



Points: 30

Time: 3 Hours

Science for Sustainable Food and Agriculture

Theoretical Test

Question Sheets

December 5, 2023

You may turn to the next **TWO** pages ONLY to
read the “EXAMINATION RULES” and “EXAM INSTRUCTIONS”

EXAMINATION RULES

1. You are **NOT** allowed to bring any personal items into the examination room, except for personal medicine or approved personal medical equipment.
2. You must sit at your designated desk.
3. Do **NOT** start reading or answering the questions before the “**START**” signal.
4. You are **NOT** allowed to leave the examination room during the examination except for the bathroom or in an emergency in which case you will be accompanied by a supervisor/volunteer/invigilator. Please raise the “fan” provided on the table if you need to leave the room in such cases. You are **NOT** allowed to go to bathroom during the last 10 minutes of the examination.



provided “fan”

5. Do **NOT** disturb other competitors. If you need any assistance, raise your “fan” and wait for a supervisor to come.
6. Do **NOT** discuss the examination questions. You must stay at your desk until the end of the examination time, even if you have finished the exam.
7. At the end of the examination time you will hear the “**STOP**” signal. You are **NOT** allowed to write anything after the signal is given. Arrange the exam sheets and the stationery items (pen, pencil, eraser, calculator, and fan) neatly on your desk. The answer sheets should be on the top and **NOT** to be put in the envelop.
8. Do **NOT** leave the room before all the exam papers have been collected by exam supervisors, and you are given the signal to leave.
9. There will be only one warning if you do not comply with the examination rules. Any failure to comply with the rules or instructions of supervisors after the warning results in disqualification, receiving total of zero points in the theoretical test.

You may turn to the exam instructions on the next page



EXAM INSTRUCTIONS

1. After the “**START**” signal, you will have 3 hours to complete the exam.
2. Check the stationery items (pen, pencil, eraser, calculator, and fan) provided by the organizers. **ONLY** use the pen and pencil provided by the organizers.
3. No additional scratch paper is provided. You may use the question sheets and their backside as scratch paper.
4. Check the front cover of your answer sheet that it has your correct student code. You are **NOT** allowed to turn to the next page of the answer sheets yet. Raise your “fan”, if you do not have the answer sheet or if the information is incorrect.
5. Only the answer sheet will be evaluated. Read each problem carefully and write your answers in the corresponding boxes of the answer sheets. Answers written elsewhere will not be graded.
6. If you want to change your answer, completely erase or clearly cross out your first answer and write in your new answer. Any ambiguous answers are marked as wrong.
7. Always show your calculations. If you do not show your calculations, no point is awarded for the question.
8. You should write your final answers down in the appropriate number of digits.
9. After the “**START**” signal is given, check that you have a complete set of the exam question sheets. Raise your “fan”, if you find any missing sheets.
 - There are total of 17 **questions**: 8 physics questions, 3 chemistry questions, and 6 biology questions.
 - The total number of pages in the question sheets is **29 pages** including the front cover.
 - The total number of pages in the answer sheets is **20 pages** including the front cover.
10. Useful information is provided on **the following page**.

DO NOT turn to the next page before the

“START SIGNAL”

Part I: Physics

Durian Picking

Durian, known as the King of Thai fruits for its unique taste, appearance, and beautiful smell, can grow over 30 meters tall. Picking a thorny and heavy durian fruit from such a height requires careful planning. Fig. P-1 shows the durian fruits on the tree.



Fig. P-1: The durian fruits on the tree

In this exam, you will use physics to explore the process of durian picking.

For each question, clearly present all equations used in solving the problem and show your calculations within the designated space in the answer sheet.

Use the gravitational acceleration $g = 9.80 \text{ m/s}^2$ wherever needed.

All numerical answers must contain three significant figures.

P1. [0.5 pt] A durian fruit with a mass of $m_d = 4.00 \text{ kg}$ is dropped from a branch at a height of $h = 12.0 \text{ m}$ above the ground. Calculate the speed of the durian fruit at the instant when it reaches the ground, disregarding air resistance.

P2. [1.0 pt] If the impact time is $\Delta t_i = 2.00 \times 10^{-2} \text{ s}$, determine the average impulsive force exerted on the durian fruit when it hits the ground, assuming that the durian does not bounce after the collision. (Impact time is defined as the time duration starting from the moment the surface of the durian fruit touches the ground until the durian fruit comes to rest.)

P3. [1.5 pt] To prevent damage to the durian fruit, a professional durian picker uses a gunny sack to catch the falling durian fruit before it hits the ground. Consider the same durian fruit with mass m_d dropped from the same height h as in question P1. Now, the durian picker uses a gunny sack to catch the durian fruit at a height of $h_p = 1.50$ m above the ground as shown in the Fig. P-2. Assume that the picker applies a constant force to the gunny sack, bringing the durian fruit to a halt just before it touches the ground.

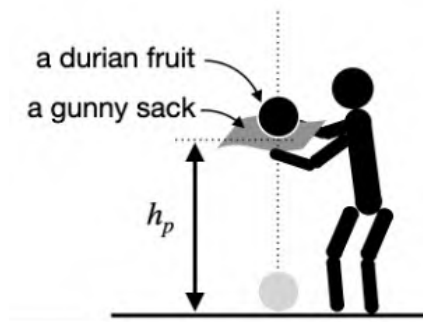


Fig. P-2: The picker uses a gunny sack to catch a durian fruit.

- Calculate the acceleration of the durian fruit during the catch.
- Calculate the magnitude of the force the picker uses to catch the durian fruit.

P4. [1.0 pt] The method described in question P3 remains risky due to the falling durian fruit's proximity to the durian picker's head and hands. Additionally, the picker must repeatedly lower their body and bend their knees, expending excessive effort and energy. A safer and more efficient approach involves the picker holding one edge of the gunny sack and swinging it to catch the falling durian fruit. As the durian fruit initially touches the gunny sack, the picker redirects it toward himself, causing the durian fruit to descend between his legs and come to a halt before striking the ground as shown in Fig. P-3 (a).

To simplify the problem, let's disregard how the velocity is redirected and how the force is applied through the gunny sack to the durian fruit. Then let's assume that the durian fruit is a point particle and consider the problem as follows. The catching process starts from point A and ends at point B in a straight line trajectory as shown in Fig. P-3 (b). At the point A, the durian fruit's speed v matches that of the falling durian fruit at $h_p = 1.50$ m above the ground as in question P3 but with a different direction. The durian picker applies a constant force to the durian fruit throughout its trajectory so that the durian fruit comes to a complete stop at point B.

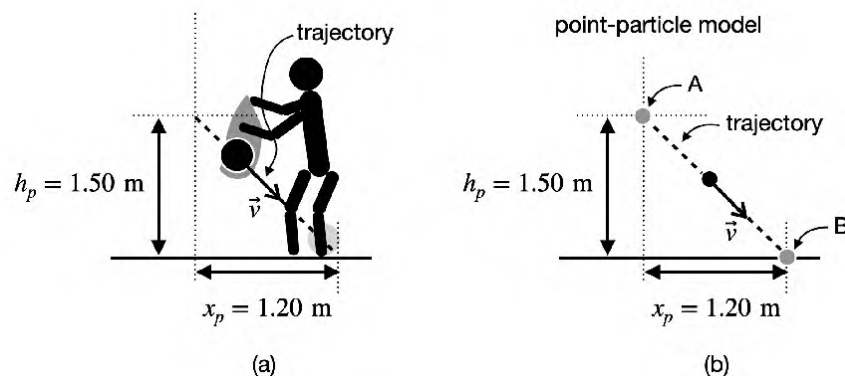


Fig. P-3: (a) The durian fruit's trajectory from problem P4. (b) The diagram for simplified problem.

- Calculate the magnitude of the acceleration of the durian fruit during this catch.
- Calculate the magnitude of the net force (F_{net}) exerts on the durian fruit during this catch.

P5. [2.0 pt]

(a) Draw a diagram of the durian fruit during the trajectory in the question P4 into a given coordinates in the answer sheet, as also shown in Fig. P-4. The diagram must show the gravitational force on the durian fruit $m_d \mathbf{g}$, the net force $\mathbf{F}_{\text{net}}$, and the force exerted by the durian picker through the gunny sack $\mathbf{F}_{\text{picker}}$.

(b) Calculate the magnitude of the force F_{picker} and the angle Φ (in degrees) between $\mathbf{F}_{\text{picker}}$ and the Y-axis.

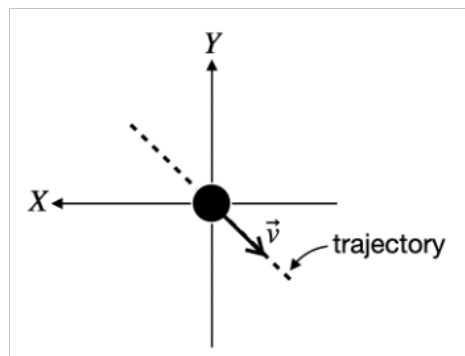


Fig. P-4: The coordinates for problem P5.

P6. [2.0 pt] In a single branch, it's common to find multiple durian fruits. The farmer must employ a plastic rope to support the thin branch and prevent it from breaking under the weight of the durian fruits. To simplify the problem, let's assume the branch with a length of $L = 5.00 \text{ m}$ has a uniform mass of $m_b = 6.00 \text{ kg}$, and all of the durians depicted in Fig. P5 have an identical mass of $m_d = 4.00 \text{ kg}$ each. A joint between the branch and the stem provides $M_j = 150 \text{ N}\cdot\text{m}$ clockwise moment as shown in Fig. P-5. Calculate the tension in the plastic rope.

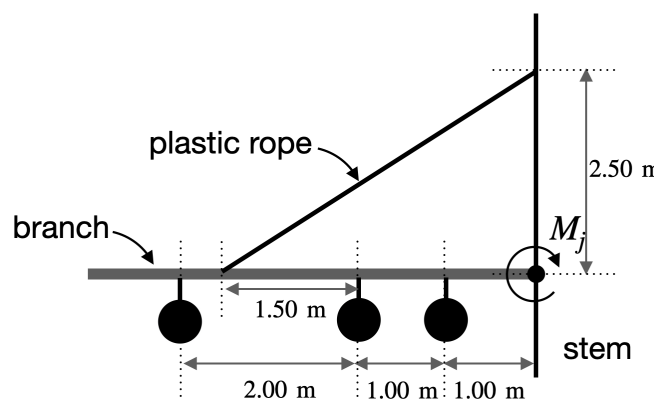


Fig. P-5: The configuration of the durian fruits on a single branch for problem P6.

In southern Thailand, many orchards cultivate durian trees and other tropical fruits on sloping terrains. As fallen durians can roll downhill and pose a potential hazard, it's essential to exercise caution when walking in these orchards.

P7. [1.0 pt] Assume that 0.001% of the kinetic energy of the durian fruit in problem P1 just before the impact, as described in problem P2, is converted into sound energy. Given that the sound energy that hits the ground get absorbed by the ground, calculate the sound intensity level (in decibels, dB) of the impact sound at a distance of $r = 10.0$ m from the point where the durian fruit hits the ground.

Additional Information: The sound intensity level β is a logarithmic measure of its intensity $I = P/A$, where P is the power and A is the area. The sound intensity level is defined by

$$\beta = (10 \text{ dB})\log\left(\frac{I}{I_0}\right),$$

where $I_0 = 1.00 \times 10^{-12} \text{ W/m}^2$.

P8. [1.0 pt] Determine the distance from the impact point, as described in problem P7, at which the sound intensity level of the impact reaches 60 dB—a level that is easily noticeable in an orchard environment.

Part II: Chemistry

Thailand has long been called “*the kitchen of the world*” with its abundant natural resources. The country is a top-ten global producer of a number of important agricultural products including rice, cassava, sugarcane, palm oil, natural rubber, and several vegetables and tropical fruits.

Question C-1 Mangosteen “Queen of fruit”

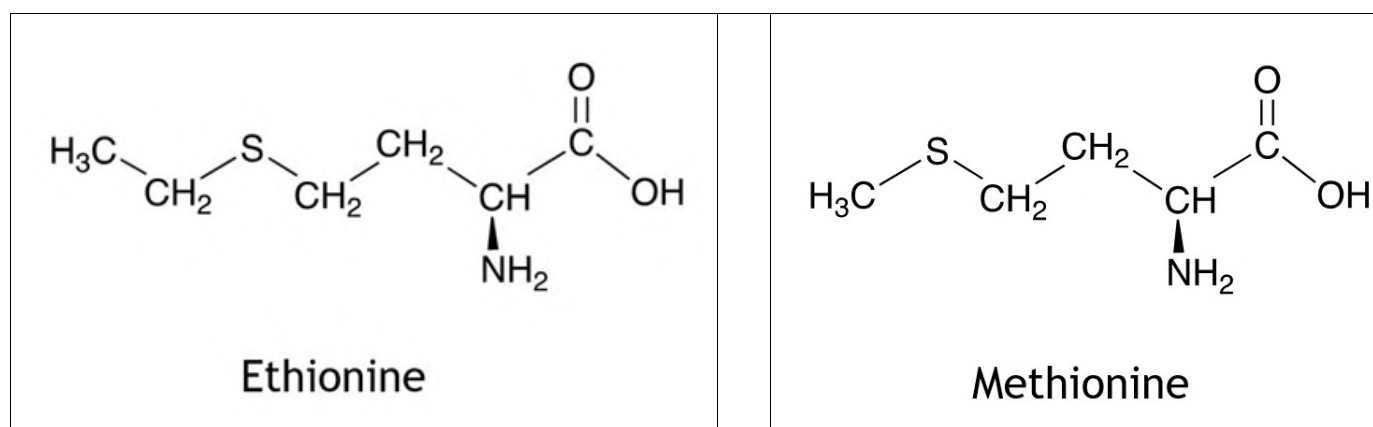
The mangosteen is a tropical fruit with a slightly sweet and sour flavor. In Thailand, it is well known as the Queen of fruit. Mangosteen has been used as a traditional medicine to treat skin infection and wounds in Southeast Asia. The fruit pericarp contains mangostin, a xanthanoid compound possessing extensive biological activity and pharmacological properties, such as anticancer, antibacterial, antiinflammatory, antioxidant and cardiovascular activity. It is also used in cosmetics and skincare due to its anti-aging and acne treatment properties.



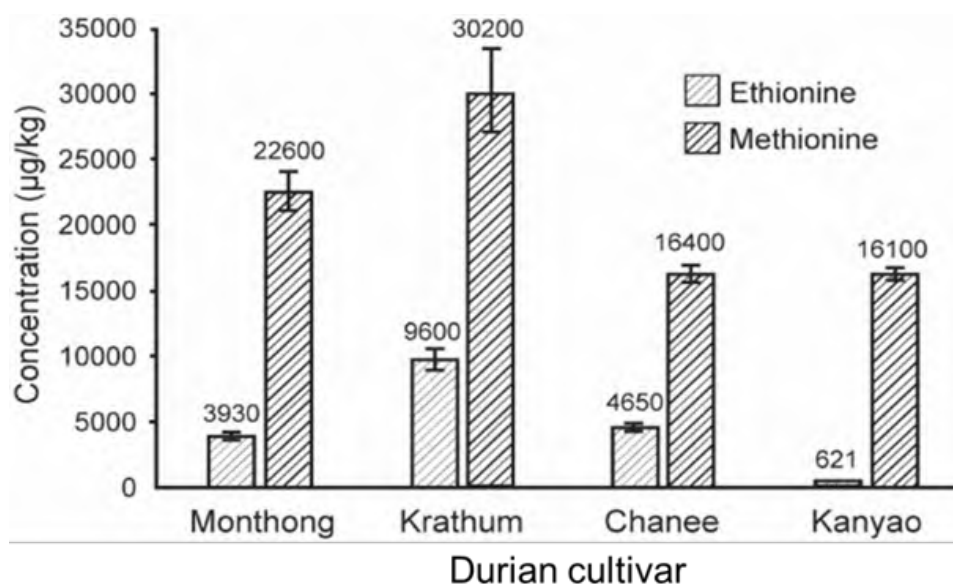
Mangosteen “Queen of fruit”

C-1.1) (2.5pt) The mangostin molecule contains atoms of three elements. Mangostin vapour is 14.65 times denser than gaseous nitrogen. Pure mangostin with a mass of 1.000 g was burned in excess oxygen gas to produce only water and carbon dioxide. The water is collected in an absorber and the mass change of this absorber is equal to 0.570 g. The carbon dioxide is collected in a separate absorber filled with 100.00 cm³ of 2.00 M sodium hydroxide solution (NaOH). A volume of 25.00 cm³ of this solution was titrated with 2.00 M hydrochloric acid solution (HCl) using 5 drops of methyl orange as indicator (pH range 3.2-4.4). A titration volume of 25.00 cm³ of HCl solution was consumed. The same volume of the solution was titrated with 2.00 M HCl solution using phenolphthalein as indicator (pH range 8.3-10.0) required 17.70 cm³ of HCl solution. Write the formula of mangostin. (H_2CO_3 ; $K_{a1} = 4.2 \times 10^{-7}$, $K_{a2} = 4.8 \times 10^{-11}$)

Question C-2 Thailand is one of the world's largest exporters of durians, producing about 700,000 tons per year. Durian's aroma, taste, and texture varies from cultivar to cultivar, owing to different sets of phytochemicals that include organosulfur compounds, esters, and alcohols. The uniquely pungent odor of durians arguably stems from organosulfur compounds such as diethyl disulfide ($\text{CH}_3\text{CH}_2\text{SSCH}_2\text{CH}_3$). Ethanethiol ($\text{CH}_3\text{CH}_2\text{SH}$) is believed to be an important precursor for the production of many volatile organosulfur compounds in durian. Through a complex biosynthetic pathway, e Ethanethiol is, in turn, produced from amino acids called ethionine and methionine. Assume a one-to-one molar conversion of either ethionine or methionine to e Ethanethiol.



Shown below are the concentrations of ethionine and methionine for four different durian cultivars best known in Thailand: Monthong, Krathum, Chanee, and Kanyao.



C-2.1) (2pt) Ethanethiol can react with hydrogen peroxide to produce diethyl disulfide and water. How many liters of diethyl disulfide will be produced via ethionine pathway from the reaction of 100.0 g of Monthong pulp with hydrogen peroxide at 160.00°C and 0.5000 atm (1 atm = 1.013×10^5 Pa)? Also provide the balanced chemical equation and report your answer in correct significant figures. Assume that diethyl disulfide behaves as an ideal gas under this condition.



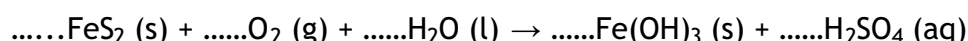
Points: 30

Time: 3 Hours

C-2.2) (1.5pt) If 5.00×10^{-4} L of gaseous diethyl disulfide is detected at 160.00°C and 0.5000 atm from 100.0 g of Krathum pulp, what is the percent conversion of sulfur from the pulp into diethyl disulfide? Report your answer to correct significant figure and show your calculation in detail. Assume that diethyl disulfide is the only gaseous organosulfur compound detected from Krathum pulp, and that it behaves as an ideal gas under this condition.

Question C-3 In Southern Thailand, soil acidity was considered a serious problem for agriculture. It was caused by flooding which led to swamp soil that became strongly acidic after the water dried up. In early 1970s, His Majesty the late King Bhumibol Adulyadej visited the area and began to seek an approach for treatment of soil acidity. Then, he initiated the project called “Klang-Din project” as a remedy for the problem. The method consists in alternately drying out and wetting the land to accelerate the soil’s chemical reaction and raise the acidity to the maximum. The soil is then de-acidified through various techniques such as controlling the ground-water level to prevent the release of sulphuric acid, applying liming materials, and washing away acidity with water. Selected crops are then introduced. His Majesty’s techniques have turned wastelands into arable farmland.

C-3.1) (1pt) Pyrite is a mineral form of iron disulfide found in soil, and contains the disulfide ion (S_2^{2-}). It reacts with oxygen causing the soil to acidify by the following reaction:



Fill the blank to complete the given equation and show the balancing method used.



Points: 30

Time: 3 Hours

C-3.2) (1.8pt) 5.0 L of solution has been prepared by treatment of 1 kg of soil which previously contained 2.4 g of pyrite which was completely oxidized to form sulfuric acid. What is the pH of the solution? The pH depends on only sulfuric acid. Assume that sulfuric acid does not react with other components of the soil such as $\text{Fe}(\text{OH})_3$. (H_2SO_4 dissociates completely in the 1st degree, and K_{a2} of $\text{H}_2\text{SO}_4 = 1.0 \times 10^{-2}$)



Points: 30

Time: 3 Hours

C-3.3) (0.7pt) One of the liming materials is CaCO_3 which is generally used to neutralize soil acidity. In this case, what is the minimum mass in grams of CaCO_3 required to neutralize the solution from C-3.2? (Round your answer to two decimal places)

C-3.4) (0.5pt) The lattice energy of calcium carbonate $\text{CaCO}_3(\text{s})$ is 2804 kJ/mol and the heat of hydration (ΔH_{hydr} of $\text{Ca}^{2+}(\text{g})$) = -1579 kJ/mol and heat of hydration (ΔH_{hydr} of $\text{CO}_3^{2-}(\text{g})$) = -1389 kJ/mol. Use these data to calculate the heat of solution (kJ/mol) of calcium carbonate. Show your calculation method.

Use (s), (l), (g), and (aq) for solid, liquid, gas, and aqueous states respectively.

Part III: Biology

Sustainable agriculture is essential to the long-term survival of humanity. Providing a balanced diet of proteins, carbohydrates, fats, vitamins and minerals is necessary for the growth of cells and the functioning of various systems within the body.

B1. (1.8pt) Beriberi is a disease caused by thiamine deficiency rather than bacterial infection. Thiamine (vitamin B1) is found in unpolished grain. Consuming mostly polished grain could cause beriberi.

To prove this, a scientist experimented by feeding healthy and sick chickens unpolished or polished grain and monitoring changes to their health status. Assume that no chicken dies in the experiment. The chickens cannot recover from the contagious bacterial infection (100% transmissibility) within the time frame of the experiment. But thiamine deficiency and its recovery can happen within the time frame of the experiment.

Table B1 shows the experimental conditions used. Depending on the cause of beriberi, the outcomes could differ. Assuming the true cause is unknown, predict the experimental outcomes depending on whether the cause is bacterial infection or thiamine deficiency. Choosing from the possible outcomes, write the corresponding letter (A-F) in the appropriate cell. Choices may be used more than once.

Possible experimental outcomes (chickens)

- A. Two healthy
- B. Two sick
- C. Three healthy
- D. Three sick
- E. Four healthy
- F. Four sick

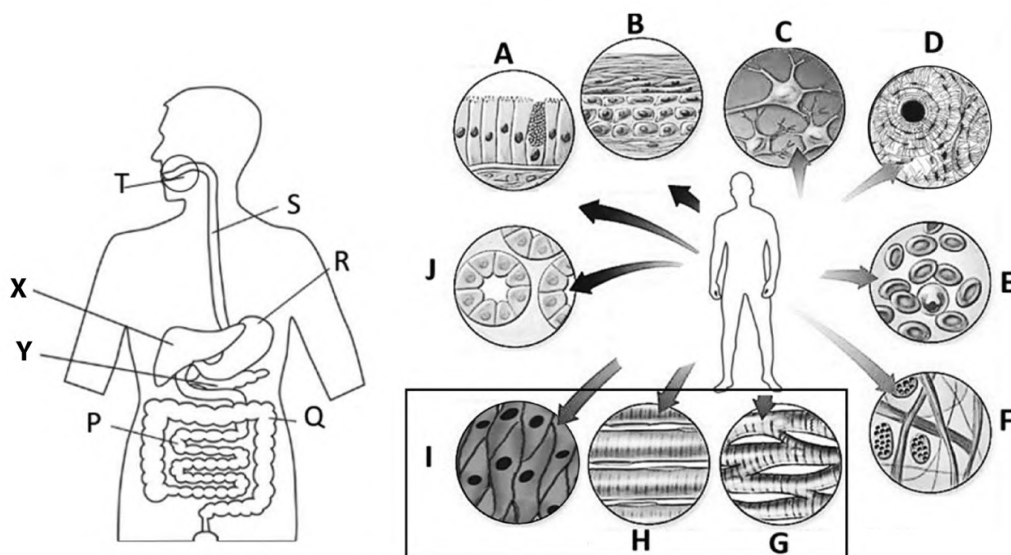
Table B1 (0.3pt for each answer)

I: Experiment	II: Food during experiment (grain)	III: Chickens used in experiment	Expected outcome (A-F), depending on the cause of beriberi	
			IV: Bacterial infection	V: Thiamine deficiency
1	Unpolished	One sick and two healthy		
2	Polished	Four healthy		
3	Unpolished	Two healthy		

B2. (1.9pt) Digestion is a complex process that occurs in various organs and involves different types of tissues. In questions referring to organ (P-T) and tissue images (A-J), place an “X” in the box under the corresponding letter. In questions asking for the tissue name, choose from the list of technical terms (TT) and write the corresponding NUMBER (1-12) in the table in the Answer Sheet.

Technical terms (TT) of tissues

1. SQUAMOUS STRATIFIED EPITHELIUM	2. SIMPLE CUBOIDAL EPITHELIUM	3. SIMPLE COLUMNAR EPITHELIUM
4. SMOOTH MUSCLE	5. SKELETAL MUSCLE	6. CARDIAC MUSCLE
7. COMPACT BONE	8. BLOOD	9. LOOSE CONNECTIVE
10. NERVOUS	11. CARTILAGE	12. SPONGY BONE



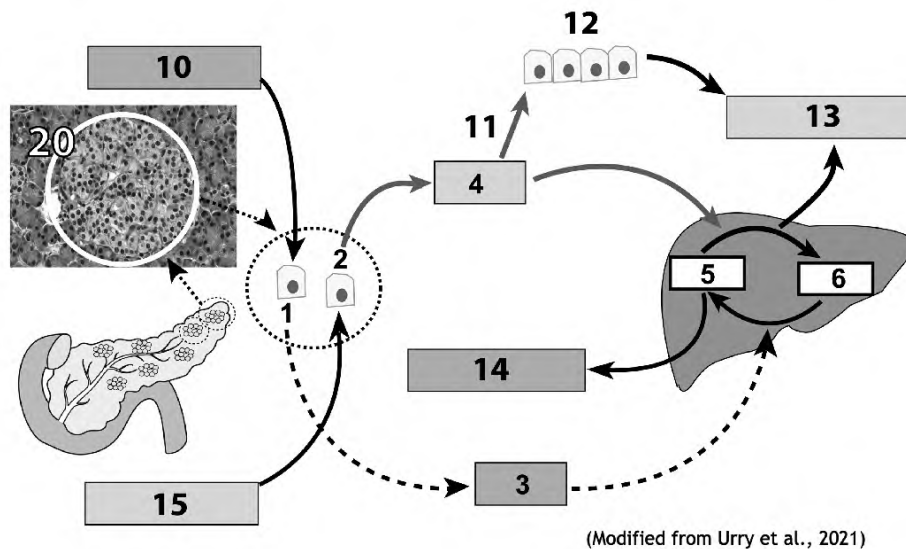
(Modified from: <https://www.stem.org.uk/resources/elibrary/resource/36133/digestive-system>
<https://www.teacharesources.com/product/animal-tissues/>)

X = Liver; Y = Pancreas

G, H and I are types of muscular tissue

	Answer															
	A	B	C	D	E	F	G	H	I	J	P	Q	R	S	T	
1. When students eat protein, in which organ (P-T) does the first enzymatic digestion occur? (0.2pt)																
2. What kind of tissue (TT) mainly covers the internal surface of the organ R? (0.3pt)																
3. Which image (A-J) shows the morphology of squamous stratified epithelium? (0.2pt)																
4. In which organ (P-T) is the protein completely digested? (0.2pt)																
5. The nutrients are transported to other cells in the body by what tissue (TT)? (0.3pt)																
6. Which image (A-J) shows the morphology of muscle tissue that controls jaw movements? (0.2pt)																
7. Which muscle tissue (TT) controls the movement within the organ P? (0.3pt)																
8. Which image (A-J) shows the morphology of the muscle tissue in organ R? (0.2pt)																

B3. (1.4pt) Carbohydrates are an animal's main energy source. Immediately after eating, blood sugar levels rise sharply. If the animal has not consumed the food, however, blood sugar levels decrease. The schematic diagram below represents blood sugar control mechanisms. Answer the related questions by placing an "X" in the box under the corresponding letter.



- 10 = Low blood sugar
- 11 = Stimulates sugar uptake from blood
- 12 = Tissue cells
- 13 = Lowers blood sugar
- 14 = Raises blood sugar
- 15 = High blood sugar

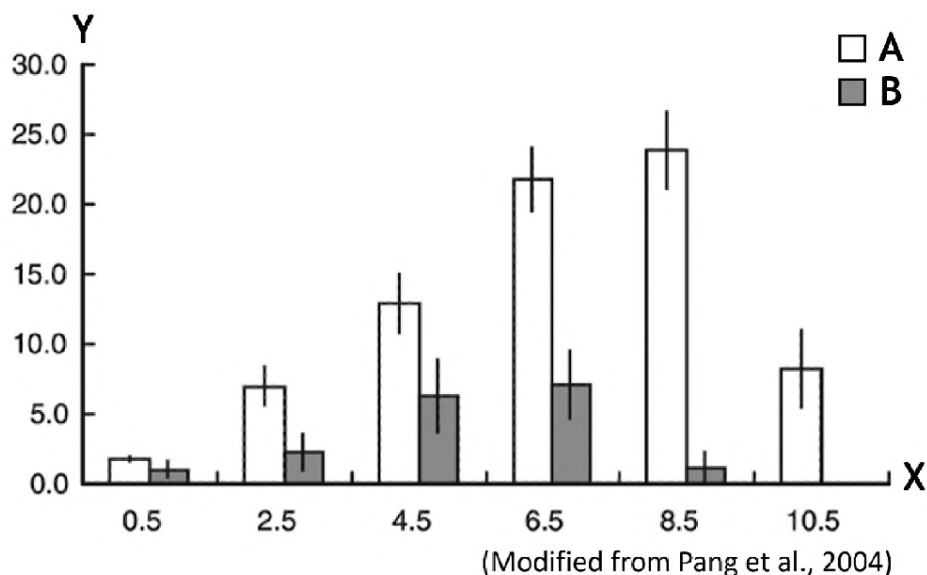
ANSWER CHOICES

A. Bowman's capsule	E. Glucagon	I. Alpha cell	M. Galactose
B. Graafian follicle	F. Insulin	J. Beta cell	N. Glucose
C. Islet of Langerhans	G. Pancreatic polypeptide	K. Delta cell	O. Glyceride
D. Hepatocyte	H. Somatostatin	L. Gamma cell	P. Glycogen

Question		pt	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Name the structure enclosed by the white circle 20	0.2																
2	Name Cell 1 (produces Hormone 3)	0.2																
3	Name Hormone 3	0.2																
4	What is denoted by the number 6?	0.2																
5	Name Cell 2 (produces Hormone 4)	0.2																
6	Name Hormone 4	0.2																
7	What is denoted by the number 5?	0.2																

B4. (1.3pt) Plant genotypes A and B have different waterlogging tolerance levels. To investigate their root anatomical responses to waterlogging, they were grown in pots - either with holes to allow drainage (control) or without holes (waterlogging treatment) - and filled with water. After 3 weeks, roots were harvested and cross-sectioned by cutting every 2 cm, starting at 5 mm from the root tip up to the root-shoot junction.

The following graph shows the percentage of aerenchyma to root cross-sectional area at different distances from the root tip of waterlogged plants. Table B4 shows photographs of each genotype and condition at 4.5 cm from the root tip. Using the data in the graph, choose the correct answer by placing an “X” in the corresponding box in Table B4 for the correct genotype and treatment condition.



A = Genotype A

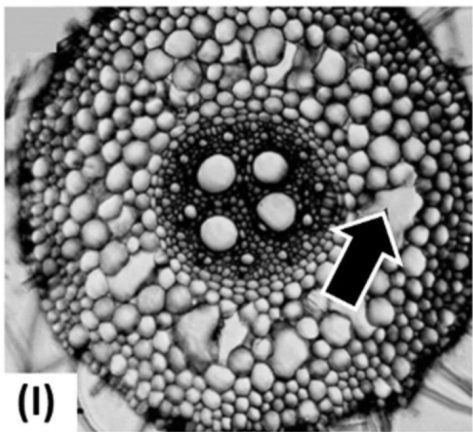
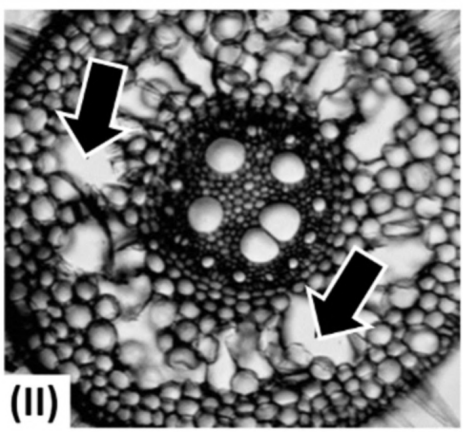
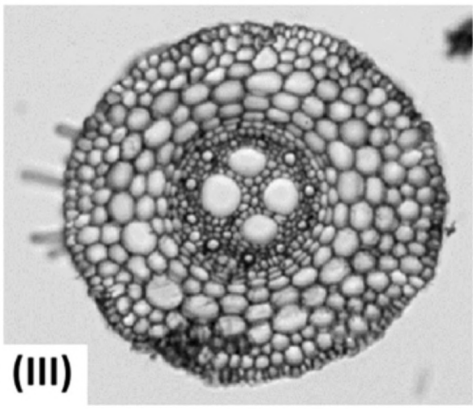
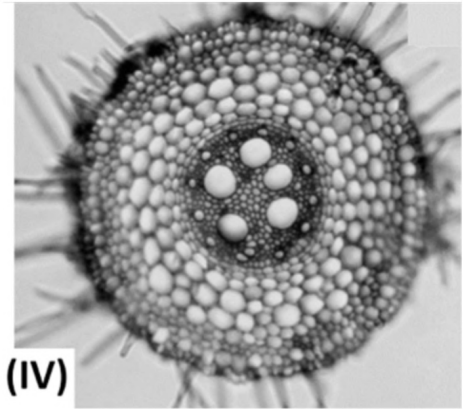
B = Genotype B

X = Distance from root tip (cm)

Y = Percentage (%) of aerenchyma to root cross-section

(data are means $\pm$ standard error, n = 5)

Table B4

P Q	☐ A ☐ B	☐ A ☐ B
☐ 1 ☐ 2	 (I)	 (II)
	 (III)	 (IV)

Note 1: Arrows indicate air spaces in the aerenchyma area.

Note 2: The same genotype is shown in the same column and the same condition (waterlogged or well-drained) is shown in the same row.

P = Condition

Q = Genotype

1 = Waterlogged

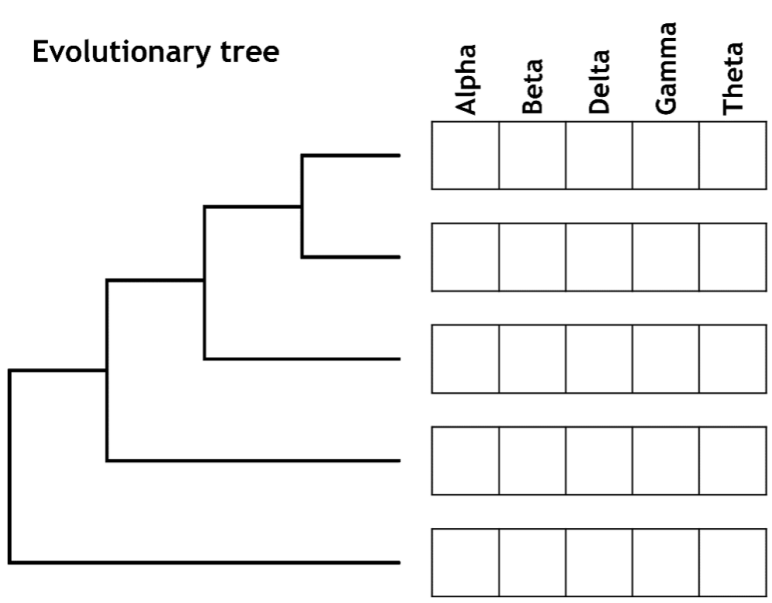
2 = Well-drained

B 5 (1.8pt) Comparative biochemistry is the study of evolutionary relationships based on similarities in DNA sequences of different organisms. Table B5A shows the percentages of base difference from 5 different lactic acid bacteria (LAB) strains that ferment carbohydrates and produce lactic acid as the main product.

Based on Table B5A and the figure of evolutionary tree provided, put an “X” in the corresponding box for the correct position of each LAB strain on the tree. Then, answer the questions in Table B5B by placing an “X” in the correct choice(s).

Table B5A

	Alpha	Beta	Delta	Gamma	Theta
Alpha					
Beta	17				
Delta	17	9			
Gamma	15	11	12		
Theta	19	25	20	21	





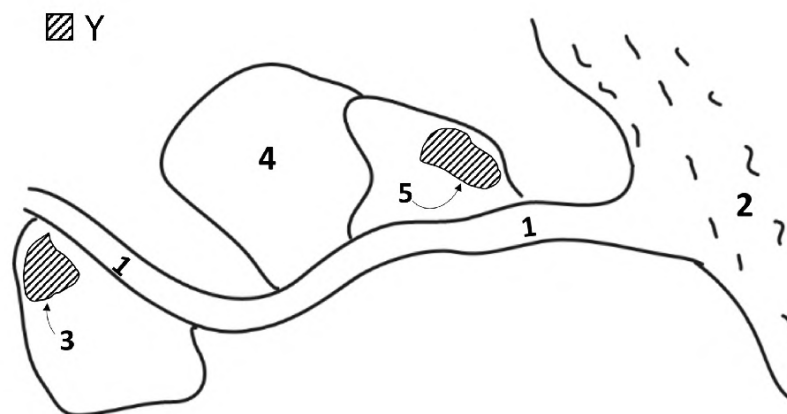
Points: 30

Time: 3 Hours

Table B5B

Question		Answer				
		Alpha	Beta	Delta	Gamma	Theta
1	Which pair of LAB strains is least closely related? (0.4pt)					
2	Which pair of LAB strains most likely shares a recent common ancestor? (0.4pt)					

B6. (1.8pt) Phosphorus (P) is an important macronutrient in ecosystems. However, it is not available in a gaseous form, and the element is **water-insoluble**. Part of the phosphorus cycle is slow, occurring in rocks and sediment. The remaining cycle is faster and P is transferred in organisms through food intake and excretions. These create important transport links between ecosystems. Consider the following scenario.



Y = Pond

1 = River

2 = Gulf of Thailand

3 = Jam's pond

4 = Som's plantation

5 = Nook's pond

Farmer Som started a securely fenced-off banana plantation near the coast 30 years ago. This plot of land was rich in nutrients. In the last decade, the soil quality has deteriorated. Nutrient concentrations, especially P, have decreased. Consequently, Som has dramatically increased her use of natural nitrogen- and phosphorus-based fertilizers.

For each of the statements in the table, **first** decide whether it is a likely occurrence in relation to the information given in the scenario. Choose "yes" or "no" and put an "X" in the corresponding box. **Then:** If yes, choose whether it is likely a cause of Som's problem OR an effect of her activities and put an "X" in the corresponding box. If no, leave the cause and effect boxes corresponding to the statement blank.

Statement	Is it likely?		Potential cause or effect?	
	Yes	No	Cause	Effect
1. Wildlife poaching in nearby forests has reduced the local elephant population.				
2. Eutrophication may occur in Jam's pond.				
3. Declining local seabird populations has led to decreased availability of P in the soil.				
4. Prolonged El Niño events have led to many years of increased drought.				
5. Fishkill in nearby rivers may result from toxic chemicals.				
6. Fish in Nook's pond may die due to a lack of oxygen.				