maillard-reaction-cooking-science.html

Maillard Reaction





https://www.seriouseats.com/2017/04/what-is-maillard-reaction-cooking-science.html

Taste

~5000 taste buds in oral cavity

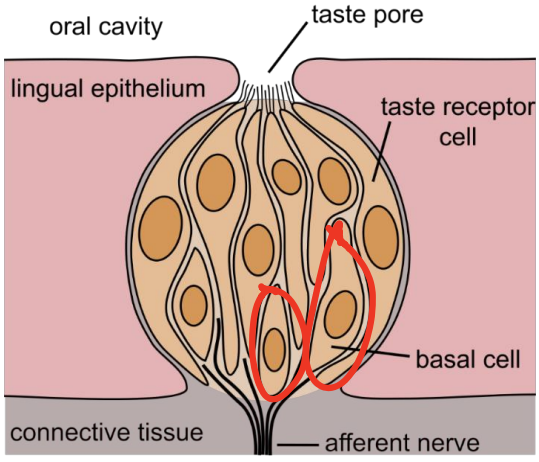
50-100 taste cells in a taste bud

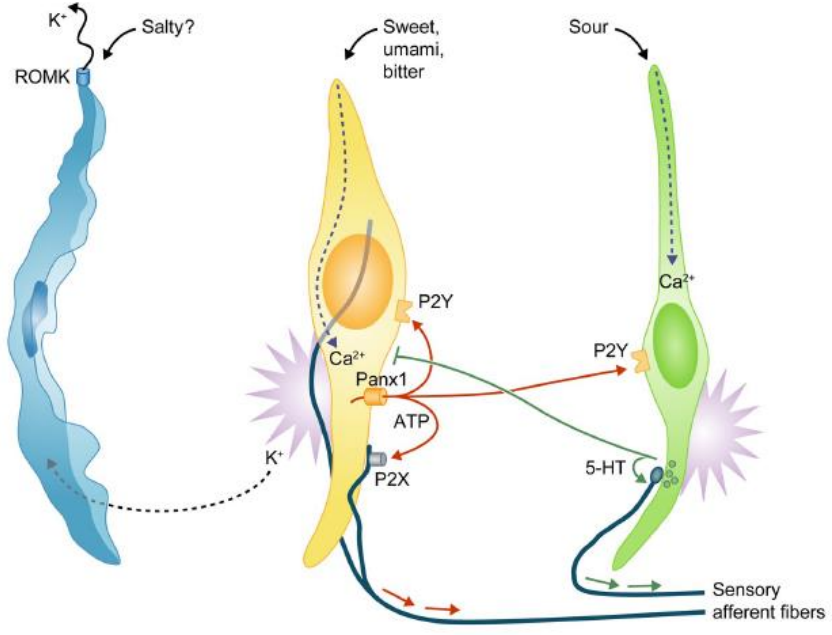
The cell biology of **taste**

Nirupa Chaudhari and Stephen D. Roper

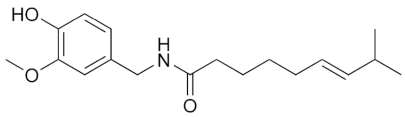
Department of Physiology and Biophysics, and Program in Neurosciences, University of Miami Miller School of Medicine, Miami, FL 33136

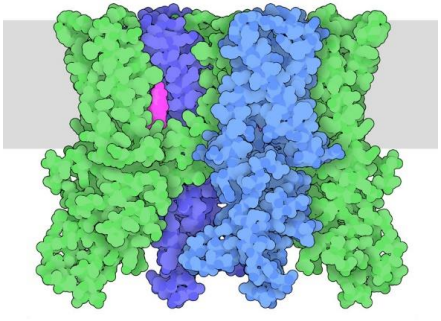
Taste bud


oral cavity
taste pore
lingual epithelium
taste receptor cell
basal cell
connective tissue
afferent nerve


K+
Salty?
ROMK
Sweet, umami, bitter
Sour
P2Y
Ca2+
Panx1
ATP
P2X
K+
Ca2+
P2Y
5-HT
Sensory afferent fibers

Taste receptors





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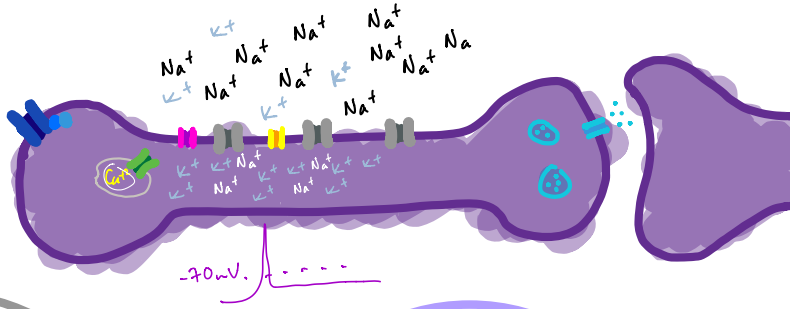
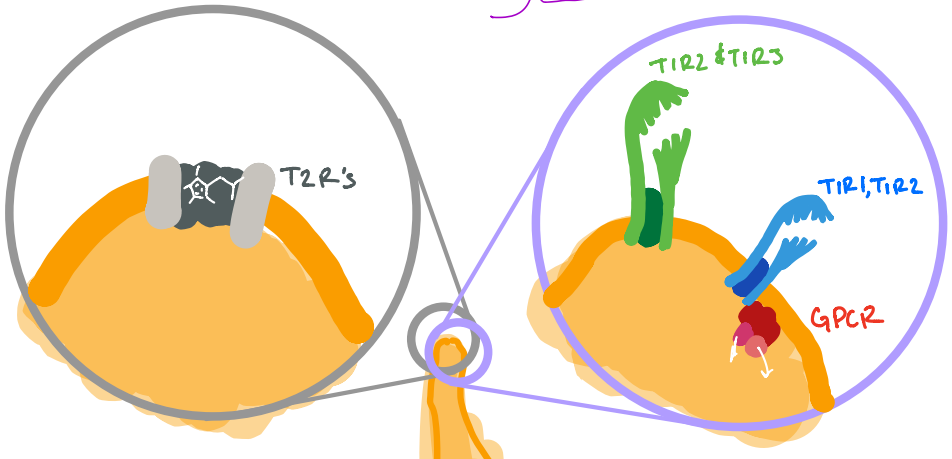
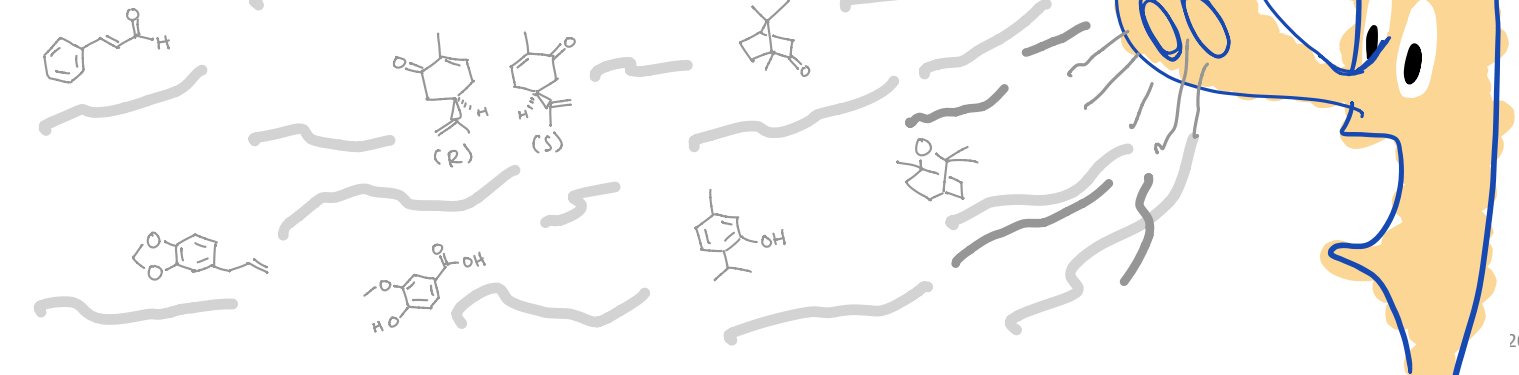


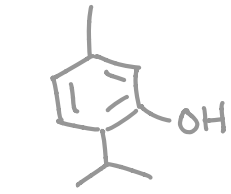


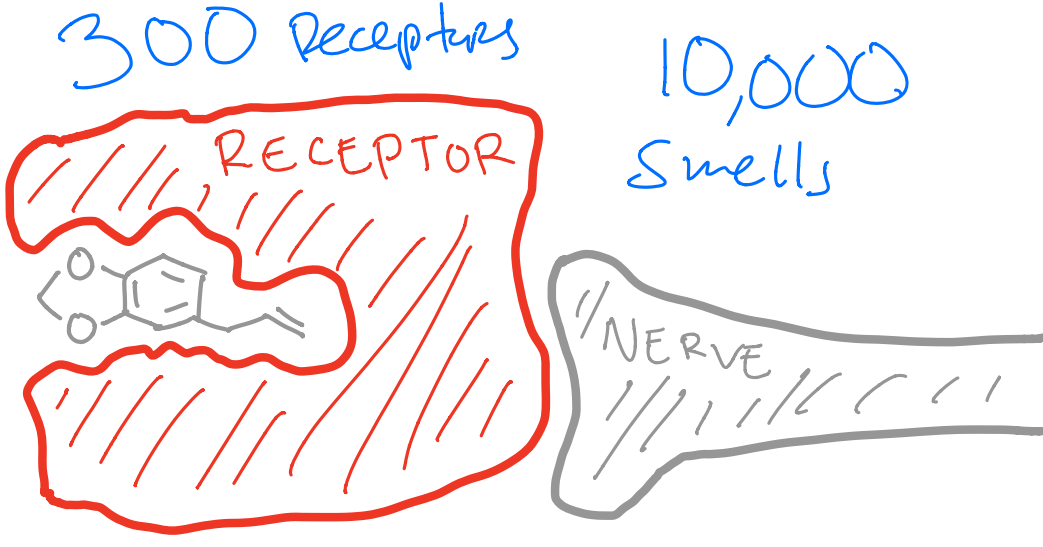
SMELL

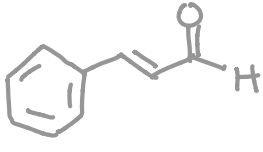
ODORANTS



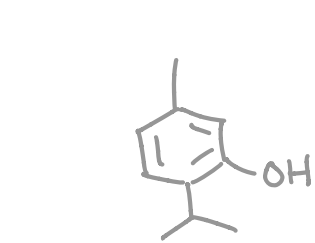
Tight-binding receptors

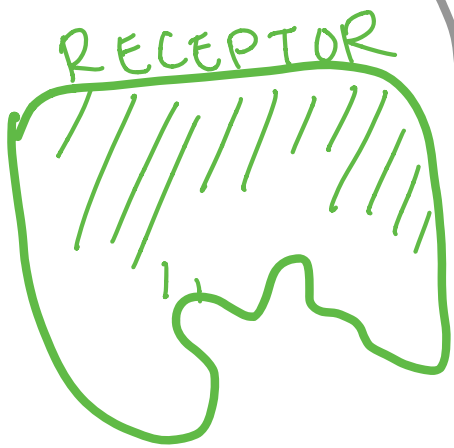


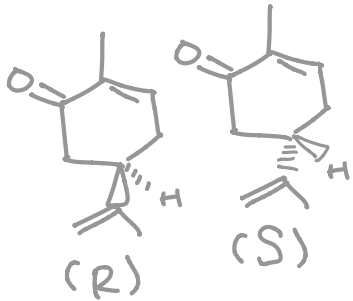


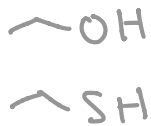


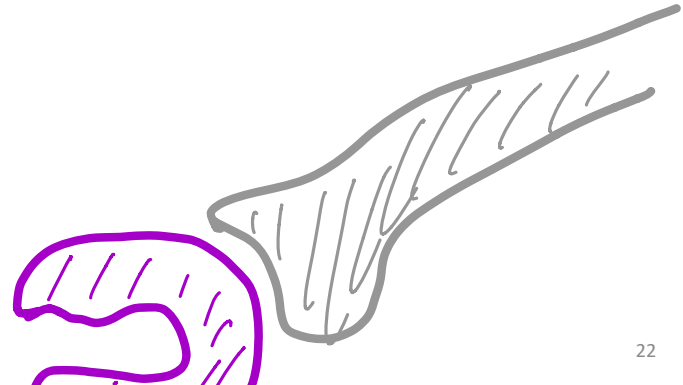
Loose-binding receptors



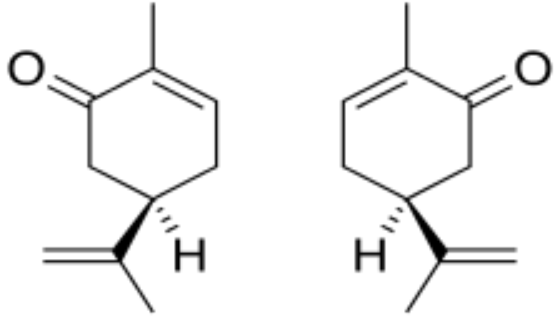




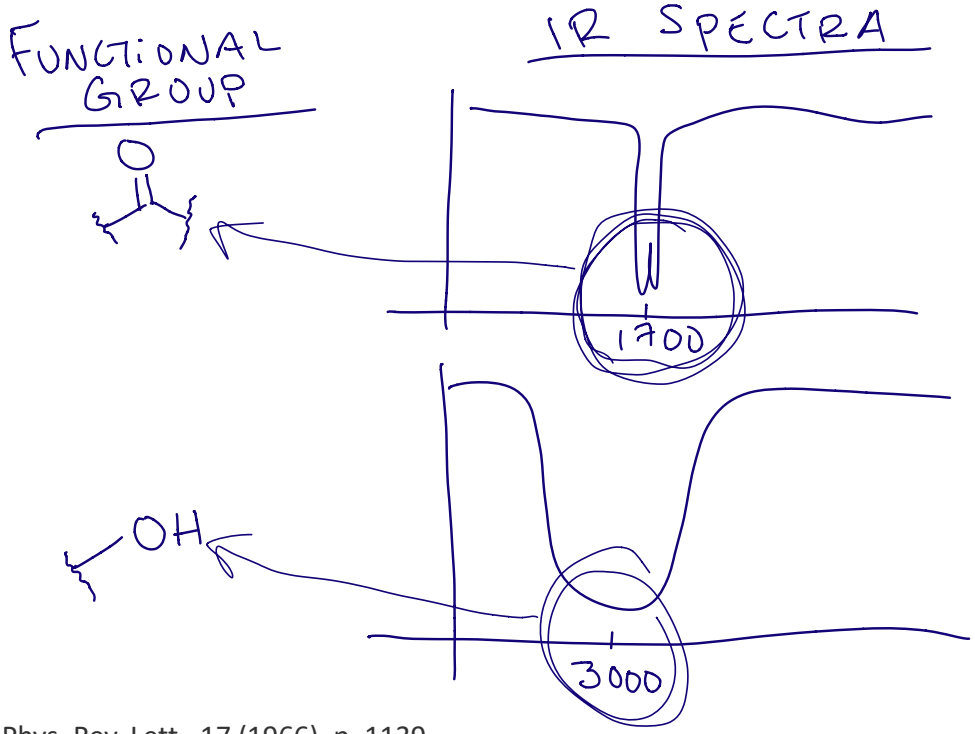




Carvone

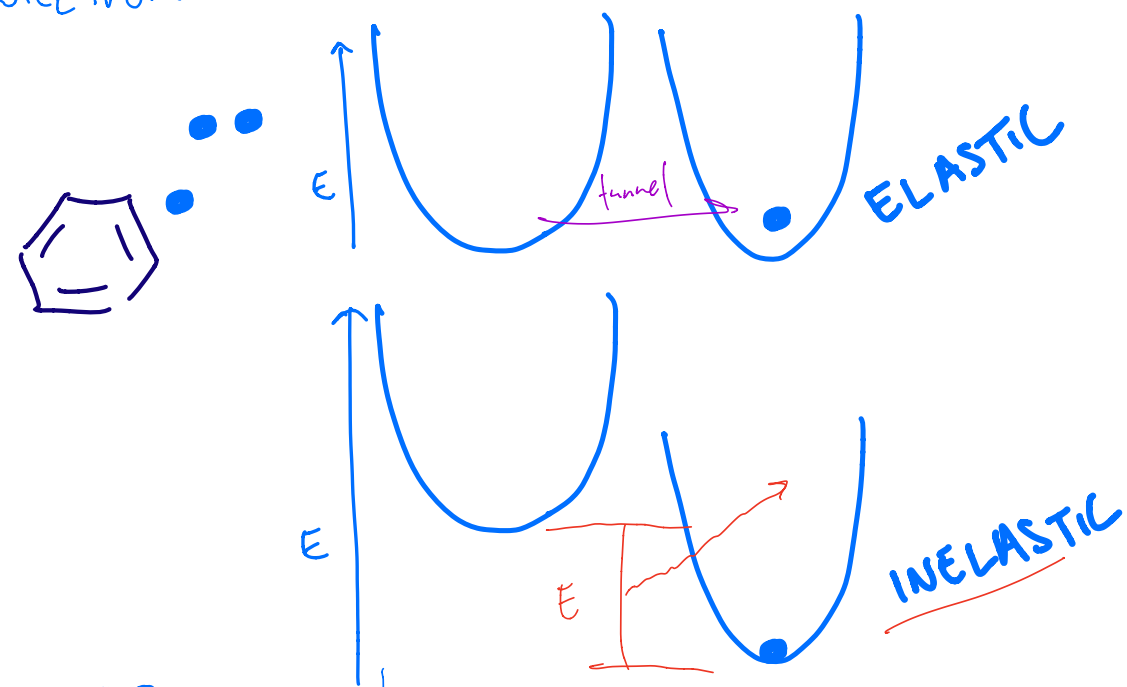


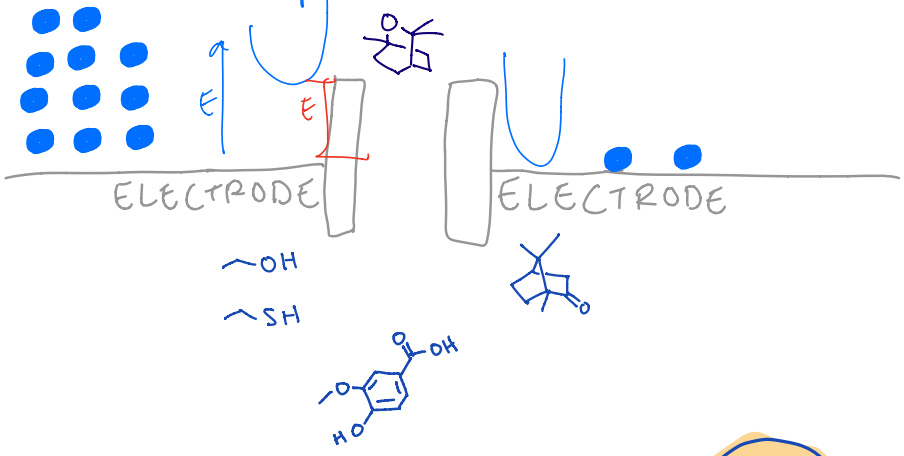
Quantum receptors



R.C. Jaklevic, J. Lambe. Phys. Rev. Lett., 17 (1966), p. 1139

● = electron





FOR FURTHER DETAILS:

LIFE ON THE EDGE

LUCA TURIN TED TALK