PTC MiniLab
Student FRQs

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The digital color version of the Student Worksheet can be found at
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This resource provides 3 total FRQs of the following types:

- Question 1: Interpreting and Evaluating Experimental Results (9 pts)
- Question 4: Conceptual Analysis (4 pts)
- Question 5: Analyze Model or Visual Representation (4 pts)

Q1. Scientists have shown that the TAS2R taste receptor transmembrane proteins are responsible for the human ability to taste bitter substances. *TAS2R38* is a gene that codes for a G protein-coupled receptor (GPCR) which contributes to the tasting of the chemical Phenylthiocarbamide (PTC). In people with functioning *TAS2R38* receptor proteins (tasters), PTC binds to the receptor protein resulting in a bitter taste. In other people the PTC cannot bind to the *TAS2R38* receptor and they do not taste the bitterness (non-tasters). The DNA sequence difference between the two alleles (taster vs non-taster) is only different at a single base pair, termed "Single Nucleotide Polymorphism (SNP)". Three SNPs in the *TAS2R38* gene: SNP1,SNP2, and SNP3 are often inherited together. These SNPs define two main phenotypes, *PAV* (the dominant taster variant) and *AVI* (the non-taster recessive trait).

SNP	Nucleotide Position (bp)	Nucleotide Change		Codon Change		Amino Acid Change	
		Non-taster	Taster	Non-taster	Taster	Non-taster (AVI)	Taster (PAV)
1	145	G	C	GCA	CCA	Alanine (A)	Proline (P)
2	785	T	C	GTT	GCT	Valine (V)	Alanine (A)
3	886	A	G	ATC	GTC	Isoleucine (I)	Valine (V)

Table 1: Three SNPs in the TAS2R38 gene control the ability to taste PTC. AVI is the non-taster (recessive) variant and PAV is the taster (dominant) variant.

Part A

Describe the structure of a nucleotide of DNA.

It has been observed that PTC tasters often reject bitter-tasting foods such as cruciferous vegetables including kale, broccoli, and cauliflower. Scientists researching the *TAS2R38* gene want to determine if there is a connection between the gene and differences in body mass composition. Scientists studied participants in two cohorts. Cohort A consisted of all elderly participants aged 90 to 103 years old. Cohort B consisted of young, middle-aged, and elderly participants. Genotyping was performed for the three single-nucleotide polymorphisms (SNPs).

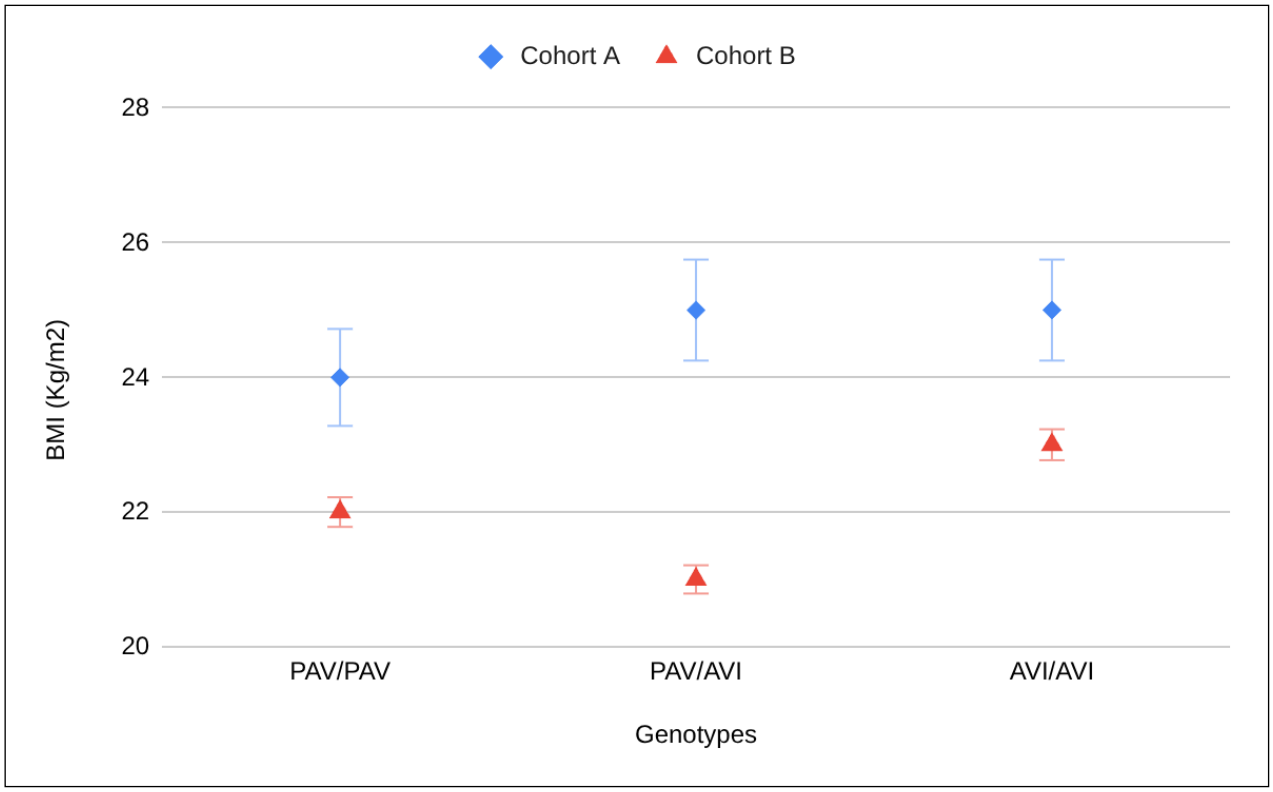


Figure 1: Mean values±SEM of body mass index (BMI) by genotype in Cohort A and Cohort B

Part B

i. Based on Figure 1, **identify** the dependent variable.

ii. **Justify** why scientists included young, middle-aged, and elderly people in Cohort B.

iii. **Describe** the relationship between the number of AVI alleles in the genotype and the BMI (Kg/m^2) in Cohort A.

A different group of scientists are studying to determine if *TAS2R38* plays a role in blood glucose homeostasis. Participants completed an Oral Glucose Tolerance Test. To perform this test, participants fasted for 12 hours. Then, their blood glucose levels were measured immediately before and two hours after drinking a sugar solution. Participants with three different SNPs, *TAS2R38* genes were also sequenced and their genotypes determined.

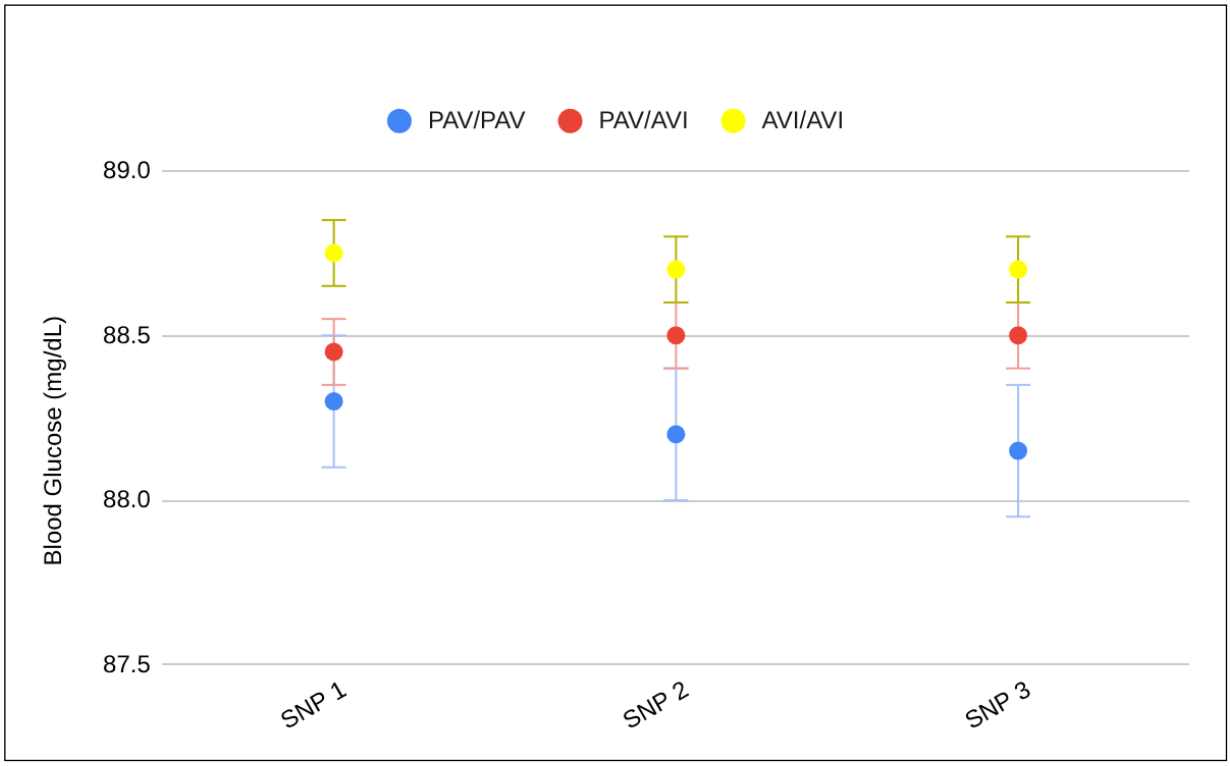


Figure 2: Mean blood glucose levels (mg/dL) ±2SEM two hours after Oral Glucose Tolerance Test for patients with different SNPs.

Part C:

i. **Justify** the scientists analyzing data from three different SNPs found in the *TAS2R38* gene.

ii. Based on figure 2, **describe** the difference between the effects of the PAV/PAV genotype and the AVI/AVI genotype on the blood glucose levels during the oral glucose tolerance test.

iii. **Calculate** the difference in mean blood glucose (mg/dL) between PAV/AVI and AVI/AVI patients, all containing SNP 3.

Part D

The single nucleotide change of SNP 1 changes the amino acid at position 49 in the protein. The original nucleotide (PAV) is proline which is polar and it is switched to alanine (AVI) which is nonpolar in SNP1.

i. **Predict** the effect of SNP1 on the shape of the *TAS2R38* receptor.

ii. **Justify** your prediction.

Q4. Scientists have shown that the TAS2R taste receptor transmembrane proteins are responsible for the human ability to taste bitter substances. *TAS2R38* is a gene that codes for a G protein-coupled receptor (GPCR) which contributes to the tasting of the chemical Phenylthiocarbamide (PTC). In people with functioning *TAS2R38* receptor proteins (tasters), PTC binds to the receptor protein resulting in a bitter taste. In other people the PTC cannot bind to the *TAS2R38* receptor and they do not taste the bitterness (non-tasters). This genetic variation in the ability to taste PTC is determined by two common alleles of the *TAS2R38* gene: the functional dominant allele and the mutated recessive allele. The DNA sequence between these two alleles is only different at a single base pair.

Part A

Describe what happens to the protein receptor when a ligand binds to it that allows it to activate a specific cell signaling pathway.

Part B

Explain how an individual with the functional *TAS2R38* gene builds a different protein than an individual with two recessive alleles.

Scientists have developed a treatment called flufenamic acid (FFA) to help patients take bitter tasting medicines. FFA binds to two sites of the TAS2R14 protein, a bitter taste receptor similar to TAS2R38 - the ligand binding site of the taste receptor and an intracellular site.

Part C

Predict the effect on the rate of signal transduction for patients exhibiting the Taster phenotype when taking FFA.

Part D

Justify your prediction from part C.

Q5. The ability to taste is due to the presence of chemically sensitive, specialized taste receptor cells on the surface of the tongue and throat. When we eat something sweet, the soluble molecules in the food dissolve in saliva and bind to specific receptor proteins on the surface of the receptor cells that detect sweet taste. The stimulated receptor cells initialize depolarization which causes nerve impulses to fire, sending the information to the gustatory region of the brain where the sense of taste is interpreted. Different types of taste receptors are activated by different chemicals, and the nerve impulses they send to the brain are interpreted as different tastes.

Figure 1: A simplified model of the signal transduction pathway for taste.

Key:

αG_{gus} :Alpha-gustducin

PLC: Phospholipase C

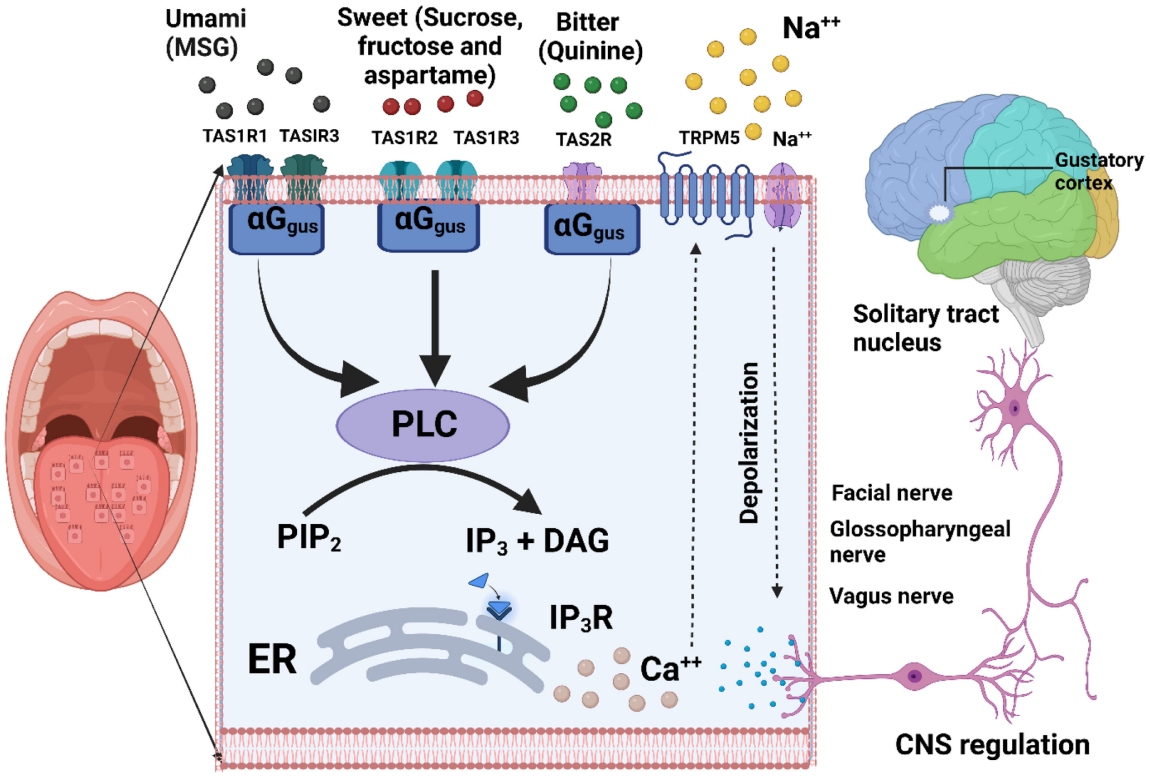
PIP_2: Phosphatidylinositol-4,5-bisphosphate

IP_3: Inositol-1,4,5-trisphosphate

DAG: Diacylglycerol

ER: Endoplasmic Reticulum

IP_3R: type 3 inositol 1,4,5-trisphosphate receptor



Part A

Describe the role of the calcium ions (Ca++) as a second messenger in the pathway for taste seen in Figure 1.

Part B

Explain how all of the taste receptors seen in Figure 1 lead to the endoplasmic reticulum releasing calcium ions.

Part C

Using the information from Figure 1, **identify** the chemical directly responsible for causing the nerves impulses to fire.

Part D

Explain how a mutation in a gene coding for a TAS2R protein would change the perception of taste.

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