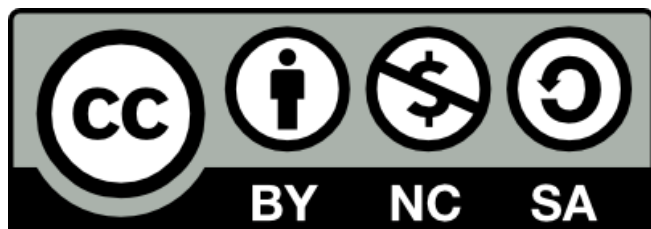




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# Final Report & Planning Suggestions

*International Biology Olympiad*



*Saskatoon Canada 2007*

## Part Two: Exams, Answers & Stats (Report Not Included)

**18<sup>th</sup> INTERNATIONAL BIOLOGY OLYMPIAD**  
**JULY 15 - 22, 2007**



**PRACTICAL EXAMINATION 1**

**ANIMAL ANATOMY, SYSTEMATICS AND ECOLOGY**

This examination is composed of 3 tasks.

<b>TASK A:</b> Dissection of two annelids	26 marks
<b>TASK B:</b> Identification of annelids using a dichotomous key	10 marks
<b>TASK C:</b> Defining the structures, body plan, life style and classification of 10 “worm-like animals”.	27 marks

**TOTAL MARKS = 63**

**TOTAL TIME AVAILABLE = 90 minutes**

## GENERAL INSTRUCTIONS

- **Before starting the exam, the invigilator will show you a red card and a green card to test for red-green color blindness. If you are unable to see the difference between the two cards, raise your hand, and you will be provided with assistance immediately.**
- Read the exam paper carefully before commencing the exam.
- It is recommended that you allocate your time according to the mark value of each task and question.

### IMPORTANT INFORMATION FOR TASK A

You must commence with Task A. When Task A is completed, raise your hand and a lab assistant will take a photo of your dissections, record the time, sign the pan labels and remove the dissections for marking.

### IMPORTANT INFORMATION FOR TASKS B AND C

- All answers for Tasks B and C must be recorded in the answer booklet provided.
- Ensure that your 4-digit student code number is written on **ALL** pages of your answer booklet.
- Use the pencil provided to fill in the appropriate circle for each question in the answer booklet.



## Task A. Annelid Dissection (26 marks)

**Objective:** To locate key features in a marine and a terrestrial annelid.

**Materials:**

- dissecting tray containing annelid 1 (tray labeled with blue sticker)
- dissecting tray containing annelid 2 (tray labeled with yellow sticker)
- 1 pair of dissecting scissors
- 1 pair of forceps
- 1 scalpel
- 20 steel pins on foam board
- 14 colored pins on foam board (2 red-orange, 2 blue, 2 yellow, 2 black, 2 white, 2 pink, 2 green)
- 1 pair disposable gloves
- 1 dissecting microscope and external lamp
- 2 specimen cards (1 labeled with blue sticker, the other labeled with yellow sticker)
- water bottle for keeping specimens wet
- 15 cm ruler from student pencil case

**NOTE:** Before beginning your dissection, ensure that you have all of the materials listed above. If you do not, immediately notify a lab assistant by raising your hand. After all materials lists are confirmed, timing will begin.

**Procedure:**

1. Fill out each of the two specimen cards with your student number and name and set aside. You will sign these cards **upon completion** of your dissections.
2. Put on your gloves and remove the wet paper towel that is covering the specimen.  
**Throughout the dissection, use the water bottle to regularly wet your specimen and any parts removed. This will ensure that the parts do not dry out.**
3. Note the differences in the external features of each worm, namely the increased number of sensory structures and the presence of multifunctional appendages on annelid 1.
4. **From the mid portion of the body** of annelid 1, detach an entire parapodium. Parapodia function as limbs and gills for the worm. Details of the parapodia allow zoologists to distinguish between different species of this annelid. Each parapodium consists of a ventral division called the **neuropodium** and a bilobed dorsal division called the **notopodium**. Each notopodium is supported by a chitinous and stiff rod called an **aciculum**. A dorsal and a ventral cirrus project

from the notopodium and the neuropodium, respectively. **Setae** extend beyond the parapodia.

5. Use the pins provided to pin the detached parapodium in one corner of the **annelid 1** dissecting pan. Ensure that it is pinned on wet paper towel. Pin as follows:

➤ **red-orange** pin for the **neuropodium** (2 marks)

➤ **blue** pin for the **notopodium** (2 marks)

*\* Before continuing, use the water bottle to moisten the parapodium & cover it with a wet piece of paper towel \**

6. Stretch out each worm in its dissecting pan, **dorsal side up**. Place one steel pin through the 1<sup>st</sup> segment of the body and one pin through the last segment of the body to secure it in place.
7. Cut open the body wall of annelid 1 from the anterior tip down the body 3-5 cm. Separate the body wall from the internal structures and pin the body wall to the dissecting tray by using the steel pins.
8. Cut open the body wall of annelid 2 from the anterior tip, and continue the cut posteriorly approximately 5 cm. Separate the body wall from the internal structures. To open up the worm, pin the body wall to the dissecting tray by using the steel pins.
9. Starting at the anterior end of each worm, locate the muscular **pharynx**. In annelid 1 the pharynx also contains jaws that are useful in its predatory lifestyle. **In both specimens**, pin the following structure:
- **yellow** pin for the **pharynx** on **annelid 1** (2 marks)
- **yellow** pin for the **pharynx** on **annelid 2** (2 marks)
10. Moving posteriorly in both specimens, locate the long and tubular intestine used in digestion. **In both specimens**, pin the following:
- **black** pin for the **intestine** on **annelid 1** (2 marks)
- **black** pin for the **intestine** on **annelid 2** (2 marks)
11. Other major features of the annelid digestive system can be seen in annelid 2. Immediately posterior to the reproductive organs in annelid 2 lie the soft **crop** and the tougher-walled **gizzard**. **In annelid 2**, pin the following:
- **pink** pin for the **crop** on **annelid 2** (2 marks)
- **green** pin for the **gizzard** on **annelid 2** (2 marks)

12. Both annelids possess a closed circulatory system with tubular hearts and a dorsal and ventral blood vessel. **In both specimens**, pin the following:
- **white** pin for the **dorsal blood vessel** on **annelid 1** (2 marks)
  - **white** pin for the **dorsal blood vessel** on **annelid 2** (2 marks)
13. Although both specimens are annelids, annelid 1 is sexually dioecious, whereas annelid 2 is hermaphroditic. Hermaphroditism is an advantage for this slow-moving organism. Examine the anterior internal structures in annelid 2, and any external features found on the body wall. **In annelid 2 only**, pin the following:
- **plain steel pin** for **clitellum** (2 marks)
  - **red- orange** pin for **seminal vesicle** (2 marks)
  - **blue** pin for **seminal receptacle** (2 marks)
14. **After finishing the task, place a wet paper towel over the dissected specimens. Raise your hand. A lab assistant will take a photo of your dissection. Both the lab assistant and yourself will sign your dissection pan labels and record the time. Your dissection will then be taken in and graded as you move onto the next section of the practicum.**

## Task B. Identification of annelids using a dichotomous key (10 marks)

**Objective:** To use a dichotomous key to identify ten annelids to the genus-level.

**Materials:**

- line drawings of 10 annelids (labeled as 1 to 10). **ALL** of the organisms are drawn in the **SAME** orientation

**Procedure:**

Use the dichotomous key below to identify the genus to which each annelid belongs. Indicate your selections in the answer booklet by filling in the **most** appropriate circle for each annelid.

### Dichotomous Key

- |  |                      |
|--|----------------------|
| 1a. Has a prominent posterior sucker .....   | go to 2              |
| 1b. Lacks a posterior sucker .....   | go to 3              |
| 2a. Posterior half of body much wider than the anterior end .....                    | <i>Glossiphonia</i>  |
| 2b. Body more ribbon like, anterior part tapered .....                               | <i>Eropobdella</i>   |
| 3a. Has a prominent clitellum .....  | <i>Lumbricus</i>     |
| 3b. Clitellum absent .....   | go to 4              |
| 4a. Each segment has a pair of lateral appendages (parapodia) .....                  | go to 5              |
| 4b. Parapodia are reduced, modified and/or not present on each segment .....         | go to 8              |
| 5a. Worm bears dorsal scales (elytra) .....  | <i>Lepidontus</i>    |
| 5b. Worm lacks dorsal scales .....   | to 6                 |
| 6a. More than 15 body segments.....  | go to 7              |
| 6b. Less than 15 body segments; prostomium with a pair of club-shaped palps....      | <i>Nerillidopsis</i> |
| 7a. Segment 2 bears a pair of long parapodial cirri .....                            | <i>Tomopteris</i>    |
| 7b. Lacks long parapodial cirri on segment 2 .....                                   | <i>Nereis</i>        |
| 8a. Possesses numerous tentacles .....   | <i>Neoamphitrite</i> |
| 8b. Lacks tentacles .....  | go to 9              |
| 9a. Parapodia of the mid-body region modified as tufted branchia (gills) .....       | <i>Arenicola</i>     |
| 9b. Body divided into distinct regions; anterior end modified for filter-feeding.... | <i>Chaetopterus</i>  |

### **Task C. Form and function of “worm-like” animals (27 marks)**

#### **Introduction**

The following 10 animals all resemble “worms” in habit or appearance based on their general tubular or “worm-like” body plans. Most people without scientific training would initially use the term “worms” to describe these ten animals but with our zoological knowledge we know that these animals actually belong to several very different phyla and are only related superficially by their “worm-like” body plan. These 10 animals have structural characteristics that are adapted to their particular environments and life styles.

**Objective:** Using the pictures provided, determine which adaptations (form) these animals have that helps them in their environment and life styles (function)

#### **Materials:**

- laminated, colour photographs of 10 animals (labeled A to J). Note: there are two photographs of each animal.

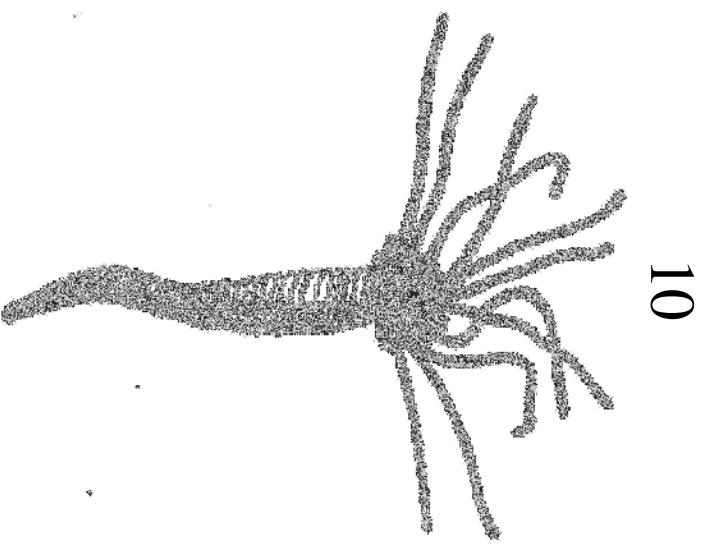
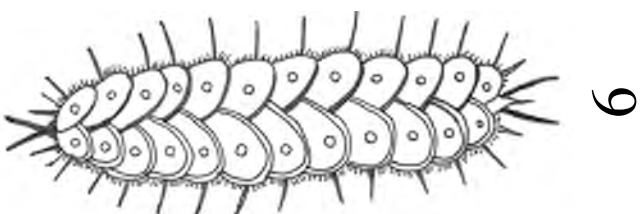
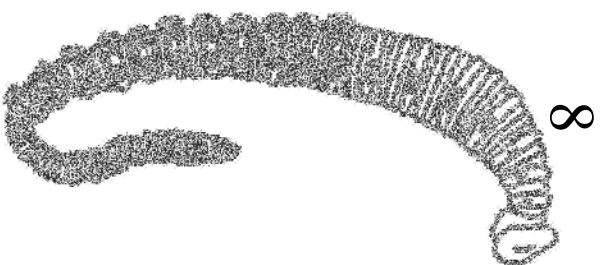
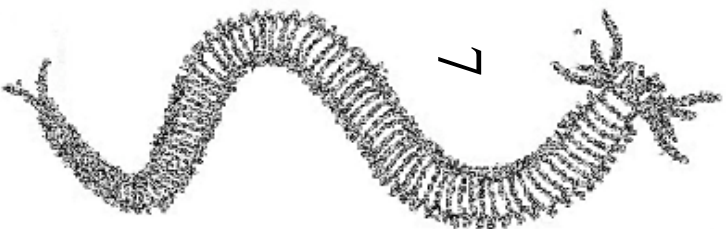
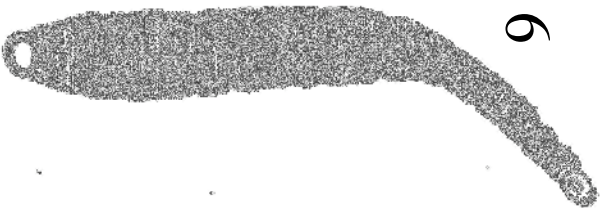
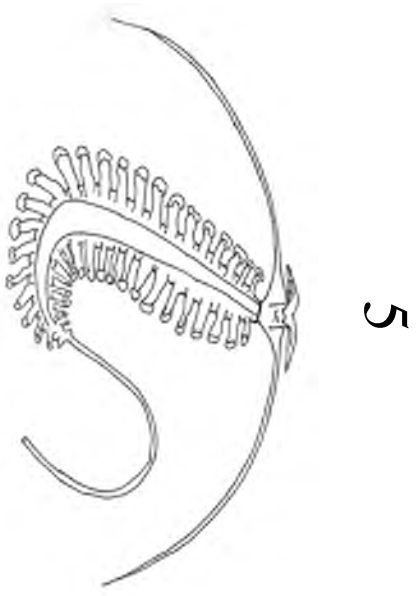
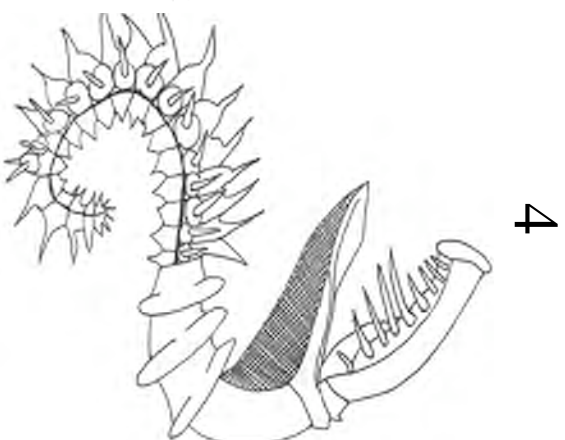
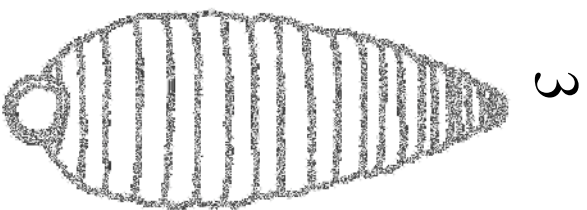
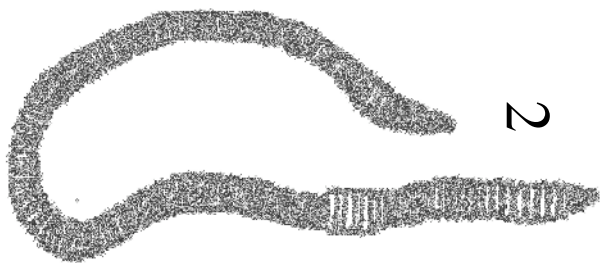
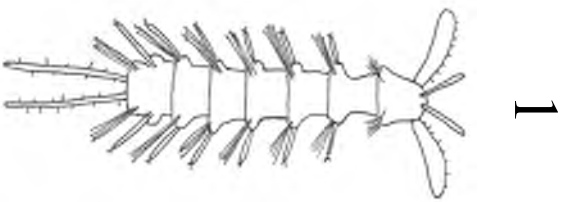
#### **Procedure:**

There are two parts to this task. Fill in the tables in your answer booklet.

1. In Part I, select the best response for each of 6 characteristics (body shape; structures used in locomotion or for attachment to a host; structures used in feeding; type of digestive tract; body segmentation; type of sensory structures) from the choices provided.
2. In Part 2, use your observations from Part 1 to select the best response from the choices provided for the life style of each animal, the phylum to which it belongs and its body plan. For each part, indicate your choices by filling in the circles in the appropriate section of the answer booklet.

**- THE END -**

Images for Task B



*International Biology Olympiad*



*Saskatoon Canada 2007*

## **ANSWER BOOKLET FOR PART 1: TASKS B & C**

### **Important**

**Ensure that your 4 digit code number is written on  
all of the following pages of this document**

**STUDENT CODE NUMBER** \_\_\_\_\_

**STUDENT NAME (printed)** \_\_\_\_\_

Do not write in the box below. For examiners use only.

Task/Part	Marks
B	
C-I	
C-2	
Total	

STUDENT NUMBER: \_\_\_\_\_

### Task B (Dichotomous key to annelid worms)

Indicate the genus for each of the ten specimens (labeled 1-10) by filing in the **most** appropriate circle

	Specimen number:									
	1	2	3	4	5	6	7	8	9	10
Glossiphonia	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Eropobdella	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lumbricus	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lepidontus	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Nerillidopsis	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Tomopteris	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Nereis	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Neoamphitrite	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Arenicola	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Chaetopterus	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

*Do not write in this box.  
For examiners use only. Total Score (10)*



STUDENT NUMBER: \_\_\_\_\_

### Task C PART 1 (Characteristics of “worm-like organisms; A to J)

Select the best response for each characteristic. **Total marks = 12 (0.2 marks/specimen/characteristic)**

Specimen	<i>characteristic 1</i>		<i>characteristic 2</i>			
	<b>Body Shape:</b>		<b>Structures used in locomotion or for attachment to a host:</b>			
	flattened	not flattened	muscular foot	jointed appendages	sucker, scolex and/or “teeth”	none of the other choices
A	O	O	O	O	O	O
B	O	O	O	O	O	O
C	O	O	O	O	O	O
D	O	O	O	O	O	O
E	O	O	O	O	O	O
F	O	O	O	O	O	O
G	O	O	O	O	O	O
H	O	O	O	O	O	O
I	O	O	O	O	O	O
J	O	O	O	O	O	O

Specimen	<i>characteristic 3</i> Structures used in feeding:				none	<i>characteristic 4</i> Digestive tract:	
	mandibles or teeth	sucker	radula	none of the other choices		incomplete (single opening for mouth and anus)	complete (separate openings for mouth and anus)
A	O	O	O	O	O	O	O
B	O	O	O	O	O	O	O
C	O	O	O	O	O	O	O
D	O	O	O	O	O	O	O
E	O	O	O	O	O	O	O
F	O	O	O	O	O	O	O
G	O	O	O	O	O	O	O
H	O	O	O	O	O	O	O
I	O	O	O	O	O	O	O
J	O	O	O	O	O	O	O

STUDENT NUMBER: \_\_\_\_\_

### Task C PART 1 continued

Specimen	<i>characteristic 5</i>		<i>characteristic 6</i>		
	<b>Body segmented:</b>		<b>Sensory structures:</b>		
	yes	no	eye spots	simple or compound eyes	none of the other choices
A	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
B	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
C	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
D	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
E	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
F	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
G	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
H	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
J	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Do not write in the boxes below. For examiners use only.

Question	No. correct
1	
2	
3	
4	
5	
6	
Total	

X 0.2 =      /12

STUDENT NUMBER \_\_\_\_\_

### **Task C PART 2 (Characteristics of “worm-like organisms; A to J)**

Select the best response for each characteristic. **Total marks = 15** (0.5 marks/specimen/characteristic)

Specimen	<i>characteristic 7</i>		<i>characteristic 8</i>					
	<b>Lifestyle:</b>		<b>Specimen belongs to the phylum</b>					
	parasitic	non-parasitic	Arthropoda	Nematoda	Mollusca	Annelida	Platyhelminthes	Other
A	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
B	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
C	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
D	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
E	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
F	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
G	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
H	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
J	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Specimen	<i>characteristic 9</i>		
	<b>Body plan:</b>		
	acoelomate	pseudocoelomate	coelomate
A	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
B	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
C	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
D	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
E	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
F	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
G	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
H	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
J	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

*Do not write in the boxes below. For examiners use only.*

<i>Question</i>	<i>No. correct</i>
7	
8	
9	
<i>Total</i>	

*X 0.5 =*

*/15*

# International Biology Olympiad



Saskatoon Canada 2007

Annellid 1 (Nervia)	Correct
Orange (neuropodium)	
Blue (notopodium)	
Yellow (pharynx)	
Black (intestine)	
White (dorsal b.v.)	
sub-total =	

\*\*each correct pinned  
structure = 2 marks

Total =  
(26)

Annellid 2 (Lusbricens)	Correct
Yellow (pharynx)	
Black (intestine)	
White (dorsal blood v.)	
Pink (crop)	
Purple (gizzard)	
Steel (olitelus)	
Orange (seminal vesicle)	
Blue (seminal receptacle)	
sub-total =	

sub-total =

**18<sup>th</sup> INTERNATIONAL BIOLOGY OLYMPIAD**  
**JULY 15 - 22, 2007**



**PRACTICAL EXAMINATION 2**

**PLANT ANATOMY, MORPHOLOGY AND PHYSIOLOGY**

**EXAM BOOKLET 1**

**TASK A.**      Identification of plant structures and organs      16 marks

**Time allowed: 20 minutes**

**WRITE YOUR 4-DIGIT STUDENT NUMBER IN THE BOX  
BELOW**

<b>STUDENT CODE</b>	
---------------------	--

## PLANT MORPHOLOGY

**TASK A.** Identification of plant structures and organs from images shown in a PowerPoint presentation (16 marks)

In this task, you are required to answer the following questions, each of which relates to a slide that you will be shown. **Each slide will be shown twice.**

In the first showing, each slide will be displayed for 45 seconds, then the second slide will be shown for 45 seconds and so on until all 16 slides have been once. The second showing is to give you the opportunity to review your answers. In this showing, each slide will be displayed for 15 seconds.

**FOR EACH QUESTION,  
WRITE THE LETTER OF YOUR ANSWER IN THE SPACE PROVIDED**

1. What mutualistic relationship between roots of land plants and specific soil fungi is displayed in this slide?

- a. mycorrhizae
- b. mycelium
- c. lichens
- d. root hairs

**ANSWER:** \_\_\_\_ **a** \_\_\_\_

2. This leaf's venation is commonly found in which group of plants?

- a. hornworts
- b. dicotyledons
- c. ferns
- d. monocotyledons
- e. gymnosperms

**ANSWER:** \_\_\_\_ **b** \_\_\_\_

3. The aerenchyma stem tissue shown here is characteristic of its adaptation as a:

- a) mesophyte
- b) xerophyte
- c) halophyte
- d) hydrophyte

**ANSWER:** \_\_\_\_ **d** \_\_\_\_

4. What type of plant do these leaf cross-sections represent?

- a) a monocot
- b) a lycopod
- c) a eudicot
- d) a tree
- e) a fern

ANSWER: \_\_\_\_a\_\_\_\_

5. In this picture of a fern sorus, what is the ploidy level of the structure indicated by the arrow?

- a) triploid
- b) diploid
- c) haploid

ANSWER: \_\_\_\_c\_\_\_\_

6. In this longitudinal section of a dicot angiosperm stem, name the structure indicated by 'X'.

- a) shoot apical meristem
- b) axillary bud
- c) lateral inflorescence
- d) lateral root
- e) leaf primordium

ANSWER: \_\_\_\_b\_\_\_\_

7. The arrow in this slide is indicating:

- a) sclerenchyma fibre
- b) sieve tube element
- c) vessel element
- d) chlorenchyma
- e) sclereid

ANSWER: \_\_\_\_c\_\_\_\_

8. What is the function(s) of the structure indicated by the arrow?

- a) to prevent an insect proboscis reaching phloem sap
- b) to provide mechanical support to the xylem tissue
- c) to initiate the formation of interfascicular vascular cambium
- d) all of the above
- e) none of the above

ANSWER: \_\_\_\_a\_\_\_\_

9. The name of the meristem responsible for generating the tissues labelled 'X' is:

- a) vascular cambium
- b) shoot apical meristem
- c) root apical meristem
- d) cork cambium
- e) lenticel

ANSWER: \_\_\_\_d\_\_\_\_

10. The presence of the following illustrated cells gives *Pyrus communis* L. (pears) their gritty texture:

- a) chlorenchyma
- b) guard cell
- c) tracheary element
- d) collenchyma
- e) sclereid

ANSWER: \_\_\_\_e\_\_\_\_

11. This type of phyllotaxy is best described as:

- a) whorled
- b) distichous
- c) opposite
- d) alternate

ANSWER: \_\_\_\_a\_\_\_\_

12. The hormone auxin, produced at the terminal meristem, inhibits lateral shoot growth which results in the illustrated phenomenon, known as:

- a) conical shape
- b) deciduousness
- c) apical dominance
- d) axillary dominance

ANSWER: \_\_\_\_c\_\_\_\_

13. These tendrils and spines represent evolutionary adaptations of what structures?

- a) leaves
- b) branches
- c) axillary shoots
- d) adventitious roots
- e) trichomes

ANSWER: \_\_\_\_a\_\_\_\_



14. Which plant cell type shown has the potential to give rise to all of the other cells in the section?

- a) parenchyma
- b) companion
- c) collenchyma
- d) sclereid
- e) tracheary element

ANSWER: \_\_\_\_\_a\_\_\_\_\_

15. In embryo development, the structure indicated by the arrow is known as the:

- a) filament
- b) endosperm
- c) heart-shaped embryo
- d) suspensor
- e) basal cell

ANSWER: \_\_\_\_\_d\_\_\_\_\_

16. What plant group does this slide represent?

- a) angiosperms
- b) bryophytes
- c) tracheophytes
- d) pteridophytes

ANSWER: \_\_\_\_\_b\_\_\_\_\_

**- THE END -**

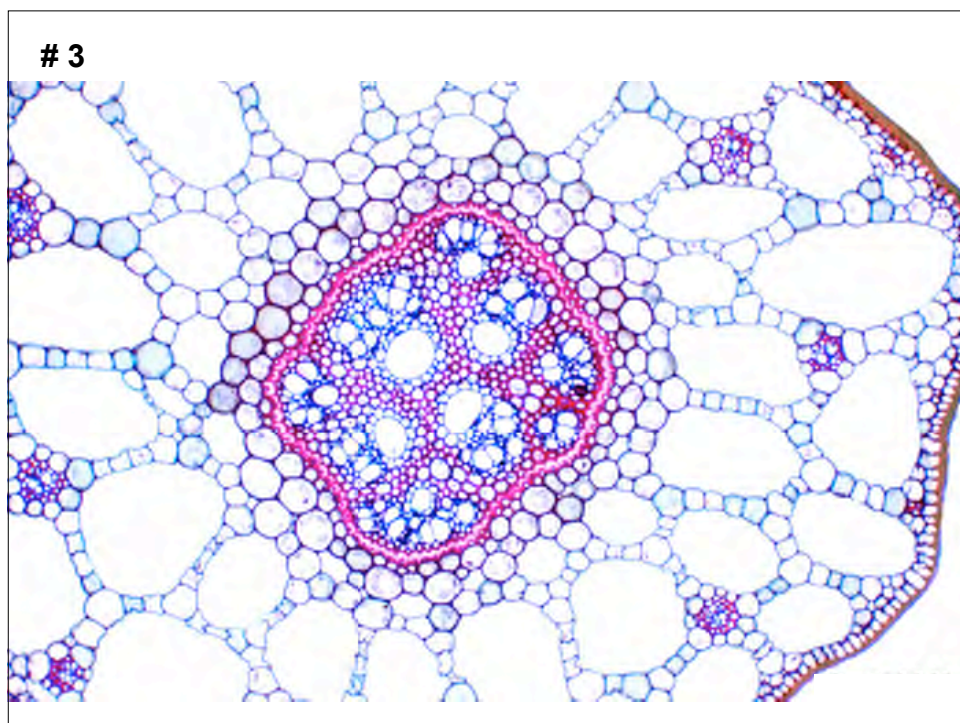
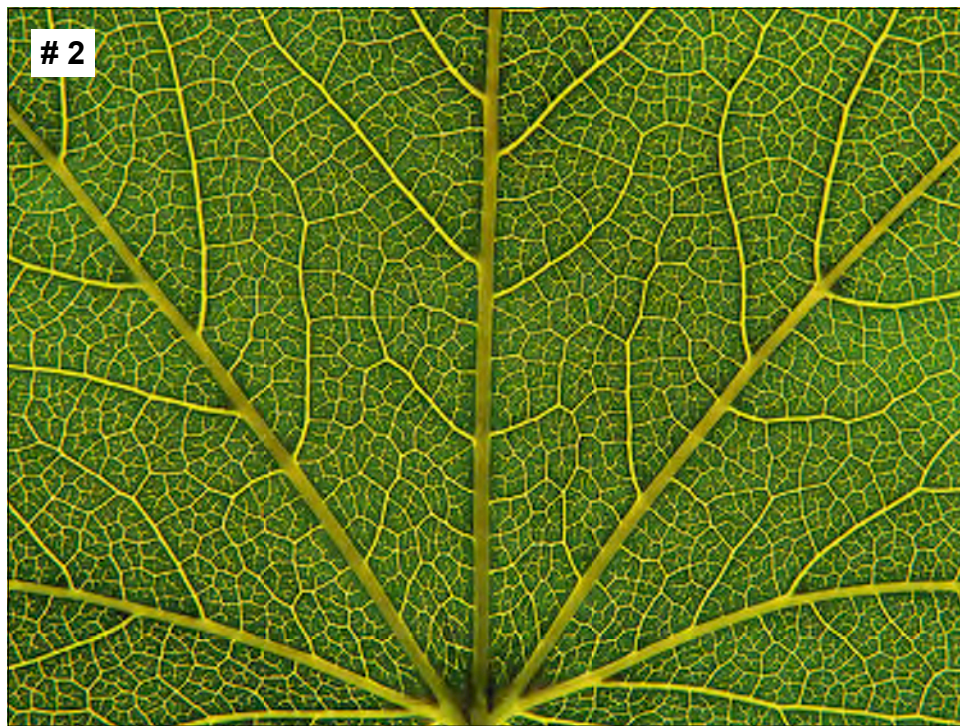
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THIS EXAM BOOKLET AND ON THE TOP OF EVERY OTHER PAGE?**

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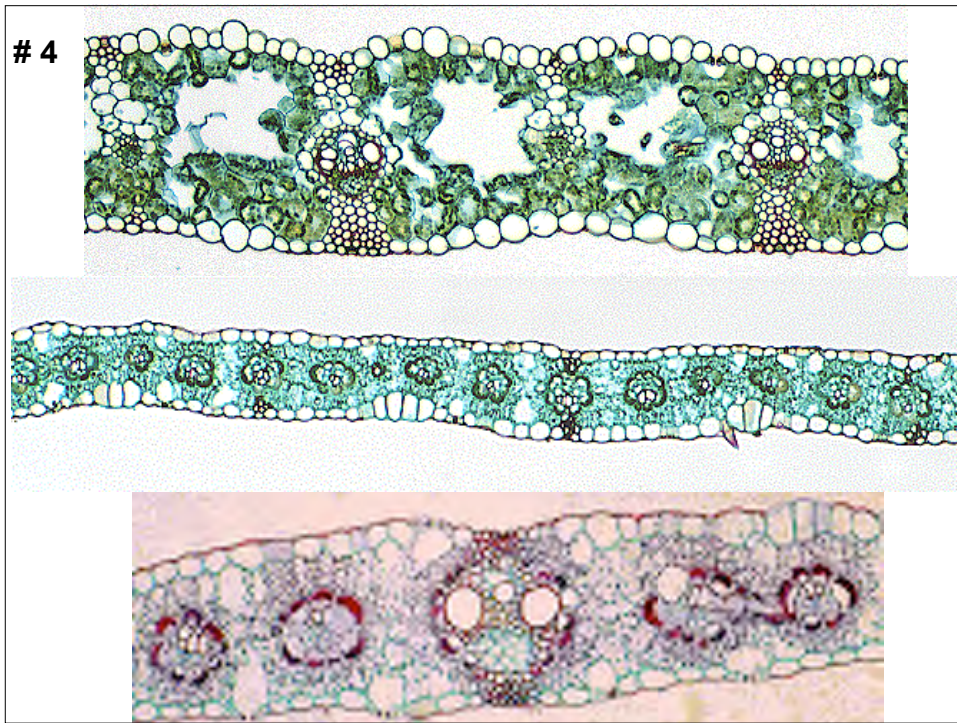


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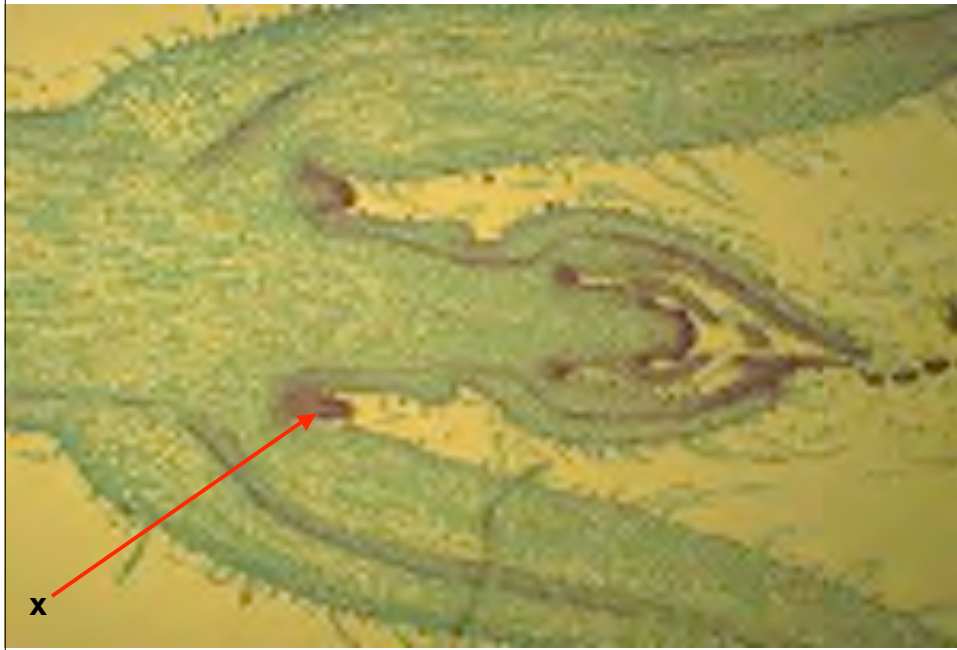




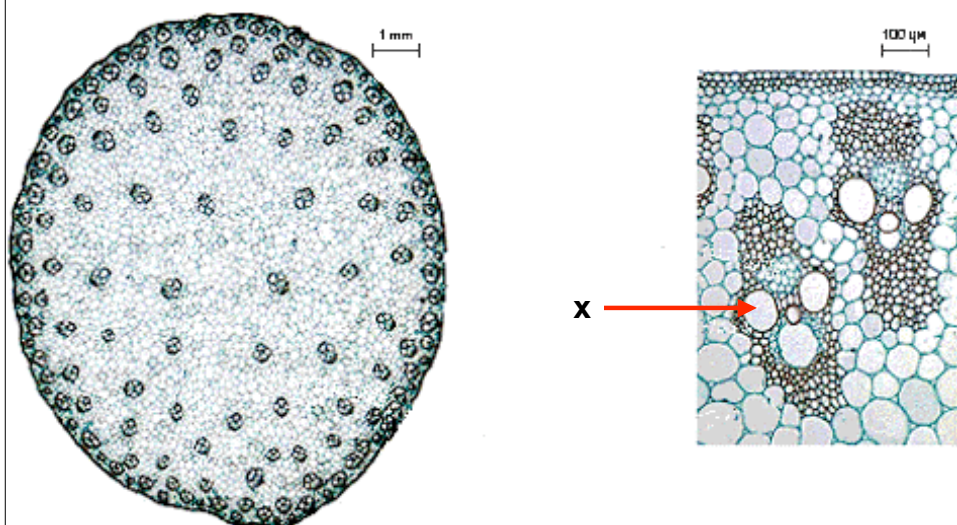




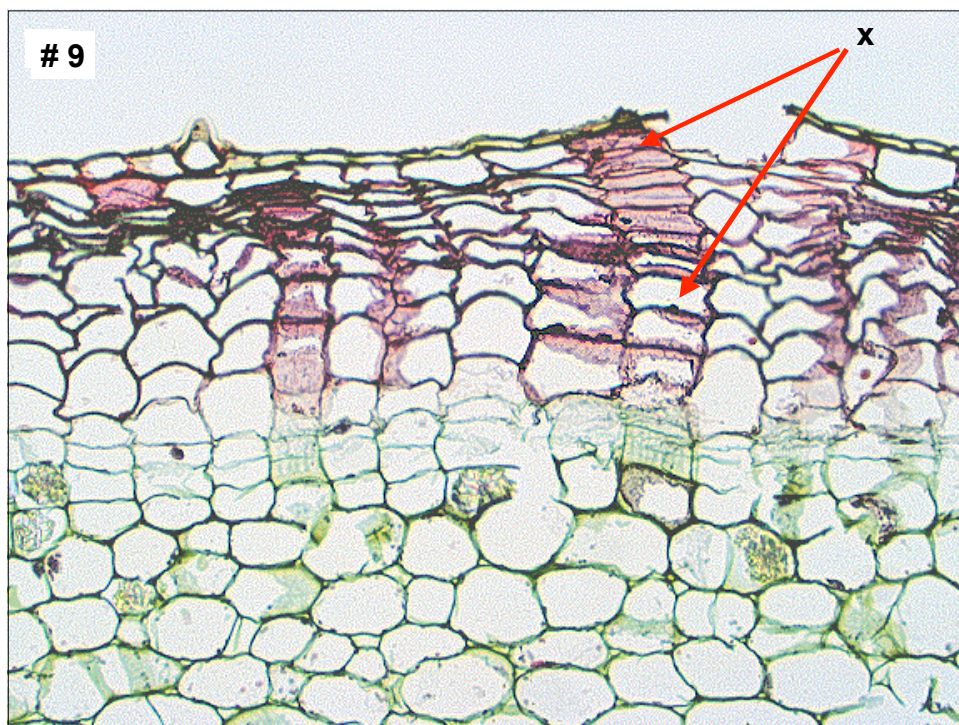
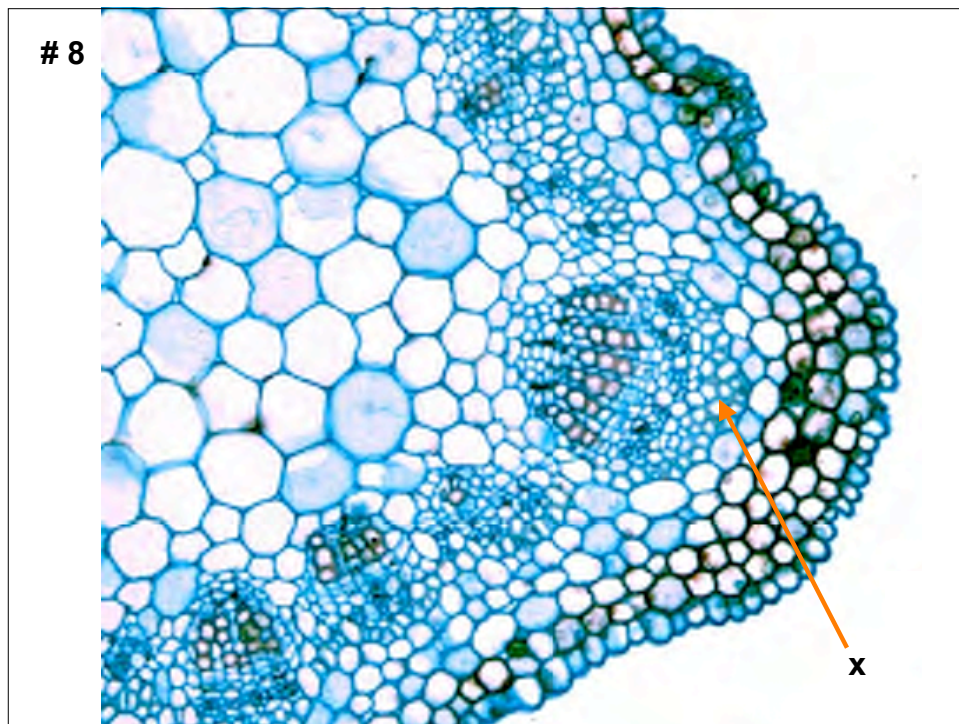
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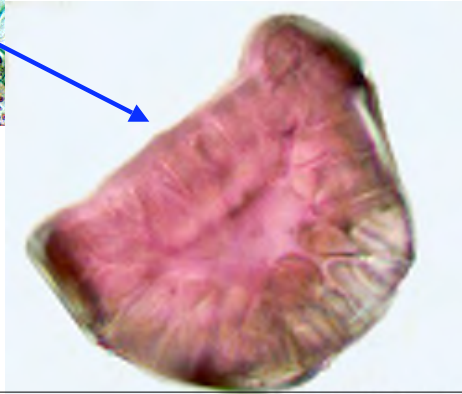
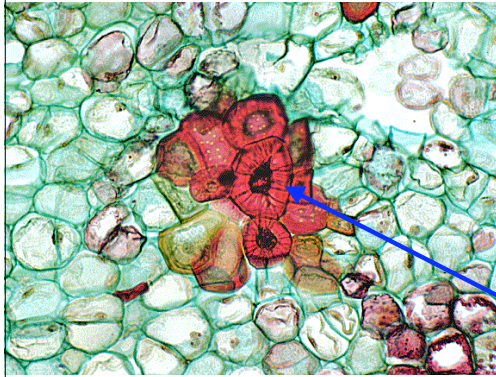
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**# 10**



**# 11**





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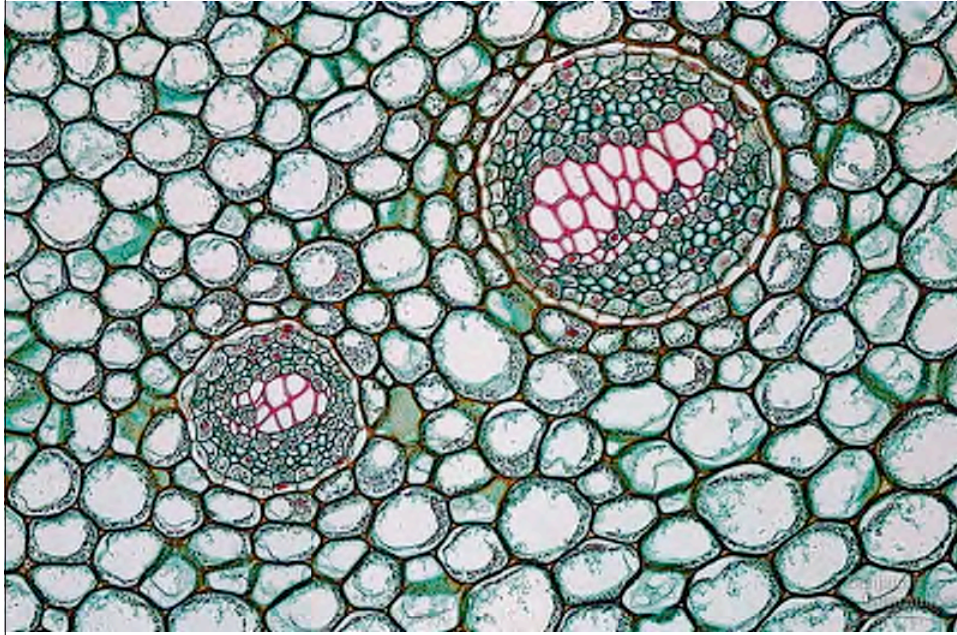


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# 14



# 15



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**PRACTICAL EXAMINATION 2**

**PLANT ANATOMY, MORPHOLOGY AND PHYSIOLOGY**

**EXAM BOOKLET 2**

**Task B.** Identification of flowering plants 23 marks

**Task C.** Dissection of a seed and a flower 25 marks

**Task D.** Plant evolution 5 points

**Task E.** Graphing and interpretation of data 8 marks

**Time allowed: 70 minutes**

(Total time allowed for Practical Examination 2 = 90 minutes)

**WRITE YOUR 4-DIGIT STUDENT CODE IN THE BOX BELOW  
AND ON THE TOP OF EACH PAGE OF THIS EXAM BOOKLET**

<b>STUDENT CODE</b>	
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## GENERAL INSTRUCTIONS

### IMPORTANT

- **Before starting the exam, the invigilator will show you a red card and a green card to test for red-green color blindness. If you are unable to see the difference between the two cards, raise your hand, and you will be provided with assistance immediately.**
- Read the exam paper carefully before commencing the exam.
- It is recommended that you allocate your time according to the mark value of the Task.
- Write your answers in the exam booklet.
- **Do not forget to hand in your graph prepared in Task E with your exam booklet.**

**BE SURE THAT YOU HAVE WRITTEN YOUR 4-DIGIT STUDENT CODE ON THE FIRST PAGE OF EACH EXAM BOOKLET**

### IMPORTANT INFORMATION FOR TASKS B AND C

- **Handle the plant samples with care.** Some samples will be used in more than one TASK.
- When you have completed **Part 7 of Task B**, please indicate so by placing your plastic bag cover back on top of the microscope and a lab assistant will grade the quality of your section.
- Make sure that you have completed **Parts 5, 6 and 7 of TASK B** before commencing **TASK C**.
- It is important that you cover your dissection board with paper towel to indicate you have completed **Task C1** (Seed Dissection) and **Task C3** (Flower Dissection). In each case, a lab assistant will ask you to sign your specimen board, photograph your dissection and then remove the dissection for marking.

## PLANT ANATOMY and MORPHOLOGY

### Materials

- 10 petri dishes containing plant samples 1 to 10
- 1 foam core specimen board labeled **SEED DISSECTION** with four coloured pins (1 black, 1 white, 1 yellow, 1 blue)
- 1 foam core specimen board labeled **FLOWER DISSECTION** with seven coloured pins (1 orange, 1 white, 1 yellow, 1 blue, 1 pink, 1 green, 1 black)
- 1 single-edge razor blade
- 1 dissecting kit
- 6 glass microscope slides
- 1 box of cover slips
- 1 drop bottle containing toluidine blue staining solution
- 1 drop bottle containing distilled water
- 3 tissues
- 1 light microscope
- 1 pair disposable gloves
- Paper towel

**NOTE:** Before beginning this task, be sure that you have all the materials listed above. If you do not, notify a lab assistant immediately by raising your hand.

### **TASK B. Identification and classification of flowering plant samples based on their anatomy and morphology. (23 marks)**

#### **Procedure:**

1. Using the razor blade, cut a thin cross section of each of the samples 1 to 4.
2. Transfer each section to a microscope slide and place 1 drop of toluidine blue staining solution and 1 drop of water on the section.
3. Put a cover slip on the section (try to avoid air bubbles when placing the cover slip) and remove excess stain by placing the corner of a piece of tissue paper against one edge of the cover slip.
4. Starting first with the 4X objective and then using either the 10X or the 40X objective, examine each slide under the microscope and observe the structure of the tissue.

5. Based on your observation of each slide prepared for samples 1 to 4, identify the tissue/organ sectioned. For each sample, enter the appropriate letter from the column labeled **KEY** in the table below. (8 marks)

Sample	Tissue/Organ
<b>1</b>	<b>B</b>
<b>2</b>	<b>C</b>
<b>3</b>	<b>B</b>
<b>4</b>	<b>C</b>

**KEY**

A = leaf

B = stem

C = root

D = petiole

6. Examine the sections you prepared for Samples 1 to 4, and the plant parts of Samples 5 to 10. Identify whether each sample is from a monocot plant or from a dicot plant and indicate your answer by writing an “X” in the appropriate column of the following table. (10 marks)

Plant Sample	Monocot	Dicot
<b>1</b>	X	
<b>2</b>		X
<b>3</b>		X
<b>4</b>	X	
<b>5</b>		X
<b>6</b>	X	
<b>7</b>	X	
<b>8</b>	X	
<b>9</b>	X	
<b>10</b>		X

7. **Once you have completed Part 6, place the slide with your best section on the microscope, focus the microscope and place your plastic bag cover back on the microscope indicating to the lab assistant that you are finished.** A lab assistant will examine the slide and grade your sectioning technique (5 marks).

**TASK C. SEED AND FLOWER ANATOMY AND MORPHOLOGY (25 marks)**

**IMPORTANT. Make sure that you have completed TASK B before starting TASK C.**

**TASK C1. SEED ANATOMY (8 marks)****Procedure**

1. Write your student number on the specimen board labeled **SEED DISSECTION**.
2. Using **Sample 5** cut the seed longitudinally with the razor blade and dissect the seed into its component parts.
3. Use the pins provided to pin the correct seed part on the specimen board
  - **black** pin for the **testa** (seed coat)
  - **white** pin for the **cotyledon**
  - **yellow** pin for the **plumule** (foliage leaves)
  - **blue** pin for the **radicle**.
4. **After finishing this task, cover the board with a paper towel indicating to the lab assistant that you are finished.** The lab assistant and yourself will sign the label on the specimen board, and the lab assistant will photograph your dissection. Your dissection will then be removed for grading.

**TASK C2. FLOWER MORPHOLOGY (2 marks)****Procedure**

1. Examine the flower in **Sample 6**. Write an “X” against the correct answer for the following questions:

(a) The sepals alone make up the

- |                |             |
|----------------|-------------|
| i) corolla     | _____       |
| ii) calyx      | _____X_____ |
| iii) perianth  | _____       |
| iv) hypanthium | _____       |

(b) The petals alone make up the whorl known as

- |                |             |
|----------------|-------------|
| i) corolla     | _____X_____ |
| ii) calyx      | _____       |
| iii) perianth  | _____       |
| iv) hypanthium | _____       |

**TASK C3. FLOWER ANATOMY (15 marks)**

**IMPORTANT. You must have completed TASK B before commencing this dissection.**

**Procedure**

1. Write your student number on the specimen board labeled **FLOWER DISSECTION**.
2. Dissect the flower (**Sample 6**) into its component parts.
3. Use the pins provided to pin the correct flower part on the specimen board
  - **orange** pin for a sepal (2 mark)
  - **white pin** for a petal (2 marks)
  - **yellow** pin for an anther (2 marks)
  - **pink** pin for the filament (2 marks)
  - **green** pin for the style (2 marks)
  - **blue** pin the stigma (2 marks)
  - **black** pin for the ovary (2 marks)
4. Use an “X” to indicate the correct classification of the placentation within the ovule of this flower (1 mark).

- |                  |             |
|------------------|-------------|
| i) marginal      | _____       |
| ii) axile        | _____X_____ |
| iii) parietal    | _____       |
| iv) free-central | _____       |



5. **After finishing this task, cover the board with a paper towel to indicate to the lab assistant that you are finished.** A lab assistant will photograph your dissection. Both the lab assistant and yourself will sign the label on the board. Your dissection will then be taken by the lab assistant for grading.

## PLANT EVOLUTION

### TASK D. Identification of the Time of Evolution of Higher Plants (5 marks)

#### Materials

- Plant samples in dishes labeled H to M. **DO NOT OPEN THE PETRI DISHES.**
- Photograph of the evolutionary time scale (Figure 1)

**NOTE:** Before beginning this task, be sure that you have all the materials listed above. If you do not, notify a lab assistant immediately by raising your hand.

#### Procedure

These plant samples possess characteristics representative of their ancestral lineages. Read the descriptions in Box A and identify the description that is most correct for each plant sample.

1. Using the codes (1 to 6) representing the different time periods in the evolutionary time scale shown in Figure 1), indicate the geologic time period that best corresponds to each description.
2. Enter the two codes (one related to the description and one related to the evolutionary time period) for each sample in Box B.

**NOTE:** **Not all descriptions in Box A will be used and no letter should be used more than once.** The answer for Sample M is provided.

**BOX A****Plant Sample Lineage Characteristics**

- a. This spore-bearing plant group has persisted relatively unchanged for hundreds of millions of years. In this time period, it was likely an important dietary element of herbivore dinosaurs.
- b. The first macrofossil evidence of the evolution of grasses appears in the fossil record at the time of the diversification of mammals.
- c. In this time period, the indehiscent integumented megasporangium (ovules/seeds) originated. It is represented in the samples by modern plants producing naked seeds on a scale.
- d. This group of spore-bearing plants included members with tree-like stature (Sample M) and were common in coal-producing swamp floras (**answers provided**).
- e. Coniferous seed plants, as represented by the sample, were driven to extinction by the diversification of the superior characteristics of the angiosperms, in this time period.
- f. The dichotomous branching and sporangia of this plant were characteristics of the first terrestrial tracheophytes, which left some of the earliest land plant macrofossils at this time in history.
- g. The evolution of flowering plants, as represented by this angiosperm, first appears in the fossil record in this time period.

**BOX B****Enter the correct codes for each sample**

<b>Sample</b>	<b>Description</b>	<b>Time Period</b>
H .....	_____g_____	_____5_____
I .....	_____f_____	_____1_____
J .....	_____a_____	_____4_____
K .....	_____b_____	_____6_____
L .....	_____c_____	_____2_____
M .....	_____d_____	_____3_____

## PLANT PHYSIOLOGY

### TASK E. Interpretation of photosynthetic data from plants grown at different light levels (8 marks)

#### Materials

- 2 sheets of graph paper, each with the axes labeled differently

**NOTE:** Before beginning this task, be sure that you have all the materials listed above. If you do not, notify a lab assistant immediately by raising your hand.

#### Introduction

Single leaves from two different plants, one grown in full sun, the other in shade, were removed and placed in separate, clear boxes. The leaves were exposed to increasing light levels and the rate of O<sub>2</sub> release was measured.

The data obtained from this experiment are presented in the following table:

Light Level ( $\mu\text{mol photons m}^{-2} \text{ s}^{-1}$ )	Rate of O <sub>2</sub> production ( $\mu\text{mol O}_2 \text{ m}^{-2} \text{ s}^{-1}$ )	
	Leaf A	Leaf B
0	-20	-2
10	-10	-0.5
25	-5	1.5
50	-1	3
100	5	6
250	15	10
500	28	12
600	30	11

#### Procedure

1. Select the sheet of graph paper that has the X-axis and the Y-axis labeled correctly for the set of data above. (1 mark)
2. Write your name and your student number on the label on the sheet of graph paper you have chosen.
3. Mark the scale of the units on each axis.
4. Plot the data presented in the table for each leaf to compare the photosynthetic rates (O<sub>2</sub> production) of the leaves with respect to light. Clearly identify which line represents **Leaf A** and which line represents **Leaf B**. (2 marks)

5. Examine the graphs you have drawn and determine which leaf (**Leaf A** or **Leaf B**) demonstrates the characteristics of a shade-adapted leaf and which demonstrates the characteristics of a sun-adapted leaf. Indicate your answer in the table below by writing an "X" in the correct cell. (1 mark)

	Leaf A	Leaf B
<b>Shade-adapted</b>		X
<b>Sun-adapted</b>	X	

6. Use the data plots on your graph to answer the following questions:

- (a) Is the light compensation point of **Leaf A** higher than the light compensation point of **Leaf B**? Circle the correct answer. (0.5 mark)

YES NO

- (b) Can the light compensation point be defined as the light level at which the photosynthetic response reaches saturation? (0.5 mark)

YES NO

- (c) Which of the answers below most correctly identifies the light compensation point of **Leaf A**? Circle the letter of that answer. (1 mark)

- i) between -10 and -5  $\mu\text{mol O}_2 \text{ m}^{-2} \text{ s}^{-1}$
- ii) between 10 and 20  $\mu\text{mol O}_2 \text{ m}^{-2} \text{ s}^{-1}$
- iii) between 25 and 50  $\mu\text{mol photons m}^{-2} \text{ s}^{-1}$
- iv) between 50 and 75  $\mu\text{mol photons m}^{-2} \text{ s}^{-1}$**
- v) between 500 and 600  $\mu\text{mol photons m}^{-2} \text{ s}^{-1}$

(d) Which of the answers below best describes the maximum rate of photosynthesis of the sun leaf? Circle the letter of that answer. (1 mark)

- i)  $12 \mu\text{mol O}_2 \text{ m}^{-2} \text{ s}^{-1}$
- ii)  $15 \mu\text{mol O}_2 \text{ m}^{-2} \text{ s}^{-1}$
- iii)  $30 \mu\text{mol O}_2 \text{ m}^{-2} \text{ s}^{-1}$**
- iv) between 250 and 600  $\mu\text{mol photons m}^{-2} \text{ s}^{-1}$
- v) greater than 600  $\mu\text{mol photons m}^{-2} \text{ s}^{-1}$

(e) This graph gives information about the photosynthetic response to light. Can it also be used to estimate the response of respiration rate with regards to light? Circle the correct answer. (1 mark)

YES

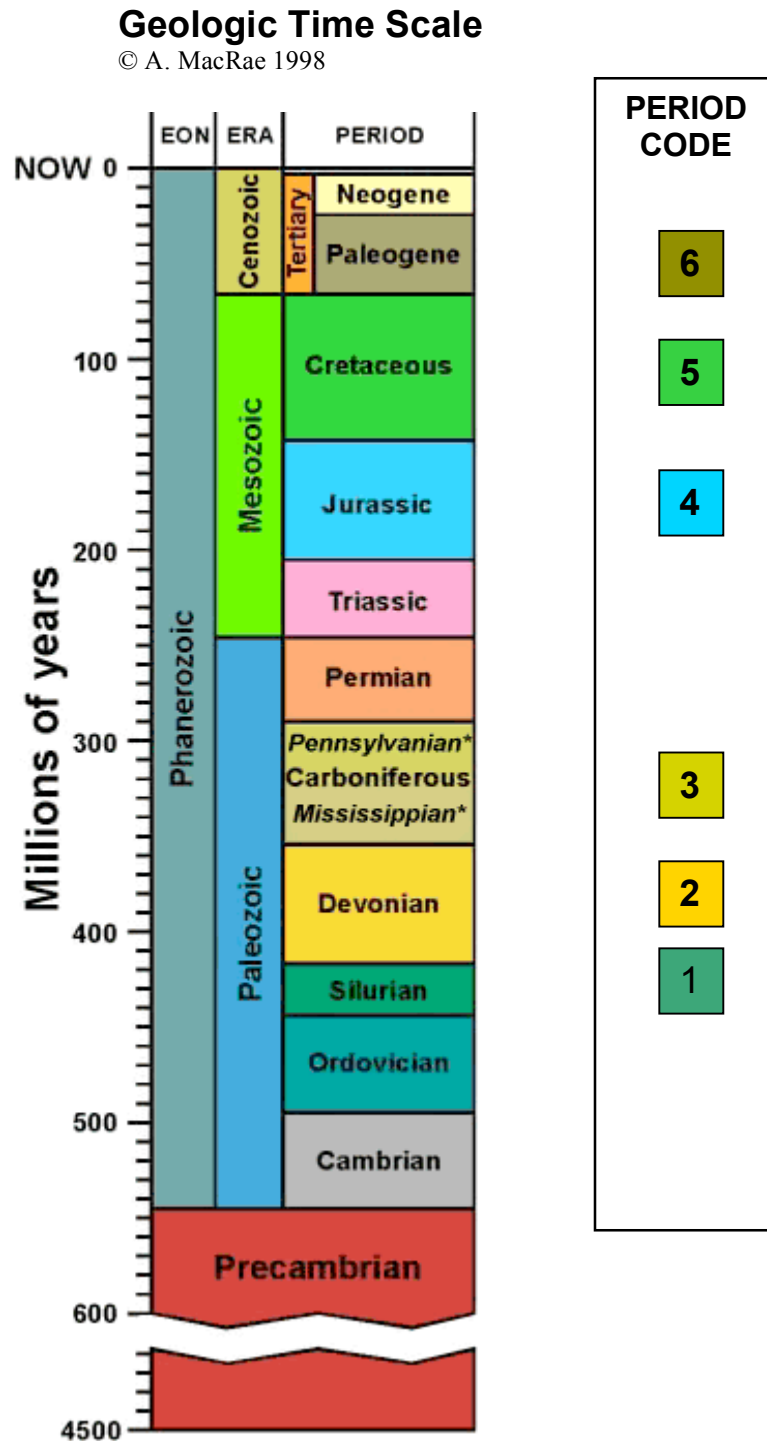
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HAVE YOU WRITTEN YOUR STUDENT CODE ON THE FIRST PAGE OF  
THIS EXAM BOOKLET AND ON THE TOP OF EACH PAGE?

REMEMBER TO HAND IN YOUR GRAPH PAPER WITH THIS EXAM  
BOOKLET.

FIGURE 1. DIAGRAM FOR TASK D.





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**JULY 15 - 22, 2007**



**PRACTICAL EXAMINATION 3**

**Cell Biology/Biochemistry**

<b>TASK A.</b>	<b>Thiocyanate analysis in cauliflower</b>	<b>27 marks</b>
<b>TASK B.</b>	<b>Determination of the amount of cauliflower needed to be consumed to cause toxicity</b>	<b>5 marks</b>
<b>TASK C.</b>	<b>Regulation of gene expression</b>	<b>18 marks</b>

**Time allowed: 90 minutes**

**WRITE ALL ANSWERS IN THIS EXAM BOOKLET**

**WRITE YOUR 4-DIGIT STUDENT CODE IN THE BOX BELOW AND  
ON THE TOP OF EACH PAGE OF THIS BOOKLET**

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## Introduction

The cabbage family contains a class of compounds known as glucosinolates. Some glucosinolates such as glucoraphanin have desired medicinal properties helping to prevent cancers while others such as glucosinalbin have toxic metabolites.

One of the products of the toxic glucosinolates is the thiocyanate ion ( $\text{SCN}^-$ ).  $\text{SCN}^-$  interferes with iodine metabolism resulting in thyroid hormone deficiency. Eating plants of the crucifer family such as cauliflower will result in the production of a limited amount of thiocyanate ion from glucosinolates such as glucosinalbin.

The glucosinolate glucoraphanin is metabolized to sulforaphane. Sulforaphane is an inducer of phase 2 proteins. One consequence of phase 2 protein induction is an increased ability of cells to scavenge free radicals and other oxidants. A consequence of decreased oxidant levels is a lower probability of activation of pathways that lead to inflammation. One such pathway is through activation of a protein complex such as NF $\kappa$ pB.

## TASK A. To determine the amount of thiocyanate ion released from cauliflower using a spectrophotometric assay. (27 marks)

**OBJECTIVE:** To use a spectrophotometer to determine how much thiocyanate ion is released from cauliflower. This assay is based upon the principle that in an acid environment thiocyanate reacts with  $\text{Fe}^{3+}$  to form a stable  $\text{Fe}^{2+}$ -SCN red-coloured complex with a maximum absorption at 447 nm.

## Materials

- Eppendorf pipettor: one 20-200 microlitre capacity set to 100 microlitres.
- Eppendorf pipette tips.
- Spectrophotometer cuvettes containing 900 microlitres of ferric nitrate reagent – as noted above, this reagent is in a strong acid.

**CAUTION:** The ferric nitrate reagent solution you will be using is dissolved in 1.0 M nitric acid. Wear gloves and use goggles to protect your eyes before starting the experiment.

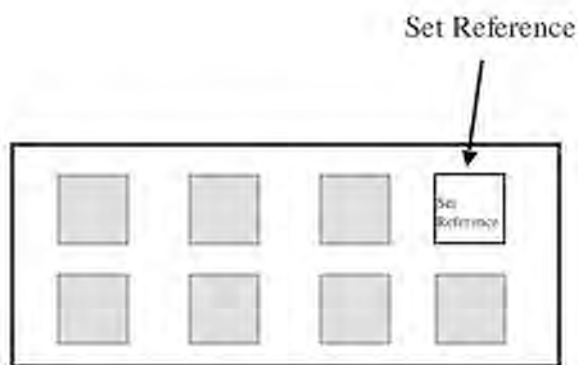
- Thiocyanate standards in tubes at the following concentrations: 0 micromoles/mL (this is your blank), 0.5 micromoles/mL, 1.0 micromoles/mL, 2.0 micromoles/mL and 4.0 micromoles/mL.
- One tube of filtered cauliflower homogenate. 1.0 g of cauliflower was homogenized and the homogenate was diluted to a total volume of 4.0 mL water. This is your unknown and you will be required to determine how many micromoles of thiocyanate are present in one millilitre of this homogenate.

- Marker pen to label the frosted side of each cuvette.
- Gloves and protective glasses
- On your bench is a spectrophotometer set to an absorbance of 447 nm.

**NOTE:** Before beginning this task, be sure that you have all the materials listed above. If you do not, notify a lab assistant by raising your hand.

## Procedure

1. Put on the gloves and the protective glasses.
2. To each of the cuvettes containing the ferric nitrate reagent add 100 microliters of each of the thiocyanate standards. The standards are: 0, 0.5, 1.0, 2.0 and 4.0 micromoles thiocyanate/mL. A coloured reaction should become visible except for the 0 micromole thiocyanate standard which serves as your blank. Be sure to label the cuvettes on the frosted surface.
3. To each of the remaining 3 cuvettes add 100 microlitres of the cauliflower homogenate.
4. Carefully carry the cuvettes to the spectrophotometer which has been set to absorb at 447 nm. Open the lid to the light path in the spectrophotometer and insert the 0 micromole thiocyanate/mL standard (i.e., blank) cuvette. **The arrow indicates the light path. Ensure that the walls of the cuvettes through which the light passes is transparent.** Close the lid and push the “set reference” button on the top right hand of the panel on the spectrophotometer – see the diagram below. **Do not touch any of the other buttons!**



5. Insert each of the standards and record the reading. Then insert each of the cuvettes containing the unknown and record the spectrophotometer reading. Leave the cuvettes at the spectrophotometer and the laboratory assistants will take care of them.

**Spectrophotometer reading (absorbance) for each standard:** (10 marks)

0.5 micromole/mL thiocyanate: \_\_\_\_\_

1.0 micromole/mL thiocyanate: \_\_\_\_\_

2.0 micromole/mL thiocyanate: \_\_\_\_\_

4.0 micromole/mL thiocyanate: \_\_\_\_\_

**Spectrophotometer reading (absorbance) for the unknown:** (4 marks)

1. \_\_\_\_\_ 2. \_\_\_\_\_ 3. \_\_\_\_\_

6. Plot, on the graph paper (page 5), the absorbance measurements for your thiocyanate standards against the concentration (micromoles/mL) of the standards. (6 marks)

7. Calculate the average absorbance of your cauliflower homogenate. (2 marks)

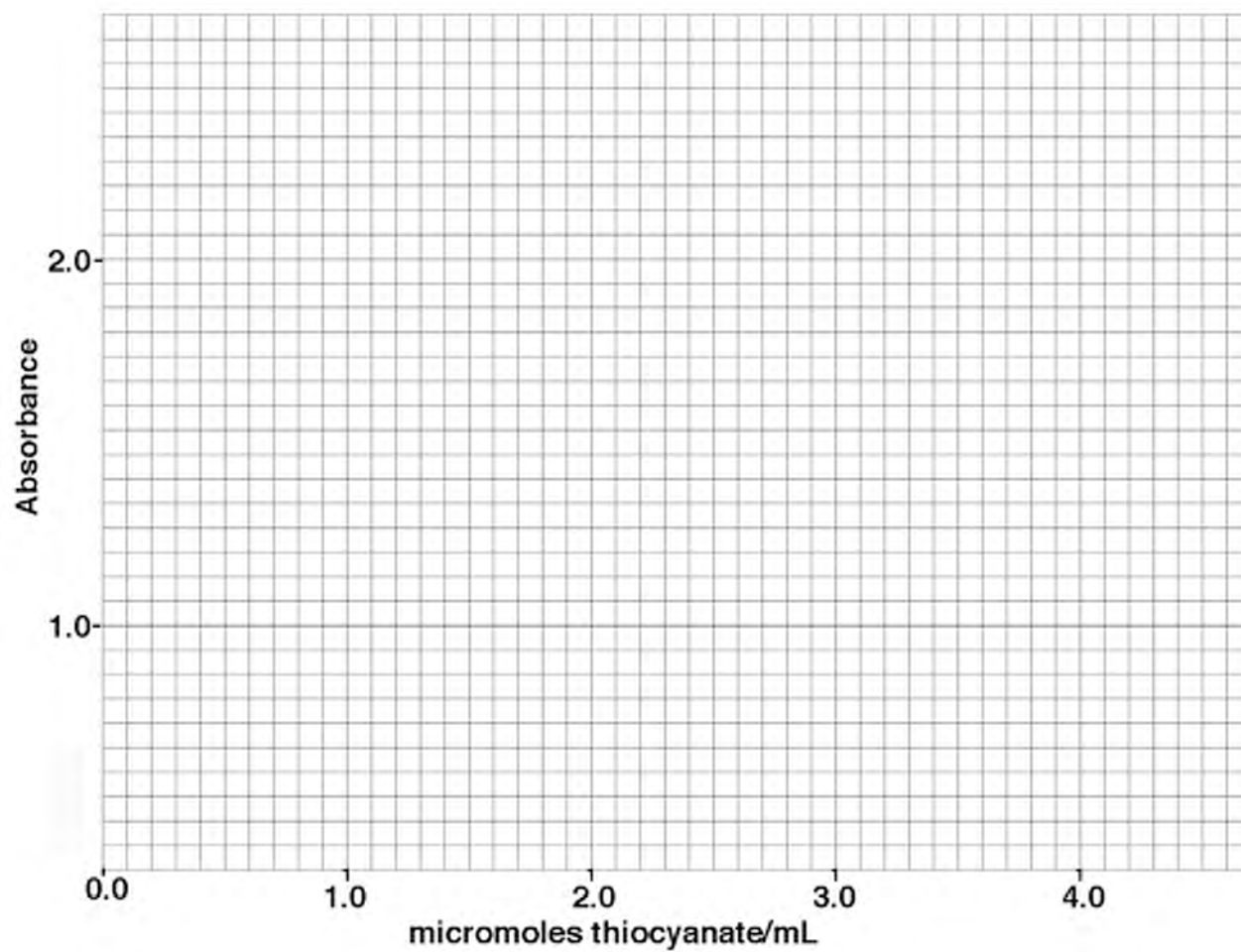
ANSWER: \_\_\_\_\_

8. What is the concentration of thiocyanate present in the cauliflower homogenate solution? (5 marks)

ANSWER: \_\_\_\_\_

9. What is the standard deviation of the absorbance of the unknown? (2 marks)

ANSWER: \_\_\_\_\_



**TASK B. To determine the amount of cauliflower needed to be consumed for it to cause toxic effects because of the presence of thiocyanate (5 marks)****Introduction**

The LD<sub>50</sub> is a toxicology term that describes the dose (i.e., moles of toxin/kg animal) of a compound that will kill 50% of the animals tested. In the rat, the LD<sub>50</sub> of sodium thiocyanate consumed is reported to be 9 millimoles/kg. Using the data of the experiment you have just performed, calculate how much cauliflower a rat that weighs 500 g would have to eat in a short time to reach the LD<sub>50</sub> of thiocyanate.

**Procedure**

Circle the letter of the range that best fits your calculated value. Show your calculations on this page. Continue on the back of this page if necessary.

- (a) 1 g to 5 g
- (b) 50 g to 250 g
- (c) 500 g to 1 kg
- (d) 1.5 kg to 14 kg
- (e) 15 kg to 25 kg

**TASK C. To interpret the regulation of gene expression. (18 marks)****Introduction**

The glucosinolate glucoraphanin is metabolized to sulforaphane. Sulforaphane is an inducer of phase 2 proteins. One consequence of phase 2 protein induction is an increased ability of cells to scavenge free radicals and other oxidants. A consequence of decreased oxidant levels is a lower probability of activation of pathways that lead to inflammation. One such pathway is through activation of a protein complex such as NFkappaB.

NFkappaB is a transcription factor complex comprised of two proteins (p50 and p65) bound to a third protein known as IkappaB that is normally present in the cytoplasm. Activation of NFkappaB involves the degradation of IkappaB resulting in the NFkappaB p50/p65 heterodimer translocating to the nucleus where it binds to specific promoter elements increasing the transcription of pro-inflammatory genes such as inducible nitric oxide synthase (iNOS). One indicator of activation of NFkappaB is that the ratio of the p65 to IkappaB protein increases.

One of the consequences of increased iNOS activity is excessive production of the nitric oxide free radical (NO). Nitric oxide reacts with the superoxide anion (O<sub>2</sub><sup>-</sup>) to form peroxynitrous acid. Peroxynitrous acid is a very strong oxidant.

Increased oxidant levels often results in activation of NFkappaB while lowering oxidant levels often results in decreased activation of NFkappaB and, hence, lowered levels of expression of pro-inflammatory genes.

**Procedure**

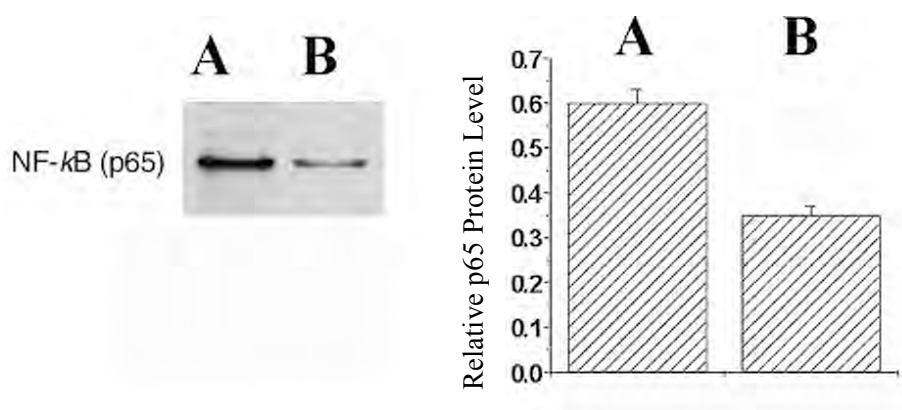
1. Examine the figures provided in each of the following sections.
2. Using the data presented, identify which data set is derived from animals fed a diet high in glucoraphanin and provide the basis for your answer.

**SECTION A.** (5 marks)

Below is a figure that gives data on NFkappaB activation in spontaneously hypertensive stroke-prone (SHRsp) male rats that were fed one of two diets: a control diet or an experimental diet containing glucoraphanin. In the experimental diet, the animals consumed 10 micromoles glucoraphanin/kg body weight.

After several months on these diets, the animals were euthanized, nuclei from the kidney cells were isolated and prepared for SDS polyacrylamide electrophoresis. Following separation of the proteins on the gel, the proteins were transferred to nitrocellulose membrane and probed with an antibody that recognized the NFkappaB p65 protein.

A representative Western blot is shown below (on the left) and next to it is a graph that depicts the quantification of blots from 5 different animals per diet group.



Answer the following questions:

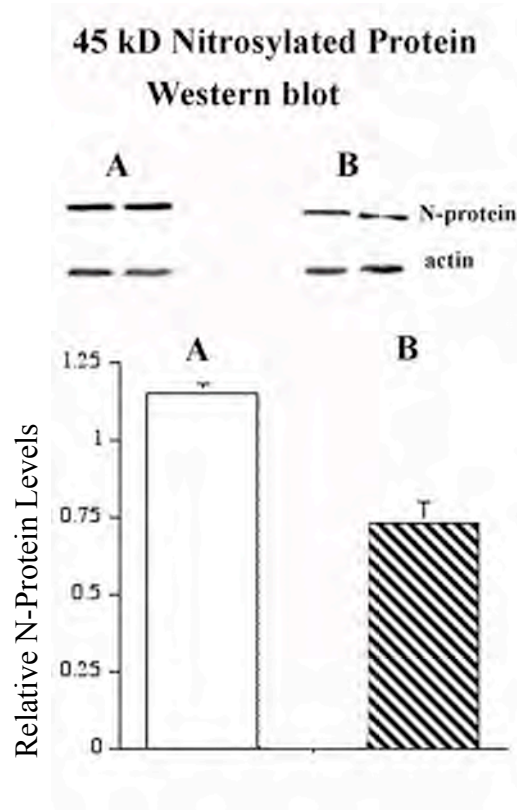
1. Which group of animals (A or B) were on the glucoraphanin-containing diet? (1 mark)

ANSWER: \_\_\_\_\_

2. Which of the following statements gives the best explanation for your answer?  
Circle the letter of that statement. (4 marks)
- (a) Less oxidative stress results in less NFkappaB activation and hence less p65 in the nuclei.
  - (b) Less oxidative stress results in less NFkappaB activation and hence more p65 in the nuclei.
  - (c) More oxidative stress results in less NFkappaB activation and hence less p65 in the nuclei.
  - (d) More oxidative stress results in less NFkappaB activation and hence more p65 in the nuclei.
  - (e) More oxidative stress results in more NFkappaB activation and hence **less** p65 in the nuclei.

**SECTION B.** (8 marks)

Below is a figure that gives Western blot data on a 45 kD nitrosylated protein (N-protein) in the kidneys of two male SHRsp rats that were put on one of two different diets: a diet containing glucoraphanin and control diets.



The top part of the figure is a representative Western blot while the bottom part of the figure is the quantification of Western blots from 5 different animals per diet group.

Answer the following questions:

1. Which group (A or B) represents the animals fed a diet containing glucoraphanin? (1 mark)

ANSWER: \_\_\_\_\_

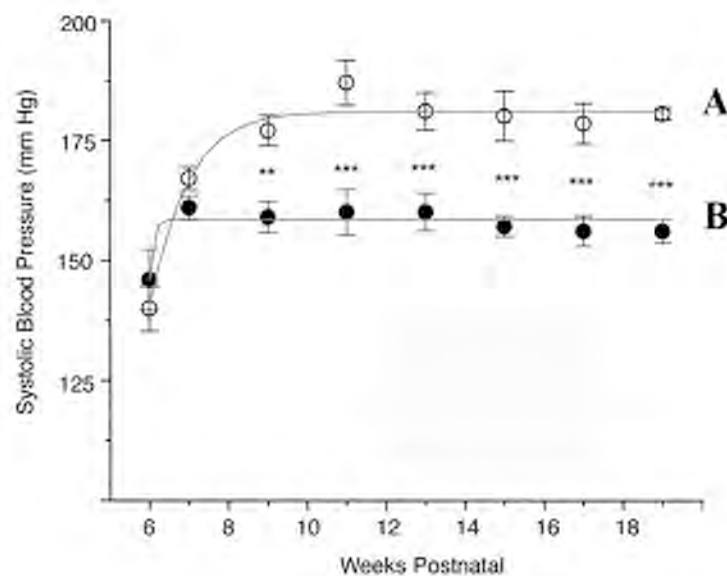


2. Circle the letter of the statement below that best explains your answer. (4 marks)
- (a) More oxidative stress results in more NFkappaB activation that results in more iNOS expression and more peroxynitrous acid formation and thus more nitrosylation of proteins.
  - (b) More oxidative stress results in more NFkappaB activation that results in more iNOS expression and more peroxynitrous acid formation but less nitrosylation of proteins.
  - (c) More oxidative stress results in more NFkappaB activation that results in more iNOS expression but less peroxynitrous acid formation and thus less nitrosylation of proteins.
  - (d) More oxidative stress results in less NFkappaB activation but results in less iNOS expression and less peroxynitrous acid formation and thus less nitrosylation of proteins.
  - (e) Less oxidative stress results in less NFkappaB activation that results in less iNOS expression and less peroxynitrous acid formation and thus less nitrosylation of proteins.
- 3) The figure above shows the amount of an additional protein, actin. Why is the level of this protein measured? (3 marks)
- a) To quantify the expression of N-protein relative to a protein that is assumed to be equally expressed in kidney cells independent of the treatment.
  - b) To show that the expression level of N-protein is independent of the effect of the treatment on the filtration rate of the kidney.
  - c) To ensure that N-protein and actin are not bound to each other in the cells of rats that received the treatment.
  - d) The level of a protein whose expression is assumed to be independent of the treatment is measured to ensure that the binding of the antibody used to detect N-protein is unaffected by the treatment.

**SECTION C. (5 marks)**

The nitric oxide radical ( $\text{NO}^\cdot$ ), that is released by endothelial cells of blood vessels, diffuses to smooth muscle cells where it causes smooth muscle cells to relax and thus decreases blood pressure. The amount of  $\text{NO}^\cdot$  that can diffuse to the smooth muscle depends upon the overall level of superoxide radicals. If there are excessive superoxide radicals present, then  $\text{NO}^\cdot$  reacts with superoxide forming peroxynitrous acid.

Below is a graph depicting the systolic blood pressures of female SHRsp rats placed on one of two diets, a control diet and a diet containing glucoraphanin. Animals were placed on these diets at the age of 5 weeks post-natal and blood pressures were monitored from 6 to 19 weeks post-natal.



Answer the following questions:

1. Which group of animals, A or B, were fed the glucoraphanin-containing diet? (1mark)

ANSWER: \_\_\_\_\_

2. Circle the letter of the statement below that best explains your answer. (4 marks)
- (a) Less oxidative stress results in lower scavenging of nitric oxide. Decreased amounts of nitric oxide available to vascular smooth muscle results in more vasorelaxation and thus lower blood pressure.
  - (b) Less oxidative stress results in higher scavenging of nitric oxide. Decreased amounts of nitric oxide available to vascular smooth muscle results in less vasorelaxation and thus higher blood pressure.
  - (c) Less oxidative stress results in lower scavenging of nitric oxide. Increased amounts of nitric oxide available to vascular smooth muscle results in more vasorelaxation and thus lower blood pressure.
  - (d) Less oxidative stress results in higher scavenging of nitric oxide. Increased amounts of nitric oxide available to vascular smooth muscle results in less vasorelaxation and thus higher blood pressure.
  - (e) Less oxidative stress results in lower scavenging of nitric oxide. Increased amount of nitric oxide available to vascular smooth muscle results in more vasorelaxation and thus lower blood pressure.

**- THE END -**

**HAVE YOU WRITTEN YOUR STUDENT CODE ON THE FIRST PAGE OF  
THIS EXAM BOOKLET AND ON THE TOP OF THE OTHER PAGES?**

**18<sup>th</sup> INTERNATIONAL BIOLOGY OLYMPIAD**  
**JULY 15 - 22, 2007**



**PRACTICAL EXAMINATION 3**

**Cell Biology/Biochemistry**

<b>TASK A.</b>	<b>Thiocyanate analysis in cauliflower</b>	<b>29 marks</b>
<b>TASK B.</b>	<b>Determination of the amount of cauliflower needed to be consumed to cause toxicity</b>	<b>5 marks</b>
<b>TASK C.</b>	<b>Regulation of gene expression</b>	<b>10 marks</b>

**Time allowed: 90 minutes**

**WRITE ALL ANSWERS IN THIS EXAM BOOKLET**

**WRITE YOUR 4-DIGIT STUDENT CODE IN THE BOX BELOW AND  
ON THE TOP OF EACH PAGE OF THIS BOOKLET**

<b>STUDENT CODE</b>	
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**Introduction**

The cabbage family contains a class of compounds known as glucosinolates. Some glucosinolates such as glucoraphanin have desired medicinal properties helping to prevent cancers while others such as glucosinalbin have toxic metabolites.

One of the products of the toxic glucosinolates is the thiocyanate ion ( $\text{SCN}^-$ ).  $\text{SCN}^-$  interferes with iodine metabolism resulting in thyroid hormone deficiency. Eating plants of the crucifer family such as cauliflower will result in the production of a limited amount of thiocyanate ion from glucosinolates such as glucosinalbin.

**TASK A. To determine the amount of thiocyanate ion released from cauliflower using a spectrophotometric assay. (29 marks)**

**OBJECTIVE:** To use a spectrophotometer to determine how much thiocyanate ion is released from cauliflower. This assay is based upon the principle that in an acid environment thiocyanate reacts with  $\text{Fe}^{3+}$  to form a stable  $\text{Fe}^{2+}$ -SCN red-coloured complex with a maximum absorption at 447 nm.

**Materials**

- Eppendorf pipettor: one 20-200 microlitre capacity set to 100 microlitres.
- Eppendorf pipette tips.
- Spectrophotometer cuvettes containing 900 microlitres of ferric nitrate reagent – as noted above, this reagent is in a strong acid.

**CAUTION:** The ferric nitrate reagent solution you will be using is dissolved in 1.0 M nitric acid. Wear gloves and use goggles to protect your eyes before starting the experiment.

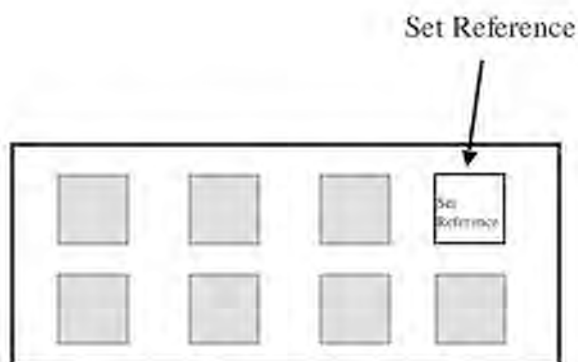
- Thiocyanate standards in tubes at the following concentrations: 0 micromoles/mL (this is your blank), 0.5 micromoles/mL, 1.0 micromoles/mL, 2.0 micromoles/mL and 4.0 micromoles/mL.
- One tube of filtered cauliflower homogenate. 1.0 g of cauliflower was homogenized and the homogenate was diluted to a total volume of 4.0 mL water. This is your unknown and you will be required to determine how many micromoles of thiocyanate are present in one millilitre of this homogenate.
- Marker pen to label the frosted side of each cuvette.
- Gloves and protective glasses
- On your bench is a spectrophotometer set to an absorbance of 447 nm.

**NOTE:** Before beginning this task, be sure that you have all the materials listed above. If you do not, notify a lab assistant by raising your hand.

**Procedure**

1. Put on the gloves and the protective glasses.
2. To each of the cuvettes containing the ferric nitrate reagent add 100 microliters of each of the thiocyanate standards. The standards are: 0, 0.5, 1.0, 2.0 and 4.0 micromoles thiocyanate/mL. A coloured reaction should become visible except for the 0 micromole thiocyanate standard which serves as your blank. Be sure to label the cuvettes on the frosted surface.
3. To each of the remaining 3 cuvettes add 100 microlitres of the cauliflower homogenate.
4. Carefully carry the cuvettes to the spectrophotometer which has been set to absorb at 447 nm. Open the lid to the light path in the spectrophotometer and insert the 0 micromole thiocyanate/mL standard (i.e., blank) cuvette. Note that the clear walls of the cuvette should be in line with the arrow indicators in the spectrophotometer chamber. Close the lid and push the “set reference” button on the top right hand of the panel on the spectrophotometer – see the diagram below.

**Do not touch any of the other buttons!**



5. Insert each of the standards and record the reading. Then insert each of the cuvettes containing the unknown and record the spectrophotometer reading. Leave the cuvettes at the spectrophotometer and the laboratory assistants will take care of them.

**Spectrophotometer reading (absorbance) for each standard:**

(10 marks)

0.5 micromole/mL thiocyanate: \_\_\_\_\_

1.0 micromole/mL thiocyanate: \_\_\_\_\_

2.0 micromole/mL thiocyanate: \_\_\_\_\_

4.0 micromole/mL thiocyanate: \_\_\_\_\_

**Spectrophotometer reading (absorbance) for the unknown: (3 marks)**

1. \_\_\_\_\_

2. \_\_\_\_\_

3. \_\_\_\_\_

6. Plot, on the graph paper (page 5), the absorbance measurements for your thiocyanate standards against the concentration (micromoles/mL) of the standards. (6 marks)
7. Take the average absorbance of your cauliflower homogenate and determine the thiocyanate ion concentration using the previously plotted graph. (5 marks)

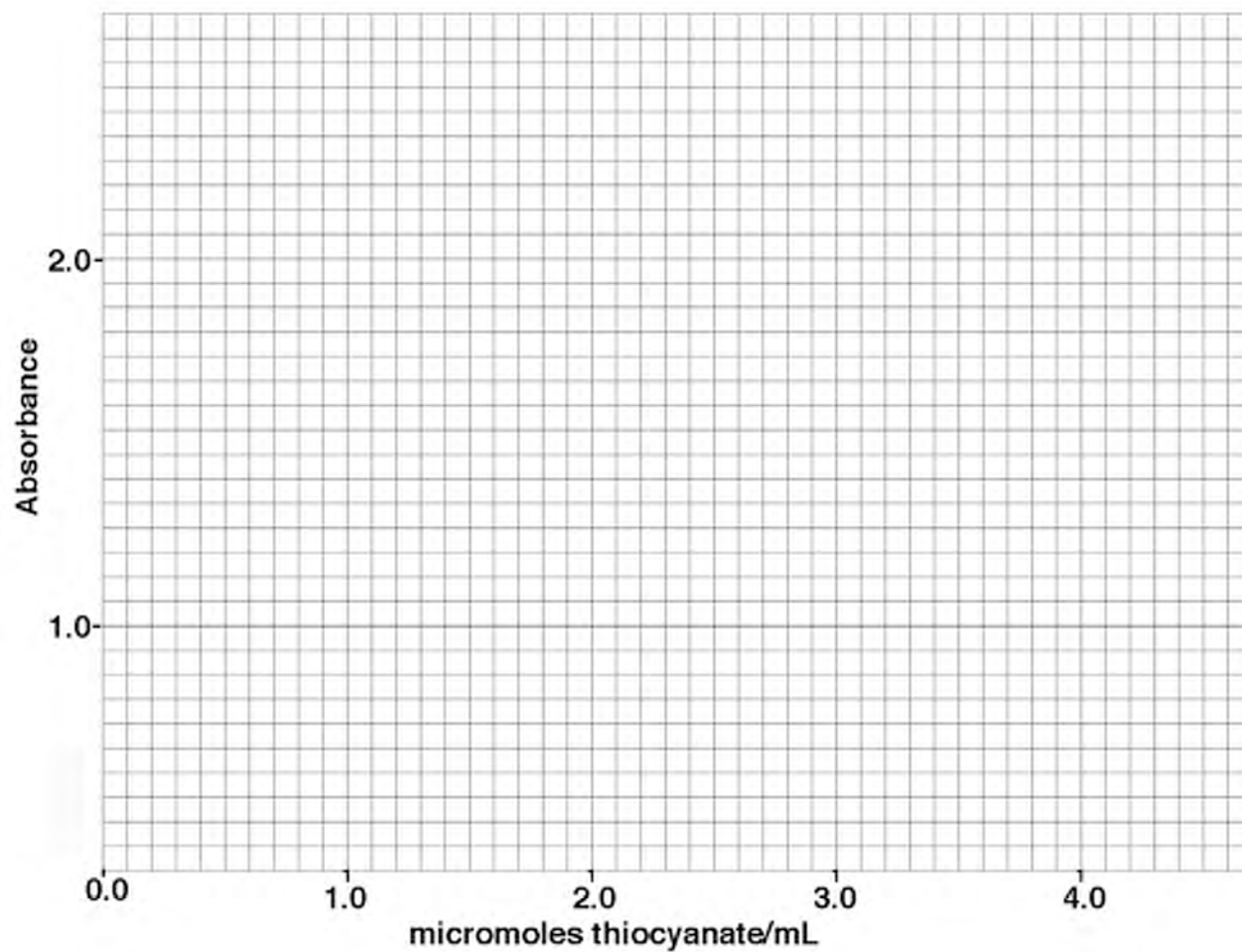
ANSWER: \_\_\_\_\_

8. What is the concentration of the thiocyanate ion present in your cauliflower homogenate? Be sure to state the units. (3 marks)

ANSWER: \_\_\_\_\_

9. Calculate the standard deviation of the spectrophotometer reading of the unknown? (2 marks)

ANSWER: \_\_\_\_\_





**TASK B. To determine the amount of cauliflower needed to be consumed for it to cause toxic effects because of the presence of thiocyanate (5 marks)****Introduction**

The LD<sub>50</sub> is a toxicology term that describes the dose (i.e., moles of toxin/kg animal) of a compound that will kill 50% of the animals tested. In the rat, the LD<sub>50</sub> of sodium thiocyanate consumed is reported to be 9 millimoles/kg. Using the data of the experiment you have just performed, calculate how much cauliflower a rat that weighs 500 g would have to eat in a short time to reach the LD<sub>50</sub> of thiocyanate.

**Procedure**

Circle the letter of the range that best fits your calculated value. Show your calculations on this page. Continue on the back of this page if necessary.

- (a) 1 g to 5 g
- (b) 50 g to 250 g
- (c) 500 g to 1 kg
- (d) 1.5 kg to 14 kg
- (e) 15 kg to 25 kg

**TASK C. To interpret the regulation of gene expression. (18 marks)****Introduction**

The glucosinolate glucoraphanin is metabolized to sulforaphane. Sulforaphane is an inducer of phase 2 proteins. One consequence of phase 2 protein induction is an increased ability of cells to scavenge free radicals and other oxidants. A consequence of decreased oxidant levels is a lower probability of activation of pathways that lead to inflammation. One such pathway is through activation of a protein complex such as NFkappaB.

NFkappaB is a transcription factor complex comprised of two proteins (p50 and p65) bound to a third protein known as IkappaB that is normally present in the cytoplasm. Activation of NFkappaB involves the degradation of IkappaB resulting in the NFkappaB p50/p65 heterodimer translocating to the nucleus where it binds to specific promoter elements increasing the transcription of pro-inflammatory genes such as inducible nitric oxide synthase (iNOS). One indicator of activation of NFkappaB is that the ratio of the p65 to IkappaB protein increases.

One of the consequences of increased iNOS activity is excessive production of the nitric oxide free radical (NO). Nitric oxide reacts with the superoxide anion (O<sub>2</sub><sup>-</sup>) to form peroxynitrous acid. Peroxynitrous acid is a very strong oxidant.

Increased oxidant levels often results in activation of NFkappaB while lowering oxidant levels often results in decreased activation of NFkappaB and, hence, lowered levels of expression of pro-inflammatory genes. The nitric oxide that is released by endothelial cells diffuses to smooth muscle cells where it causes smooth muscle cells to relax. Hence, nitric oxide is a major regulator of blood pressure.

## Procedure

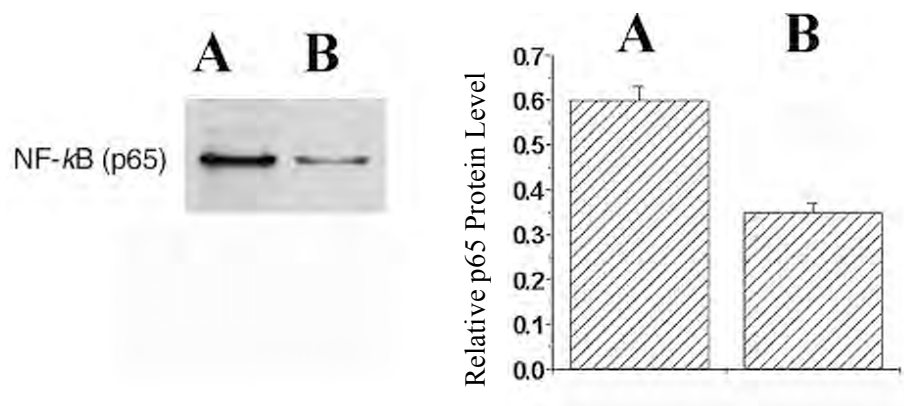
1. Examine the figures provided in each of the following sections.
2. Using the data presented, identify which data set is derived from animals fed a diet high in glucoraphanin and provide the basis for your answer.

### SECTION A. (5 marks)

Below is a figure that gives data on NFkappaB activation in spontaneously hypertensive stroke-prone (SHRsp) male rats that were fed one of two diets: a control diet or an experimental diet containing glucoraphanin. In the experimental diet, the animals consumed 10 micromoles glucoraphanin/kg body weight.

After several months on these diets, the animals were euthanized, nuclei from the kidney cells were isolated and prepared for SDS polyacrylamide electrophoresis. Following separation of the proteins on the gel, the proteins were transferred to nitrocellulose membrane and probed with an antibody that recognized the NFkappaB p65 protein.

A representative Western blot is shown below (on the left) and next to it is a graph that depicts the quantification of blots from 5 different animals per diet group.



Answer the following questions:

1. Which group of animals were on the glucoraphanin-containing diet? The group represented by A or B? (1 mark)

ANSWER: \_\_\_\_\_ **B** \_\_\_\_\_

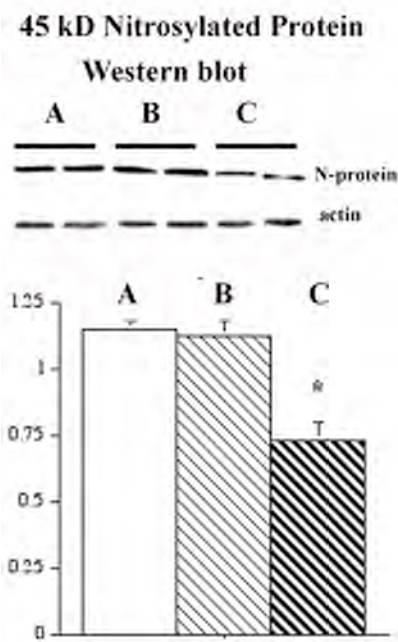
2. Which of the following statements gives the best explanation for your answer?

Circle the letter of that statement. (4 marks)

- (a) **Less oxidative stress results in less NFkappaB activation and hence less p65 in the nuclei.**
- (b) Less oxidative stress results in less NFkappaB activation and hence more p65 in the nuclei.
- (c) More oxidative stress results in less NFkappaB activation and hence less p65 in the nuclei.
- (d) More oxidative stress results in less NFkappaB activation and hence more p65 in the nuclei.
- (e) More oxidative stress results in more NFkappaB activation and hence less p65 in the nuclei.

### SECTION B. (5 marks)

Below is a figure that gives Western blot data on a 45 kD nitrosylated protein (N-protein) in the kidneys of two male SHRsp rats that were put on one of two different diets: a diet containing glucoraphanin and control diets.



The top part of the figure is a representative Western blot while the bottom part of the figure is the quantification of Western blots from 5 different animals per diet group.

Answer the following questions:

1. Which group represents the animals fed a diet containing glucoraphanin? (1 mark)

ANSWER: \_\_\_\_\_ C \_\_\_\_\_

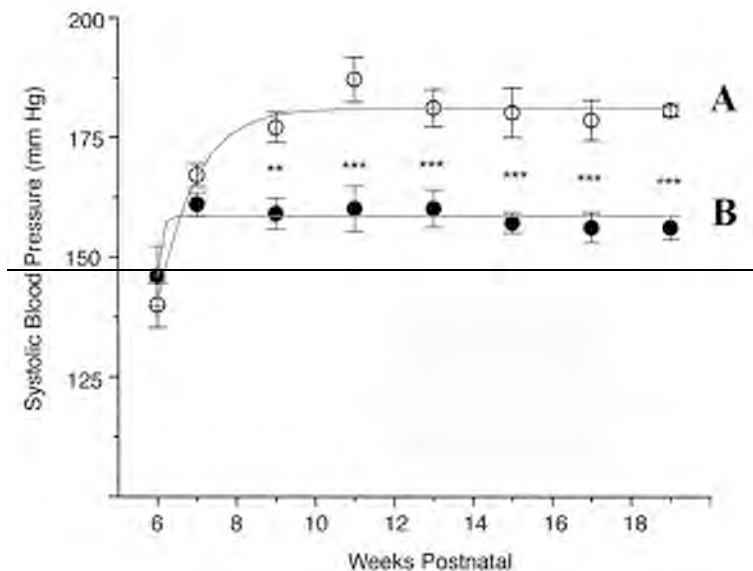
2. Circle the letter of the statement below that best explains your answer. (4 marks)

- (a) More oxidative stress results in more NFkappaB activation that results in more iNOS expression and more peroxynitrous acid formation and thus more nitrosylation of proteins.
- (b) More oxidative stress results in more NFkappaB activation that results in more iNOS expression and more peroxynitrous acid formation but less nitrosylation of proteins.
- (c) More oxidative stress results in more NFkappaB activation that results in more iNOS expression but less peroxynitrous acid formation and thus less nitrosylation of proteins.
- (d) More oxidative stress results in less NFkappaB activation but results in less iNOS expression and less peroxynitrous acid formation and thus less nitrosylation of proteins.
- (e) Less oxidative stress results in less NFkappaB activation that results in less iNOS expression and less peroxynitrous acid formation and thus less nitrosylation of proteins.**

### SECTION C. (5 marks)

The nitric oxide radical ( $\text{NO}^\cdot$ ), that is released by endothelial cells of blood vessels, diffuses to smooth muscle cells where it causes smooth muscle cells to relax and thus decreases blood pressure. The amount of  $\text{NO}^\cdot$  that can diffuse to the smooth muscle depends upon the overall level of superoxide radicals. If there are excessive superoxide radicals present, then  $\text{NO}^\cdot$  reacts with superoxide forming peroxynitrous acid.

Below is a graph depicting the systolic blood pressures of female SHRsp rats placed on one of two diets, a control diet and a diet containing glucoraphanin. Animals were placed on these diets at the age of 5 weeks post natal and blood pressures were monitored from 6 to 19 weeks post natal.



Answer the following questions:

1. Which group of animals, A or B, were fed the glucoraphanin-containing diet? (1 mark)

\_\_\_\_\_

ANSWER: \_\_\_\_\_

2. Circle the letter of the statement below that best explains your answer. (4 marks)

- (a) ~~Less oxidative stress results in lower scavenging of nitric oxide. Decreased amounts of nitric oxide available to vascular smooth muscle results in more vasorelaxation and thus lower blood pressure.~~
- (b) ~~Less oxidative stress results in higher scavenging of nitric oxide. Decreased amounts of nitric oxide available to vascular smooth muscle results in less vasorelaxation and thus higher blood pressure.~~
- (c) ~~Less oxidative stress results in lower scavenging of nitric oxide. Increased amounts of nitric oxide available to vascular smooth muscle results in more vasorelaxation and thus lower blood pressure.~~
- (d) ~~Less oxidative stress results in higher scavenging of nitric oxide. Increased amounts of nitric oxide available to vascular smooth muscle results in less vasorelaxation and thus higher blood pressure.~~
- (e) ~~Less oxidative stress results in lower scavenging of nitric oxide. Increased amount of nitric oxide available to vascular smooth muscle results in more vasorelaxation and thus lower blood pressure.~~

- THE END -

**HAVE YOU WRITTEN YOUR STUDENT CODE ON THE FIRST PAGE OF  
THIS EXAM BOOKLET AND ON THE TOP OF THE OTHER PAGES?**

International Biology Olympiad

**IBO**

Saskatoon Canada 2007

- ***Before starting the exam, the invigilator will show you a red card and a green card to test for red-green color blindness. If you are unable to see the difference between the two cards, raise your hand, and you will be provided with assistance immediately.***

Student code:	
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**TASK A. Sequence Confirmation of a cDNA (23 marks)**

**Objective:** To isolate plasmid DNA containing a cDNA of interest and to determine the sequence of the cDNA.

**Introduction:**

To over-express a gene of interest in a plant or animal you must first isolate the gene of interest in the form of a cDNA. You have done this and in order to amplify this DNA, you have cloned it into the pBluescript SK plasmid vector which you have subsequently used to transform bacteria cells. You must now carry out a quick plasmid preparation to isolate the plasmid and confirm the sequence of your cDNA insert.

Materials	Quantity
➤ Bacterial cell culture	4 mL
➤ 1.5 mL microcentrifuge tubes	5
➤ Microcentrifuge rack	1
➤ P1000 micropipettor	1
➤ Box of 200-1000 uL pipette tips	1
➤ GET buffer (1.5 mL tube)	0.5 mL
➤ 10% Sodium Dodecyl Sulphate (1.5 mL tube)	0.5 mL
➤ 2 N NaOH (1.5 mL tube)	0.5 mL
➤ 3 M Potassium 5 M Acetate (1.5 mL tube)	0.5 mL
➤ 95% ethanol (Falcon tube)	3 mL
➤ Distilled water (Falcon tube)	3 mL
➤ Timer	1
➤ Tube labels	2
➤ Marker pen	1
➤ Red card	1
➤ Garbage (tips & tubes) bag	1
➤ Access to a microcentrifuge	
➤ Access to vortex	

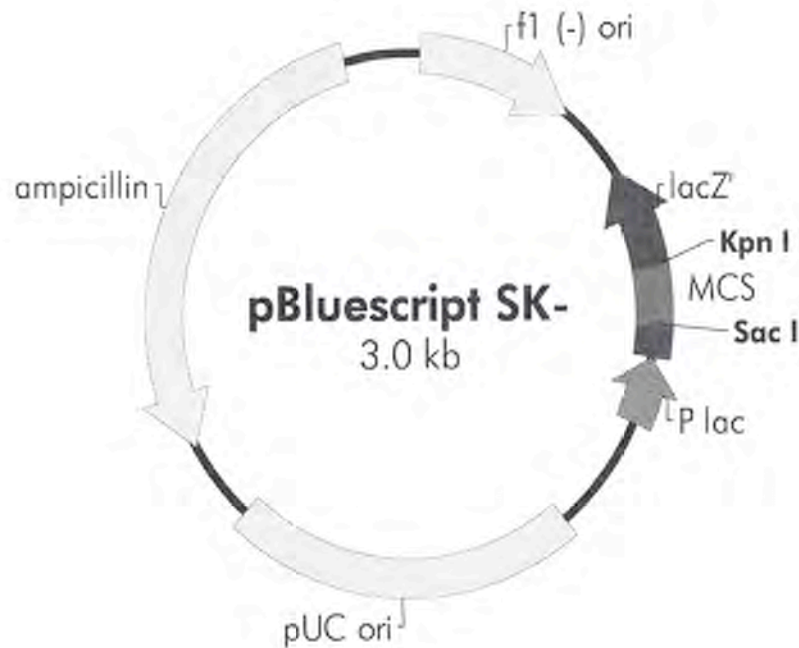
**NOTE:** Before beginning this task, be sure that you have all the materials listed above. If you do not, raise your RED card to call a lab assistant.

### Procedure

1. Pipette 1.5 mL of bacterial culture into each of two 1.5 mL microcentrifuge tubes.
2. Centrifuge the tubes in a benchtop microcentrifuge for 1 minute - make sure that the centrifuge rotor is **BALANCED**.
3. Completely remove and discard the growth medium from each tube.
4. Add 100  $\mu$ L of GET (Glucose-EDTA-Tris) buffer pH 7.9 to the cell pellet (no need to cap the tubes) - vortex vigorously to resuspend the pellet and leave at room temperature for 5 minutes.
5. In a separate 1.5 mL microcentrifuge tube, make a combined mixture of 1% SDS and 0.2 N NaOH in water to a final volume of 1 mL.
6. To each tube from 4. above add 200  $\mu$ L of this freshly prepared mixture of 1% SDS and 0.2 N NaOH - cap the tubes and invert 4-5 times.
7. Incubate at room temperature for 3 minutes.
8. To each tube add 150  $\mu$ L 5M KOAc (3 M potassium and 5 M acetate), cap the tubes and shake briefly by hand to mix.
9. Incubate at room temperature for 3 minutes.
10. Centrifuge the tubes for 3 minutes - full speed in microcentrifuge - **remember to balance the rotor**.
11. Label 2 clean microcentrifuge tubes with your 4-digit student code number.
12. Pipette the supernatant from each of the centrifuged tubes into each of the clean tubes. Discard the **original** tube which now contains a white pellet - this is bacterial chromosomal DNA.
13. Add 800  $\mu$ L of 95% ethanol to each tube. Cap the tubes, shake vigorously for 10 sec and leave on bench 10 minutes.
14. Centrifuge the tubes for 5 minutes - full speed in microcentrifuge.
15. Pour off the supernatant from each tube, cap the tube and **raise your RED card**.
16. The lab assistant will check your pellet (10 marks for a white pellet).
17. The lab assistant will then give you the sequence trace for your plasmid and cDNA. The cDNA was sequenced from the **T<sub>3</sub>** promoter.

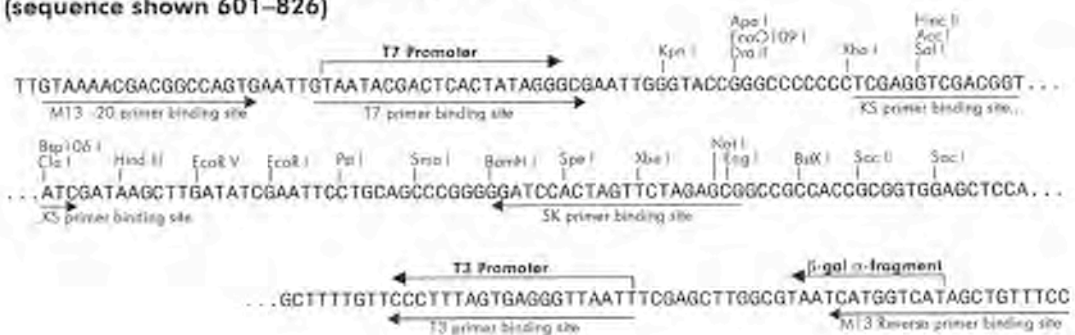


18. Check your sequence (starting at nucleotide 21) against that for the pBluescript vector and answer the questions on page 5.



## PLASMID MAP AND MULTIPLE CLONING SITE SEQUENCE FOR pBLUESCRIPT

### pBluescript SK (+/-) Multiple Cloning Site Region (sequence shown 601-826)



**Questions** (13 marks)

1. The enzyme site into which you cloned your fragment of DNA is **EcoR1**.

**NOTE:** The first letter of the enzyme's name is located above the first nucleotide of its recognition sequence. (5 marks)

2. List the first 20 nucleotides of your fragment of DNA (not including the restriction site sequence). (2 marks)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
nucleotide	<b>G</b>	<b>A</b>	<b>G</b>	<b>A</b>	<b>A</b>	<b>G</b>	<b>A</b>	<b>C</b>	<b>T</b>	<b>C</b>	<b>T</b>	<b>T</b>	<b>A</b>	<b>G</b>	<b>T</b>	<b>C</b>	<b>T</b>	<b>T</b>	<b>G</b>	<b>A</b>

3. Find the first start codon. Using the genetic code table provided, and starting with the start codon, translate the first 21 nucleotides into their appropriate amino acids. (4 marks)

Start codon

Amino acid	<b>MET</b>			<b>VAL</b>			<b>TYR</b>			<b>LEU</b>			<b>LEU</b>			<b>LEU</b>			<b>LEU</b>		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
nucleotide																					

4. (a) If the nucleotide at position 13 was mutated to an 'A', what would be the corresponding amino acid? (1 mark)

**MET**

- (b). If the nucleotide at position 14 was mutated to an 'A', what would be the corresponding amino acid? (1 mark)

**STOP**

### Task C. Genetic Control of Seed Coat Colour and Seed Shape in Beans (20 marks)

#### Material

- 1 plastic bag containing flat red parent beans – **DO NOT OPEN**
- 1 plastic bag containing round red parent beans – **DO NOT OPEN**
- 1 plastic bag containing  $F_1$  seeds (flat yellow) from the cross between the parent beans – **DO NOT OPEN**
- 1 plastic bag of  $F_2$  bean seeds (representing 250  $F_2$  plants) – **THIS BAG MAY BE OPENED**

To help you answer the questions below, fill in the following table:

Generation	Seed shape (round or flat)	Seed coat colour (yellow or red)
Parent 1	<b>FLAT</b>	<b>RED</b>
Parent 2	<b>ROUND</b>	<b>RED</b>
$F_1$ from a cross between these two parents	<b>FLAT</b>	<b>YELLOW</b>

Answer the following questions.

1. Is the seed coat colour controlled by (circle one)

- (i) one gene
- (ii) **more than one gene?** (1 mark)

2. a) Red seed coat colour is (circle one)

- (i) dominant
- (ii) partially dominant
- (iii) **recessive** (1 mark)

b) Round seed shape is (circle one)

(i) dominant

(ii) partially dominant

(iii) **recessive**

(1 mark)

3. (a) There are four phenotypes in your sample of F<sub>2</sub> seeds. Classify the seeds into these phenotypic classes and write the number of each phenotype in the table below. (2 points)

Phenotype (seed colour/seed shape)	Number of seeds (= number of F <sub>2</sub> plants)
round, red	<b>13</b>
flat, red	<b>38</b>
round, yellow	<b>18</b>
flat, yellow	<b>55</b>
<b>Total</b>	<b>124</b>

Use these F<sub>2</sub> segregation data to answer the following questions:

4. (a) From your data how many genes could be controlling seed shape?     **1**      
(1 mark)

(b) How many round beans and how many flat ones would you expect in a population this size?

ROUND     **31**    

FLAT     **93**    

(2 marks)

(c) Is this segregation ratio significantly different from the observed ratio (circle one)?

YES

**NO**

(1 mark)

And what is the probability?

**0.95 < p < 1.0**

(3 marks)

5. (a) From your data how many genes could be controlling seed coat colour?   2    
(1 mark)

(b) How many red beans and how many yellow beans would you expect in a population this size?

RED      **54.25**                      YELLOW      **69.75**                      (3 marks)

(c) Is this segregation ratio significantly different from the observed ratio? (circle one)

YES                      NO                      (1 mark)

And what is the probability?      **0.56 or  $0.5 < p < 0.7$**                       (3 marks)

#### Chi-square Distribution

	Probability										
Df	0.95	0.90	0.80	0.70	0.50	0.30	0.20	0.10	0.05	0.01	0.001
1	0.004	0.02	0.06	0.15	0.46	1.07	1.64	2.71	3.84	6.64	10.83
2	0.10	0.21	0.45	0.71	1.39	2.41	3.22	4.60	5.99	9.21	13.82
3	0.35	0.58	1.01	1.42	2.37	3.66	4.64	6.25	7.82	11.34	16.27
4	0.71	1.06	1.65	2.20	3.36	4.88	5.99	7.78	9.49	13.28	18.47

**- THE END -**

## GENETIC CODE TABLE

This table shows the 64 codons and the amino acid each codon codes for. The direction is 5' to 3'.

		2nd base			
		U	C	A	G
1st base	U	UUU (Phe/F)Phenylalanine	UCU (Ser/S)Serine	UAU (Tyr/Y)Tyrosine	UGU (Cys/C)Cysteine
		UUC (Phe/F)Phenylalanine	UCC (Ser/S)Serine	UAC (Tyr/Y)Tyrosine	UGC (Cys/C)Cysteine
		UUA (Leu/L)Leucine	UCA (Ser/S)Serine	UAA Ochre ( <i>Stop</i> )	UGA Opal ( <i>Stop</i> )
		UUG (Leu/L)Leucine	UCG (Ser/S)Serine	UAG Amber ( <i>Stop</i> )	UGG (Trp/W)Tryptophan
	C	CUU (Leu/L)Leucine	CCU (Pro/P)Proline	CAU (His/H)Histidine	CGU (Arg/R)Arginine
		CUC (Leu/L)Leucine	CCC (Pro/P)Proline	CAC (His/H)Histidine	CGC (Arg/R)Arginine
		CUA (Leu/L)Leucine	CCA (Pro/P)Proline	CAA (Gln/Q)Glutamine	CGA (Arg/R)Arginine
		CUG (Leu/L)Leucine	CCG (Pro/P)Proline	CAG (Gln/Q)Glutamine	CGG (Arg/R)Arginine
	A	AUU (Ile/I)Isoleucine	ACU (Thr/T)Threonine	AAU (Asn/N)Asparagine	AGU (Ser/S)Serine
		AUC (Ile/I)Isoleucine	ACC (Thr/T)Threonine	AAC (Asn/N)Asparagine	AGC (Ser/S)Serine
		AUA (Ile/I)Isoleucine	ACA (Thr/T)Threonine	AAA (Lys/K)Lysine	AGA (Arg/R)Arginine
		AUG (Met/M)Methionine	ACG (Thr/T)Threonine	AAG (Lys/K)Lysine	AGG (Arg/R)Arginine
	G	GUU (Val/V)Valine	GCU (Ala/A)Alanine	GAU (Asp/D)Aspartic acid	GGU (Gly/G)Glycine
		GUC (Val/V)Valine	GCC (Ala/A)Alanine	GAC (Asp/D)Aspartic acid	GGC (Gly/G)Glycine
		GUA (Val/V)Valine	GCA (Ala/A)Alanine	GAA (Glu/E)Glutamic acid	GGA (Gly/G)Glycine
		GUG (Val/V)Valine	GCG (Ala/A)Alanine	GAG (Glu/E)Glutamic acid	GGG (Gly/G)Glycine

## MARKING NOTES for TASK C of the GENETICS PRACTICAL EXAM

Q. 3. Deviations of  $\pm 3$  were accepted in each category.

If these numbers were different, the remaining calculations were done with the student's numbers and marked accordingly.

Q. 4. (b) 63 :187 was also accepted if the students used 250 as the population size

(c)  $P = 0.95$  was not accepted unless it was the actual p-value.

This answer is based on the expected values in 4b, if the student had different expected values their numbers were used in a chi-square calculation. This was necessary as the students did not always get the right # of seeds/phenotype.

Q. 5. (b) 109:140 was also accepted if the students used 250 as the population size. Full marks were given if the ratio was reversed (not convinced the translations were always correct)

(c) This answer is based on the expected values in 5 (b). If the student had different expected values, those numbers were used in the chi-square calculation. This was necessary as the students did not always get the right # of seeds/phenotype.

**18<sup>th</sup> INTERNATIONAL BIOLOGY OLYMPIAD**  
**JULY 15 - 22, 2007**



**THEORY EXAMINATION # 1**

**Total marks possible: 99.0**

**Time allowed: 2.5 hours (150 minutes)**

**WRITE YOUR 4-DIGIT STUDENT NUMBER IN THE BOX  
BELOW**

<b>STUDENT CODE</b>	
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## GENERAL INSTRUCTIONS

Check that you have the correct examination paper and an answer sheet.

**WHEN YOU HAVE FINISHED THE EXAM, PLACE YOUR ANSWER SHEET INSIDE YOUR QUESTION PAPER AND HAND BOTH TO THE INVIGILATOR BEFORE LEAVING THE EXAM ROOM.**

**REMEMBER TO WRITE YOUR 4-DIGIT STUDENT CODE ON THE FRONT PAGE OF THE QUESTION PAPER.**

Read each question carefully before attempting it.

### INSTRUCTIONS REGARDING RECORDING YOUR ANSWERS

**QUESTIONS 1 - 31.** RECORD YOUR ANSWERS ON THE ANSWER SHEET.

**QUESTIONS 32 – 59.** RECORD YOUR ANSWERS IN THE EXAM QUESTION BOOKLET.

### IMPORTANT

- Use the answer sheet provided to record your answers.
- **Ensure that your name and student code is PRINTED in the top margin of the front page of the answer sheet.** The invigilators will enter this information in the correct places on the reverse side of the answer sheet.
- Use only the HB pencil provided to mark the answer sheet. **Completely fill in the circle.**

A      B      C      D      E

**This is the correct way:**      o      •      o      o      o

- **DO NOT USE AN X OR ANY OTHER SYMBOL TO MARK YOUR ANSWER.**
- If you want to change your answer, use the eraser to remove your incorrect response and fill in the new circle you require.
- There is only one correct answer to each question.
- Questions 1 - 30 are worth one mark each. The mark value for questions 31 – 60 varies according to the length and difficulty of the question.
- **Marks will not be deducted for incorrect answers.**

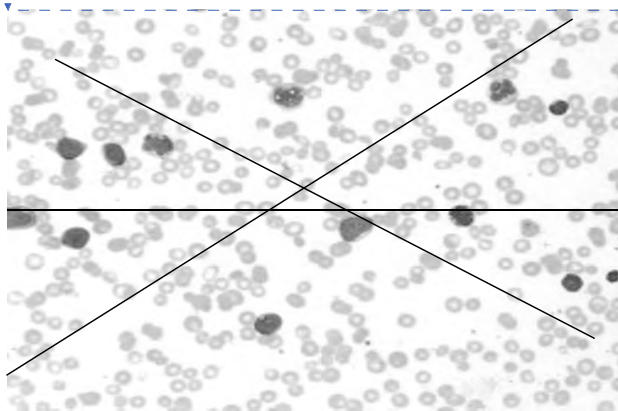
**ANSWERS TO QUESTIONS 1 TO 31 ARE TO BE RECORDED ON THE  
ANSWER SHEET.**

**Question 1.** Which of the following statements is FALSE?

“For almost every antigen you may encounter.....”

- A. a subset of B-cells already exists in your body specific to it.
- B. a subset of T-helper cells already exists in your body that expresses a T-cell receptor specific to it
- C. a subset of phagocytes already exists in your body that attacks only that antigen.**
- D. a subset of antigen-specific antibodies already exists, but are not yet produced in large numbers.
- E. a subset of antigen-specific memory cells can be produced upon exposure to that antigen.

**Question 2.** A blood smear of a human shows higher than normal numbers of eosinophils. Which of the following may be occurring in his body?

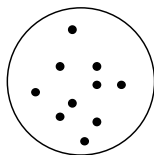
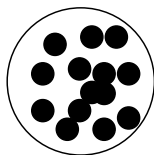


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- A. chronic nematode infection**
- B. anaphylactic shock
- C. reduced white blood cells (leucopenia)
- D. initial response to invading bacteria
- E. hemostasis

**Question 3.** The ABO blood type of humans can be determined by a coagulation reaction with anti-A and anti-B antibodies.



**Positive coagulation**

**Negative Coagulation**

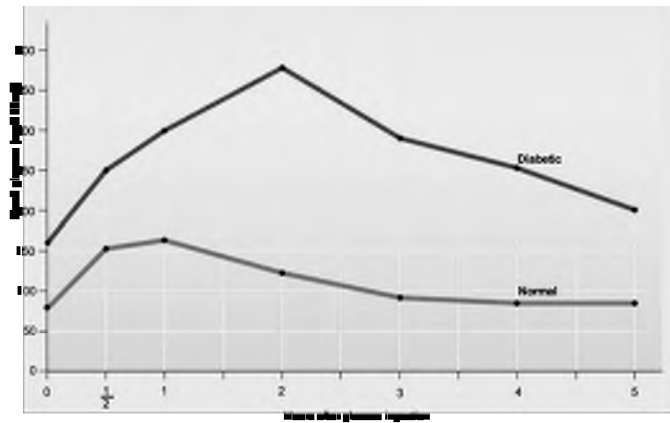
Coagulation tests of person's blood produced the results shown below:

With anti-A and anti-B antibodies	With anti-A antibodies	With anti-B antibodies	None

Which of the following statements can be deduced from the above?

- A. **This person's blood contains anti-B antibodies.**
- B. This person's parents had to be type-A and type-O.
- C. This person can receive neither type-A nor type-B blood.
- D. Type-B antigens are present on the surface of this person's red blood cells.
- E. This person's blood can be donated to both type-B and type-O individuals.

Question 4. The graph below shows the result of blood glucose test from a diabetes patient.

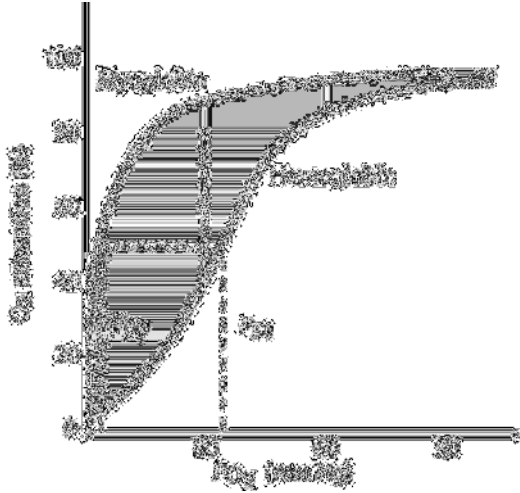


When tested 3 hours after having a carbohydrate rich meal, the blood glucose level of this patient was 3 times higher than that of a normal individual. However, there was no difference in the level of insulin in the blood between the two individuals.

Which of the following could be the reason for diabetic symptoms in this patient?

- A. Degradation of pancreatic beta-islets cells.
- B. Degradation of pancreatic alpha-islets cells.
- C. Abnormal proliferation of pancreatic beta-islet cells.
- D. Reduced sensitivity of insulin-receptor mediated signal transduction.**
- E. Increased sensitivity of insulin-receptor mediated signal transduction.

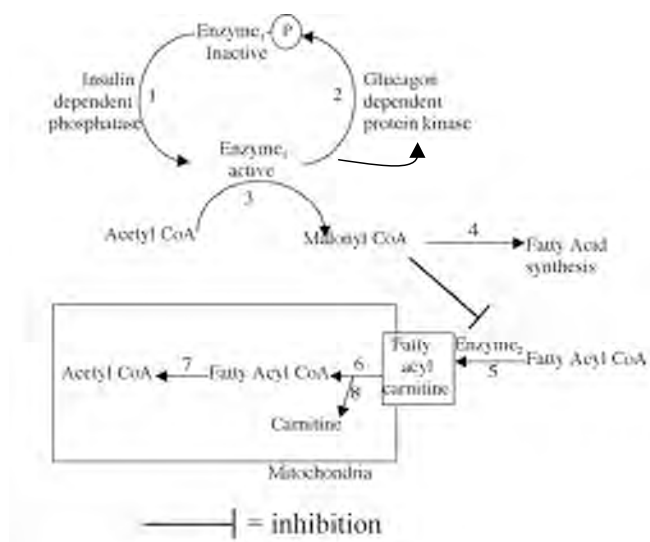
Question 5. The following graph shows the dissociation curves for hemoglobin and myoglobin.



Based on the data presented in the graph, which of the following statements is true?

- A. The high affinity of myoglobin for  $O_2$  at low partial pressures of  $O_2$  prevents hemoglobin from unloading  $O_2$  to muscle.
- B. Myoglobin binds to oxygen with greater affinity than hemoglobin and unloads oxygen after hemoglobin unloading.**
- C. Myoglobin helps hemoglobin bind as much  $O_2$  as possible from lungs.
- D. Hemoglobin binds to  $O_2$  tightly thus preventing  $O_2$  from being made available to skeletal muscle.
- E. The high affinity of hemoglobin for  $O_2$  at low partial pressures of  $O_2$  prevents myoglobin from unloading  $O_2$  to muscle.

**Questions 6 - 8.** This figure indicates some of the pathways involved in the metabolism of food.



Question 6. When a person consumes a diet rich in carbohydrate, the reactions up-regulated will be:

- A. 5, 6, 7
- B. 2, 8
- C. 5, 8
- D. 1, 3, 4**
- E. 2, 5, 6

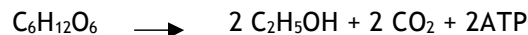
Question 7. When a person performs heavy exercise, the reactions that will be down-regulated will be:

- ~~A. 5, 6, 7, 8~~
- ~~B. 1, 3, 4~~
- ~~C. 4, 5, 6, 7~~
- ~~D. 1, 2, 4~~
- ~~E. 7, 3, 4~~

Question 8. If a person suffers from carnitine deficiency, the reactions that will be down-regulated are:

- A. 6, 8 only
- B. 1, 3, 4
- C. 4, 5, 6, 7
- D. 2, 5, 6
- E. 5, 6, 7, 8**

**Question 9.** A yeast extract contains all the enzymes required for alcohol production. The extract is incubated under anaerobic conditions in 1 liter of medium containing: 200 mM glucose, 20 mM ADP, 40 mM ATP, 2 mM NADH, 2 mM NAD<sup>+</sup> and 20 mM Pi (inorganic phosphates). Ethanol production can be summarized by the following equation:

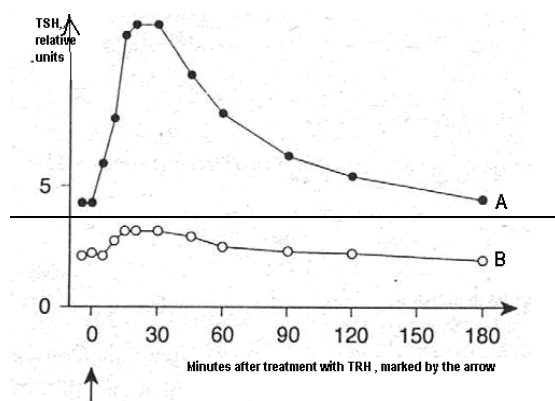


What is the maximum amount of ethanol that can be produced under these conditions?

- A. 2 mM
- B. 20 mM**
- C. 40 mM
- D. 200 mM
- E. 400 mM

**Question 10.** Thyroid hormone release is due to the action of thyroid stimulating hormone (TSH) released by the pituitary gland. Release of TSH is governed by the TSH releasing hormone (TRH) which is synthesized in the hypothalamus and released into the pituitary gland.

The graph below shows the concentration of TSH in human blood during the three hours following an injection of TRH in two groups of people, A and B. One group was treated with thyroxine in the days prior to the experiment. Consider endocrine feed back regulation when answering the following question.



Which of the statement(s) below are true?

- ~~I. Thyroxine inhibits the release of TSH~~
- ~~II. Group B has been treated with thyroxin daily before treatment with TRH~~
- ~~III. TRH is needed for stimulating excretion of TSH~~
- ~~IV. TSH inhibits the release of thyroxin~~

- ~~—A. I and II~~
- ~~—B. II and III~~
- ~~—C. III and IV~~
- ~~—D. I and IV~~
- ~~—E. I and III~~

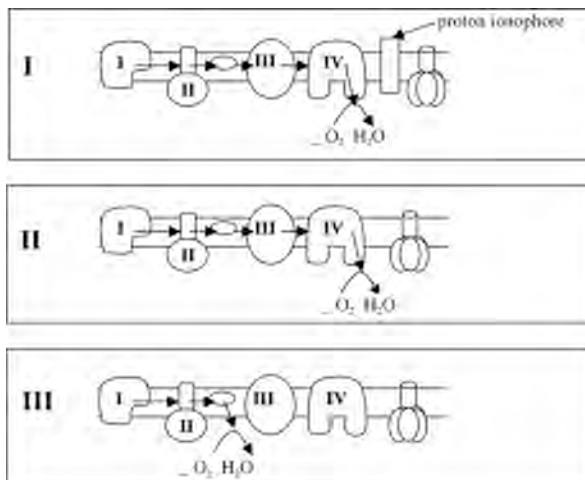
**Question 11.** Typical intracellular concentrations of the  $\text{Na}^+$ ,  $\text{K}^+$  and  $\text{Ca}^{2+}$  ions are 15 mM, 120 mM and 100 nM, respectively. In the cell we are interested in the usual  $\text{Na}^+$ ,  $\text{K}^+$  leak channels that are present as well as the  $\text{Na}^+/\text{K}^+$  pump (ATPase). Extracellularly, the concentrations of  $\text{Na}^+$ ,  $\text{K}^+$  and  $\text{Ca}^{2+}$  are 140 mM, 4 mM and 2 mM, respectively. Which of the following would happen if the extracellular  $\text{K}^+$  concentration were to be increased to 10 mM?

- I. Intracellular  $\text{Na}^+$  would increase
- II. There would be increased ATP utilization
- III. There is an large increase in intracellular  $\text{Ca}^{2+}$
- IV. Intracellular  $\text{Na}^+$  would decrease
- V. Intracellular  $\text{K}^+$  would increase

- ~~—A. I~~
- ~~—B. I, II, III~~
- ~~—C. III~~
- ~~—D. III, IV, V~~
- ~~—E. IV, V~~

**Question 12.** Thermogenesis is a process where heat is generated. The energy present in the reducing equivalents such as  $\text{NADH} + \text{H}^+$  or  $\text{FADH}_2$  in mitochondria is normally used to pump protons across the inner mitochondrial membrane to the intermembranous space. This proton gradient is the motive force for ATP production. Examine the figures below and consider whether ATP synthesis or thermogenesis predominates when answering the following question.

The molecules represented by I, II, III and IV represent mitochondrial electron carriers.

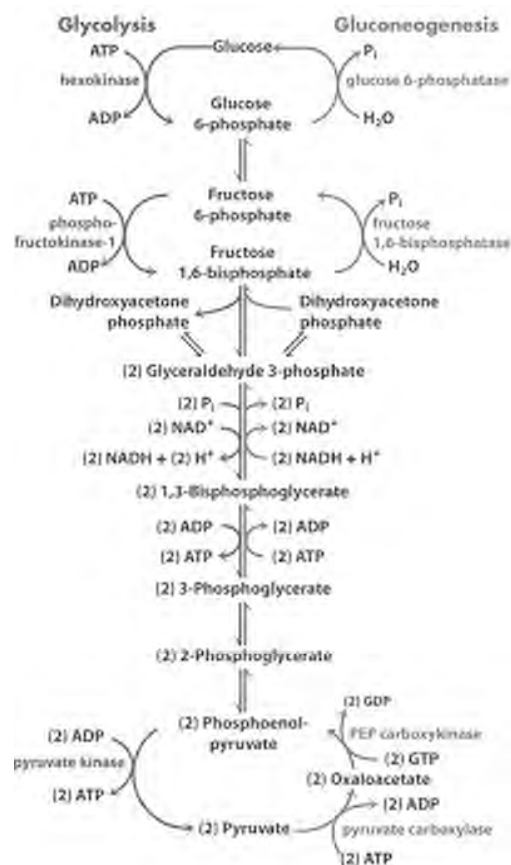




In which of the three situations shown in the figure above does thermogenesis predominate over ATP synthesis?

- A. only I
- B. only II
- C. only III
- D. I and II
- E. I and III

**Question 13.** The figure below outlines the glycolytic pathway. There are several regulatory steps in glycolysis. A major regulatory step in glycolysis is the conversion of fructose 6-phosphate to fructose 1,6-bisphosphate by phosphofructokinase. This enzyme is allosterically inhibited by ATP and allosterically activated by AMP. Thus, cellular ATP:AMP ratios are important in the regulation of phosphofructokinase. In addition, low pH inhibits phosphofructokinase activity.



What effect will poisoning of mitochondrial function by the mitochondrial uncoupler dinitrophenol (DNP) have on glycolysis?

- A. It will increase the rate of glycolysis if there is a means of oxidizing NADH.
- B. It will result in the immediate death of the cell.
- C. It will increase the rate of glycolysis if there is a means of further increasing the reduction of  $\text{NAD}^+$ .
- D. It will inhibit the conversion of phosphoenol pyruvate to pyruvic acid.
- E. It will promote the formation of 1,3 biphosphoglycerate from 3-phosphoglycerate.

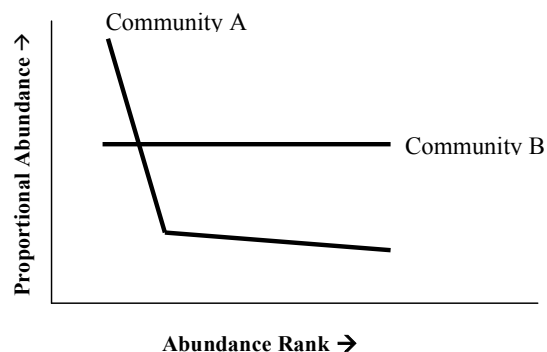
**Question 14.** Lions (*Panthera leo*) live in stable social groups called prides which usually have three or more adult females, their dependent offspring and one or two dominant adult males. The old and weak male(s) in a pride may be driven away by other strong males or by a new coalition of males.

Which combination of the following statements is correct.?

- I. Females born into a pride leave before they reproductive maturity.
- II. Males born into a pride remain there for life.
- III. Females born into a pride remain there for life.
- IV. New dominant male try to kill only newly born females.
- V. Males born into a pride leave before they reach reproductive activity.
- VI. New dominant male try to kill only newly born males.
- VII. Adult females in a lion pride are never related to each other.
- VIII. New dominant male try to kill as many young cubs as possible.
- IX. Adult females in a lion pride are often related each other.

- A. I, IV, VI, VII
- B. III, V, VIII, IX**
- C. III, IV, V, IX
- D. II, V, VI, VIII
- E. I, II, VII, VIII

**Question 15.** The correct statement pertaining to the following Rank-Abundance Curve is:



- ~~A. Species richness in Community A is lower than in Community B~~
- ~~B. Species richness in Community A is higher than in Community B~~
- ~~C. Species diversity in Community A is lower than in Community B~~
- ~~D. Species diversity in Community A is higher than in Community B~~
- ~~E. Species evenness in Community A is higher than in Community B~~

**Question 16.** Stromatolites, layered mounds created by cyanobacteria, have been found in shallow waters. They resemble small rocks but are organic in origin. Fossilised stromatolites are thought to be important because they are suggestive of:

- A. the origin of earth.
- B. the origin of photo-autotrophy.**
- C. oxidation of iron in oceans.
- D. the appearance of the ozone layer in the atmosphere.
- E. the origin of life.

**Questions 17 – 18.** A student studied the influence of temperature and light intensity upon CO<sub>2</sub> flux of plants in a greenhouse. During the experiment cellular respiration is not influenced by light intensity and cellular respiration of glucose is completely aerobic. At each temperature CO<sub>2</sub> uptake was measured during light exposure and loss of CO<sub>2</sub> was measured during the dark period. The light intensity was constant during the light period and was not a limiting factor for photosynthesis.

The data collected are presented in the following table.

Temp (°C)	CO <sub>2</sub> uptake in light*	Loss of CO <sub>2</sub> in dark*
5	0.5	0.2
10	0.7	0.5
15	1.2	0.9
20	1.9	1.5
25	2.3	2.6
30	2.0	3.9
35	1.5	3.3

\* units: mg per gram dried weight per hour

**Question 17.** At which temperatures does the plant release O<sub>2</sub> when exposed to light?

- A. only in the range 5 – 20 °C
- B. only in the range 20 – 25 °C
- C. only at temperatures over 20 °C
- D. only at temperatures over 25 °C
- E. at all temperatures**

**Question 18.** The optimum temperature for photosynthesis and the optimum temperature of respiration is somewhere in the range of 5 - 35 °C. Which of the following statements is correct?

- A. optimum temp for photosynthesis < optimum temp for dissimilation
- B. optimum temp for photosynthesis = optimum temp for dissimilation**
- C. optimum temp for photosynthesis > optimum temp for dissimilation

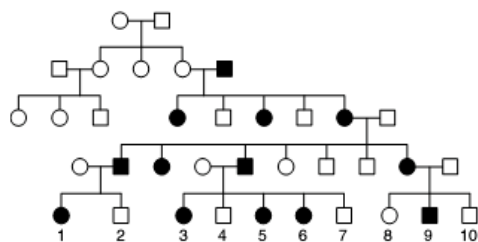
**Question 19.** A woman with Turner syndrome is found to be haemophilic (X-linked recessive phenotype). Both her mother and her father have normal blood coagulation.

Which of the statements below gives what you consider to be the best answer to each of following questions?

- I. How can the simultaneous origin of Turner syndrome and haemophilia by abnormal chromosome behavior during meiosis be explained?
- II. Did the abnormal chromosome behavior occur in the mother or the father?
- III. During which division of meiosis did the abnormal chromosome behavior occur?

- ~~A. The father of the woman with Turner syndrome (XXX) must have been a carrier for haemophilia, an X-linked recessive disorder. Nondisjunction occurred in her mother. An egg lacking a sex chromosome was fertilized with a sperm with X chromosome carrying the haemophilic allele. The nondisjunctive event could have occurred only during first meiotic division.~~
- ~~B. One of the parents of the woman with Turner syndrome (X0) must have been a carrier for haemophilia, an X-linked recessive disorder. Because her father has normal blood coagulation, she could not have obtained her only X-chromosome from him. Therefore nondisjunction occurred in her father. A sperm lacking a sex chromosome fertilized an egg with X-chromosome carrying the haemophilic allele. The nondisjunctive event could have occurred during either meiotic division.~~
- ~~C. One of the parents of the woman with Turner syndrome (XXY) is a carrier for haemophilia, an X-linked recessive disorder. Because her mother has normal blood coagulation, she could not have obtained her X-chromosome from her mother. Therefore, nondisjunction occurred in her mother. A sperm with a sex chromosome carrying the haemophilic allele fertilized an egg with XX-chromosome. The nondisjunctive event could have occurred during second meiotic division.~~
- ~~D. One of the parents of the woman with Turner syndrome is a carrier for haemophilia, an X-linked recessive disorder. Because her father has normal blood coagulation, she has obtained her only X-chromosome from her mother. A nondisjunction occurred in her father during either meiotic division. A sperm lacking a sex chromosome fertilized an egg with X-chromosome carrying the haemophilic allele.~~

**Questions 20 – 21.** A rare human disease afflicted a family as shown in the following pedigree.



**Question 20.** What is the most likely mode of inheritance of this disease?

- A. Mode of inheritance is autosomal recessive.
- B. Mode of inheritance is autosomal dominant.
- C. Mode of inheritance is X-linked recessive.
- D. Mode of inheritance is X-linked dominant**
- E. Mode of inheritance could not be deduced.

**Question 21.** What is the probability that the first child of the marriage between cousins, 1 x 4, is a boy with the disease?

- A. 1/2
- B. 1/4**
- C. 1/8
- D. 1/16
- E. 0

**Questions 22 - 23.** The wild-type flower color of harebell plants (genus *Campanula*) is blue. Using radiation, three mutants with white petals were produced, white 1, white 2 and white 3. They all look the same, so it was not known whether they were genetically identical. The mutant strains are available as homozygous pure-breeding lines.

The mutant strains were crossed with the wild-type blue genotype and with each other to produce the following results:

Parental cross	F1 phenotype	F2 segregation ratio
White 1 x blue	all blue	3/4 blue : 1/4 white
White 2 x blue	all blue	3/4 blue : 1/4 white
White 3 x blue	all blue	3/4 blue : 1/4 white
White 1 x white 2	all white	no data available
White 1 x white 3	all blue	no data available
White 2 x white 3	all blue	no data available

**Question 22.** Using these results, determine which statement is the correct conclusion for this study.

- A. The mutant genes in white-1 and 3 are allelic and are different to the mutant gene in white 2.
- B. The mutant genes in white 2 and 3 are allelic and are different to the mutant gene in white 1.
- C. The mutant genes in white 1 and 2 are allelic and are different to the mutant gene in white 3.**
- D. The mutant genes in white 1, 2 and 3 are all allelic.

**Question 23.** The type of gene action operating among the crosses between the mutants in this study is

- A. complete dominance.
- B. dominant epistasis.
- C. recessive (complementary) epistasis**
- D. duplicate gene interaction.

**Question 24 - 25.** Hemoglobin in the erythrocytes of adults is composed of a combination of two  $\alpha$ -globin molecules and two  $\beta$ -globin molecules. Sick-cell anemia is caused by the substitution of a single amino acid in the  $\beta$ -globin subunit.

In 1957, Vernon M. Ingram and his colleagues investigated the amino acid sequences of normal and sickle-cell anemia hemoglobins in several short peptide chains obtained by trypsin digestion. A difference in the “fourth peptide” between both types of  $\beta$ -globin was found and further hydrolytic digestion of the “fourth peptides” revealed six hydrolyzed products.

- the “fourth peptide” products of normal  $\beta$ -globin were (amino acid residues are abbreviated by the following letters: V=valine, H= histidine, L= leucine, T= threonine, P= proline, E= glutamic acid and K= lysine):

V—H  
 V—H—L  
 V—H—L—T  
 T—P—E  
 T—P—E—E—K  
 E—K

- the “fourth peptide” products of  $\beta$ -globin of sickle cell anemia were

V—H  
 V—H—L  
 V—H—L—T  
 T—P—V  
 T—P—V—E—K  
 E—K

**Question 24.** From these results, how many amino acids is the “fourth peptide” composed of and what was the substituted position of amino acid residue counting from the N-terminus?

From the following, choose the one statement which is most appropriate. Assume that this fourth peptide contains only one molecule of T (threonine).

- It was composed of 8 amino acids and the 6<sup>th</sup> amino acid was substituted.
- It was composed of 8 amino acids and the 3<sup>rd</sup> amino acid was substituted.
- It was composed of 7 amino acids and the 6<sup>th</sup> amino acid was substituted.
- It was composed of 7 amino acids and the 3<sup>rd</sup> amino acid was substituted.
- It was composed of 9 amino acids and the 6<sup>th</sup> amino acid was substituted.

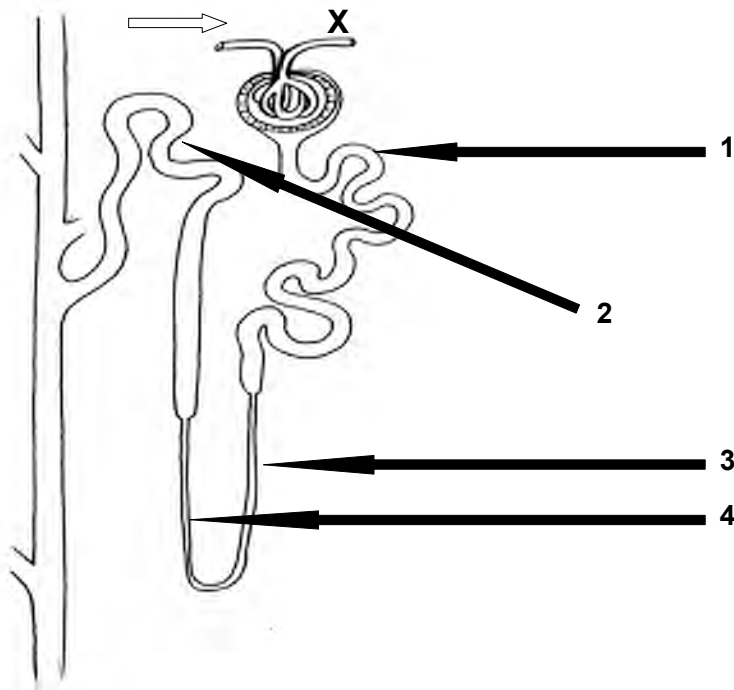
**Question 25.** Below is a DNA sequence coding a part of the amino acid sequence in the “fourth peptide” of normal  $\beta$ -globin. In sickle cell anemia, it is known that a mutation occurs in the region enclosed by   .

From the following, choose one that is an appropriate DNA sequence of the mutation.

Normal! TGAGGACTCCTCTTCAGA

- TGAGGACCCTCTTCAGA
- TGAGGACTACCTCTTCAGA
- TGAGGACACCTCTTCAGA**
- TGAGGACCTCTTCAGA
- TGAGGAACTCCTCTTCAGA

**Question 26 - 28.** The diagram below represents a nephron from an adult human.



**Question 26.** At which of the numbered points would the filtrate be hypertonic to the blood?

- A. 1 and 3 only
- B. 1, 2 and 3
- C. 2 and 3 only
- D. 4 only
- E. **3 and 4**

**Question 27.** At which of the numbered points is sodium reabsorbed from the filtrate?

- A. 1 only
- B. 1 and 2 only
- C. 1, 2 and 3
- D. **1, 2 and 4**
- E. 4 only



**Question 28.** The open arrow shows the direction of blood flow into the Glomerulus. What happens if the diameter of the blood vessel is constricted at point **X**?

- A. More sodium will appear in the urine
- B. Water reabsorption will be decreased
- C. The rate of ultrafiltration will be increased**
- D. The rate of urine production will be reduced
- E. Glucose will be appear in the urine

**Question 29.** A and B are two 70 Kg individuals with same body water volume. Both of them had a snack that had a high salt content, and B also drank a glass of an alcoholic drink . Based on this information, which one of following statements is true?

- A. A will have a lower circulating level of antidiuretic hormone (ADH) than B
- B. B will have a lower circulating level of antidiuretic hormone (ADH) than A**
- C. Both of them will have the same level of circulating ADH
- D. A will have less body water than B
- E. B will produce less urine than A

**Question 30.** Which of the following RNA sequences would hybridize most effectively with the DNA sequence 5' - ATA CTT ACT CAT TTT - 3'?

- A. 5' - AAA AAC GUC CCC UAA - 3'
- B. 5' - ATA CTT ACT CAT TTT - 3'
- C. 5' - UAU GAA UGA GUA AAA - 3'
- D. 5' - AAA AUG AGU AAG UAU - 3'**
- E. 5' - AAA ATG AGT AAG TAT - 3'

**Question 31.** What does a small standard deviation indicate about data obtained from an experiment?

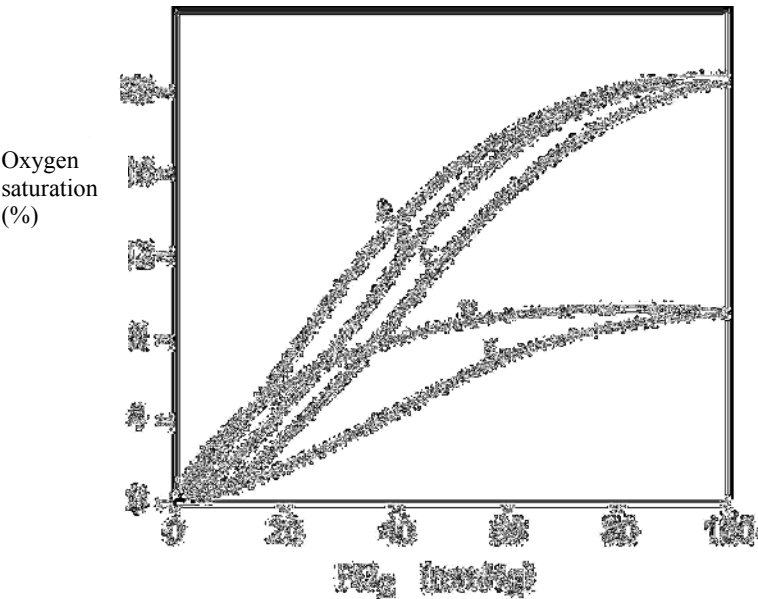
- A. The data are not reliable.
- B. More data needs to be collected.
- C. More of the values are above the mean than below the mean
- D. The data are grouped closely around the mean.**
- E. More of the group values are below the mean than above the mean.

## **IMPORTANT**

**ANSWERS TO QUESTIONS 32 TO 59 ARE  
TO BE WRITTEN IN THIS EXAM  
BOOKLET.**

**STARTING AT THE NEXT PAGE, WRITE  
YOUR STUDENT CODE AT THE TOP OF  
EVERY PAGE IN THIS EXAM BOOKLET**

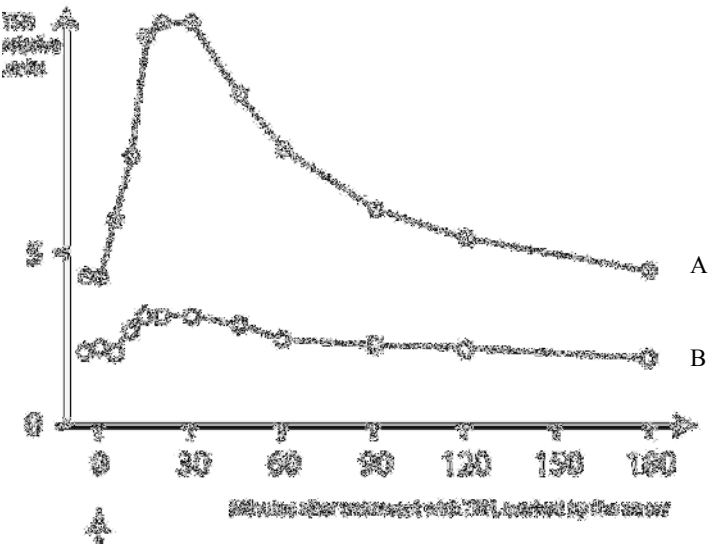
**Question 32.** For blood under each of the conditions described below, select the letter of the oxy-hemoglobin dissociation curve with which it is most likely to be associated. (3 marks)



- 1. Normal adult arterial blood
- 2. ~~Blood stored for 2 weeks~~
- 3. Anaemic blood
- 4. Foetal blood
- 5. ~~Blood exposed to CO~~
- 6. Blood from a person with hypothermia
- 7. Blood with PaCO<sub>2</sub> above normal
- 8. Blood with an increased pH

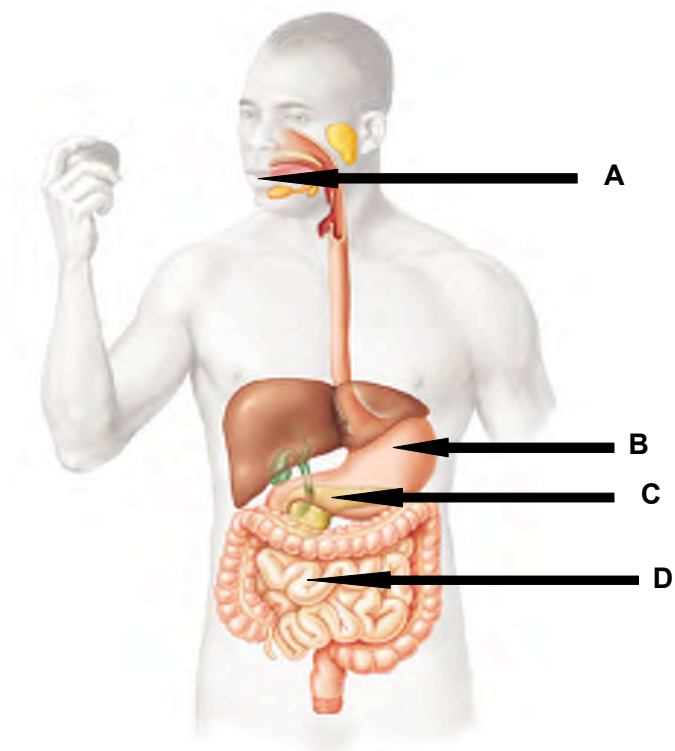
B
E
A
A
C
A

**Question 33.** The following graph shows the concentration of thyroid-stimulating hormone (TSH) in human blood during the 3 hours following an injection of TSH-releasing hormone (TRH) in two groups of people (A and B). One group was treated with thyroxine daily for a week prior to the experiment. (2 marks)



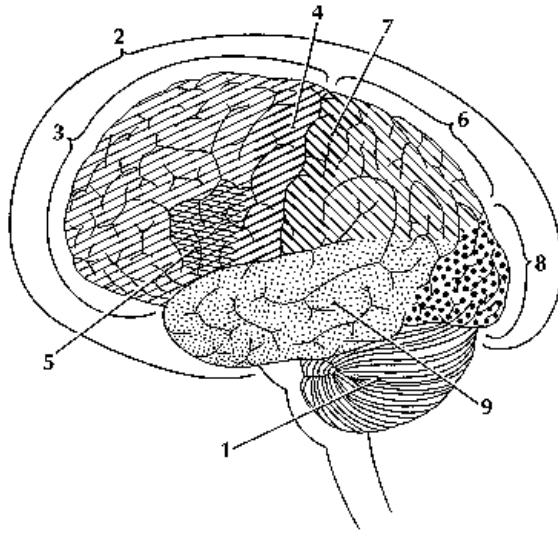
STATEMENT	True (1) or False (2)
a. Thyroxine treatment stimulated TSH release in Group A	2
b. Group A has been treated with thyroxine daily before treatment with TRH	2
c. Group B has been treated with thyroxine daily before treatment with TRH	1
d. Thyroxine treatment inhibited TSH release in Group B	1

**Question 34.** Digestion of food is facilitated by enzymes and hormones secreted at various regions of the gastro-intestinal tract. Select the organs (identified by different letters) from the diagram below that secretes the following enzymes and hormones: (4 marks)



- |                          |                  |
|--------------------------|------------------|
| I. Amylase               | _____ A, C _____ |
| II. Lipase               | _____ C, D _____ |
| III. Chymotrypsin        | _____ C _____    |
| IV. Insulin              | _____ C _____    |
| V. Cholecystikinin (CCK) | _____ D _____    |
| VI. Aminopeptidase       | _____ D _____    |
| VII. Gastrin             | _____ B _____    |
| VIII. Carboxypeptidase   | _____ C _____    |

**Questions 35 – 37.** A 21 year-old student gets into a car accident and experiences brain trauma. Use the figure below to answer the following questions.. Use the appropriate number to refer to the region of the brain affected.



**Question 35.** The patient experiences lack of co-ordination and problems in balance. What part of the brain is most likely damaged? (0.5 mark)

ANSWER:

1

~~**Question 36.** The patient slurs her speech and is unable to clearly read even simple passages from a book. What part of the brain is most likely damaged? (0.5 mark)~~

ANSWER:

**Question 37.** The patient experiences double vision and images are blurry. What part of the brain is most likely damaged? (0.5 mark)

ANSWER:

8

**Question 38.** To study hierarchical reaction in crickets (*Gryllus campestris*), five crickets, A, B, C, D and E, were marked with colours and placed two by two in an experimental field. Observations were made on their aggressive behaviour and the results are shown below:

Partner	Won fights	Lost fights
B	6	0
C	2	9
D	7	0
E	2	6

**Table 1 : Fight results for cricket A**

Partner	Won fights	Lost fights
A	0	6
C	0	5
D	5	1
E	0	7

**Table 2 : Fight results for cricket B**

Partner	Won fights	Lost fights
A	9	2
B	5	0
D	6	0
E	9	3

**Table 3 : Fight results for cricket C**

Partner	Won fights	Lost fights
A	0	7
B	1	5
C	0	6
E	0	5

**Table 4 : Fight results for cricket D**

Partner	Won fights	Lost fights
A	6	2
B	7	0
C	3	9
D	5	0

**Table 5 : Fight results for cricket E**

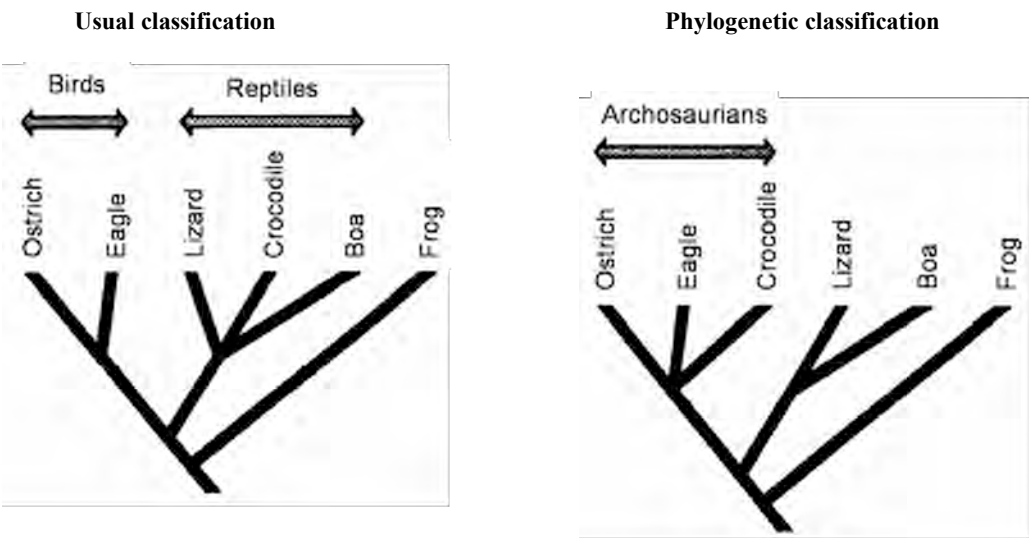
Indicate if the following statements are correct by writing the appropriate answer code in the answer column of the following table. (3 marks)

**Answer code :**      **1** = CORRECT      **2** = INCORRECT

Statement	Answer
a. Cricket D is last in the hierarchical order.	1
b. Cricket E is first in the hierarchical order.	2
c. The hierarchy is linear: with the following order: C → E → A → B → D	1
d. Some crickets won fights against crickets that were higher in the hierarchical order.	1

**Question 39.** According to the usual classification, birds are classified as vertebrates with feathers and reptiles as epidermal scale vertebrates. A different phylogenetic classification has been proposed and includes birds and crocodiles in the Archosaurian group.

Below are the two types of classification:





Comparison of selected anatomical characteristics of these vertebrates

	<b>Epidermal scales</b>	<b>Preorbital fenestra</b>	<b>Gizzard</b>	<b>Feathers</b>
<b>Eagle</b>	covering feet	present	present	present
<b>Ostrich</b>	covering feet	present	present	present
<b>Crocodile</b>	covering all the body	present	present	none
<b>Boa</b>	covering all the body	none	none	none
<b>Lizard</b>	covering all the body	none	none	none
<b>Frog</b>	none	none	none	none

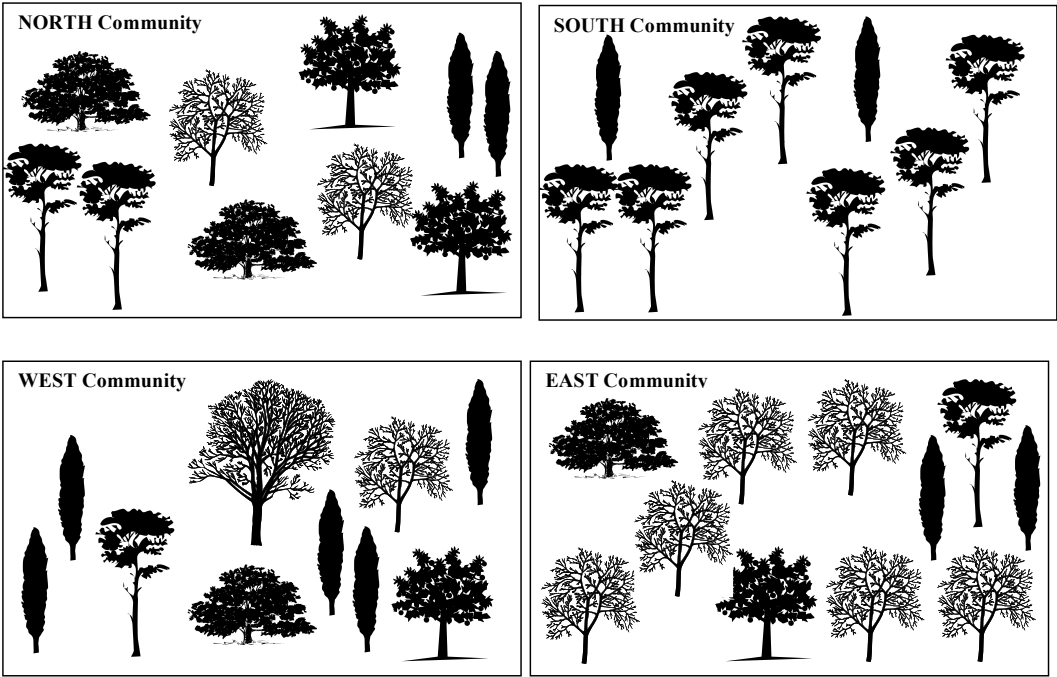
Indicate if the following statements are correct by writing the appropriate answer code in the answer column of the table. (2 marks)

**Answer code :**      **1** = CORRECT                      **2** = INCORRECT

<b>Statement</b>	<b>Answer</b>
a. Birds and reptiles both have scales. Therefore, we can assume that they share a common ancestor which is not a common ancestor of the frog.	1
b. The eagle, ostrich and crocodile are homologous for the preorbital fenestra feature	1
c. Possession of feathers is an ancestral characteristic, whereas the possession of scales is a more recent modification.	2
d. <del>Since crocodiles are more closely related to birds than to lizards, scales are not a relevant characteristic to be used in this type of classification.</del>	

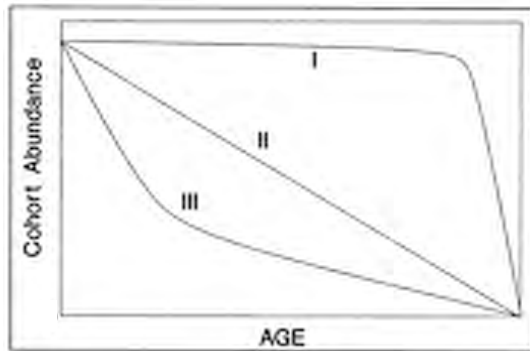


**Question 40.** Four tree communities were identified at four different locations to the north, south, west and east of Ottawa, Canada. The communities are represented below, with each different tree figure symbolizing a different species. (6 marks)



No	Community attribute	ANSWER			
		A. North	B. South	C. West	D. East
a.	Highest species richness			T	
b.	Lowest species richness		T		
c.	Highest species evenness (balance)				
d.	Lowest species evenness (balance)				
e.	Highest species diversity	T			
f.	Lowest species diversity		T		
g.	Highest total abundance				T
h.	Lowest total abundance		T		

**Question 41.** A survivorship curve depicts the age-specific mortality through survivorship. Indicate whether the following statements about the survivorship are true. The graphs shown below indicate different types of survivorship curves.



Circle whether each statement is TRUE or FALSE. (2 marks)

- A. Graph I represents organisms that provide good care of their offspring, such as humans and many other large mammals.

TRUE FALSE

- B. Graph II is typical of survivorship curves for organisms such as many fishes and marine invertebrates

TRUE FALSE

- C. Graph II is characteristics of the adult stages of birds after a period of high juvenile mortality.

TRUE FALSE

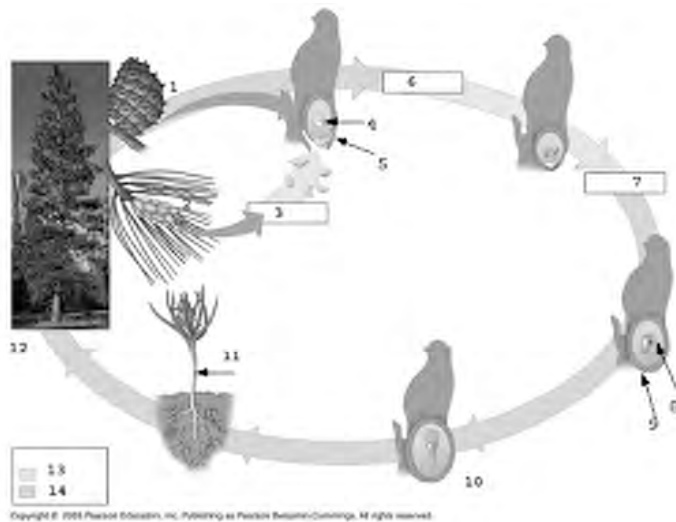
- D. Birds may have a Graph III-type survivorship curve with a brief period of high mortality among the youngest individuals, followed by increasing periods of lower mortality.

TRUE FALSE

- ~~E. In populations where migration is common, survivorship is important factor in determining changes in population size~~

~~TRUE FALSE~~

**Question 42.** The following diagram represents the gymnosperm life cycle.



To match the structures and processes involved in this life cycle, match each number from the diagram of the life cycle with the letter of the proper term in the list below and write that letter in the appropriate box. (3.5 marks)

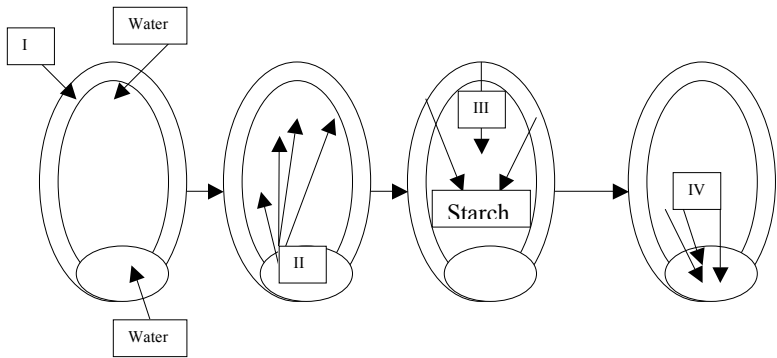
Diagram number	Term from list	Diagram number	Term from list	Diagram number	Term from list
----------------	----------------	----------------	----------------	----------------	----------------

1	<input type="text"/>	7	<input type="text"/>	13	<input type="text"/>
2	<input type="text"/>	8	<input type="text"/>	14	<input type="text"/>
3	<input type="text"/>	9	<input type="text"/>		
4	<input type="text"/>	10	<input type="text"/>		
5	<input type="text"/>	11	<input type="text"/>		
6	<input type="text"/>	12	<input type="text"/>		

**List of Terms**

a. megasporangium produces eggs by meiosis	h. seed coat
b. fertilization	i. mature sporophyte
c. zygote	j. integument
d. embryo	k. haploid portion of life cycle
e. diploid portion of life cycle	l. megaspore mother cell
f. seedling	m. ovulate cone, bearing ovules
g. pollen cone, producing pollen	n. microsporangium produces pollen by meiosis

**Question 43.** The diagram below represents the stages in the mobilization of starch reserves in a barley grain.



Match the appropriate term with the correct Roman numeral from the diagram above. (Note: not all terms have answers.) (3 marks)

TERM FROM DIAGRAM	ANSWER
Alpha-amylase	III
Aleurone layer	I
Auxin	
Gibberellic acid	II
Sugar	IV
Protein	

**Question 44.** The structures in **List B** develop from the structures shown in **List A**. Match each structure in **List A** with the appropriate structures in **List B**. Enter your answers in the table below. (2.5 marks)

**List A**

- a. Microspore
- b. Microsporophyll
- c. Megaspore
- d. Megasporangium
- e. Megasporophyll

**List B**

- 1. Pollen sac
- 2. Primary cell of Embryo sac
- 3. Carpel
- 4. Nucellus
- 5. Pollen grain

LIST A	LIST B
a.	5
b.	1
c.	2
d.	4
e.	3

**Question 45.** Plants obtain various mineral nutrients from the soil. These nutrients have different physiological roles in plants.

Match the elements/compounds from the left column with their functions in plants in the right column. Write your answers in the answer table below. (5 marks)

1. Calcium	A. A cation that is important in the formation of turgor in stomata
2. Nitrogen	B. A nitrogen anionic compound that is accessible to plants in natural ecosystems
3. Nitrate	C. Necessary for the synthesis of the side chains of cysteine and methionine
4. Iodine	D. An element present in all amino acids, nucleotides and chlorophyll
5. Phosphate	E. A metal present in the chlorophyll molecule
6. Magnesium	F. Enables the crosslinking of pectates in the cell wall
7. Potassium	G. A component of DNA and RNA that is not a part of purine or pyrimidine bases.
8. Sulfate	H. Is the most abundant metal in the electron transport chain proteins
9. Manganese	I. Participates in the photo-oxidization of water during photosynthesis
10. Iron	J. Is not essential for the growth of plants

**Answer Table**

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
F	D	B	J	G	E	A	C	I	H

**Questions 46 - 48.** The ways different substances can be transported through the biological membrane is shown in Figure 1.

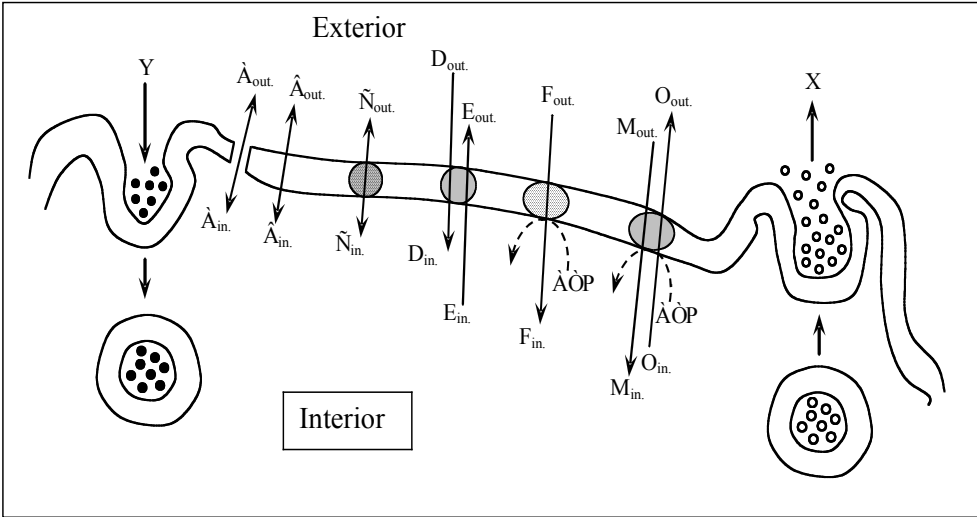


Figure 1. Transport of different substances through the biological membrane.

**Question 46.** Match the name of the transport systems to the letter(s) in Figure 1 (4 marks)

Transport mechanism		Answer
1.	Conjugated active transport	M, O
2.	Active transport (non-conjugated)	F
3.	Exocytosis	Y
4.	Transport through membrane pores	A
5.	Phagocytosis/pinocytosis;	X
6.	Facilitated (mediated) diffusion;	C
7.	Simple diffusion through membrane phospholipid bilayer	B
8.	Co-transport	D, E

**Question 47.** Indicate which letters in Figure 1 correspond to each transport system. (4 marks)

		<b>Answer</b>
9.	Direct membrane transport (without carrier)	
10.	Mediated membrane transport (using specific systems of carriers)	
11.	Passive transport	
12.	Active transport	

**Question 48.** Identify from Figure 1 the correct example for each transport type. (4 marks)

	<b>Membrane transport type</b>	<b>Answer</b>
13.	Na <sup>+</sup> , K <sup>+</sup> -ATPase	M, O
14.	Low-density lipoproteins	Y
15.	water, urea	A
16.	Inner mitochondrial membrane H <sup>+</sup> -ATPase	F
17.	glucose, aminoacids	C
18.	Exchange of ADP for ATP across inner mitochondrial membrane	D, E
19.	Long chain fatty acids and alcohols	B
20.	Hormonal secretion	X



**Question 49.** The total respiration (R) of a young growing plant can be described by the following expression:

$$\text{Total R} = \text{Maintenance R} + \text{Growth R}$$

Some of the processes that occur during growth of this plant are:

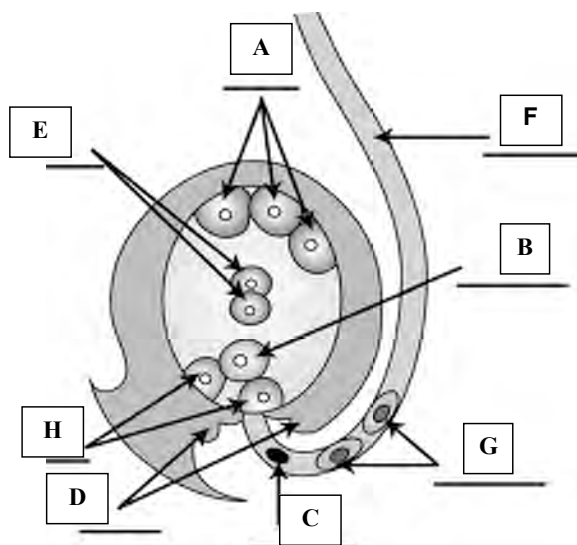
1. Movement of water within a cell
2. Reduction of nitrate ( $\text{NO}_3^-$ )-ions to ammonium ( $\text{NH}_4^+$ )-ions
3. Uptake of  $\text{K}^+$ -ions through the plasma membrane of a endodermis cell
4. Uptake of  $\text{CO}_2$  in cells of palisade parenchyma
5. Opening and closing of stomata
6. Lengthening of a polypeptide chain
7. Absorption of light by chlorophyll A

Certain of these processes require energy, some supply energy to the plant and others are not involved in energy use or supply. Indicate which processes require or supply energy by writing a + (plus sign) and which processes have no energy involvement by writing a — (minus sign) in the correct places in the following table. (3.5 marks)

Process number	Energy required/supplied (+) or no energy involvement (-)
1	-
2	+
3	+
4	-
5	+
6	+
7	-

**Question 50.** The following diagram shows an ovule just prior to double fertilization.

Identify each of the structures indicated by an arrow and label it on the diagram with the appropriate letter code from the table below. (4 marks)



STRUCTURE	LETTER CODE
Antipodal cell	A
Egg cell	B
Vegetative cell nucleus (Pollen tube nucleus)	C
Integument	D
Polar nuclei	E
Pollen tube	F
Sperm cell (male gamete)	G
Synergid cell	H

**Question 51.** A family consists of three children, David, Edna and Sophie and their parents Alison and Alfred. One of the children is blood group A and is also red green colour blind. Edna is blood group B and Sophie is blood group O. Of the children only David has blue eyes. Neither parent is colour blind, but only Alfred has blue eyes and is blood group B.

Choose a possible genotype for each family member and write the appropriate capital letter for that genotype against the name. (2.5 marks)

A =  $X^C X^c$  AO Bb      B =  $X^C Y$  AO bb      C =  $X^C X^c$  BO Bb      ~~D =  $X^c X^c$  AO Bb~~

E =  $X^C Y$  AO Bb      F =  $X^C X^c$  OO Bb      G =  $X^C Y$  BO bb      H =  $X^c Y$  AO bb

Family member	Genotype
David	H
Edna	C
Sophie	F
Alison	A
Alfred	G

**Question 52.** In Canada, 7,0 % of the male population is colorblind. This is a sex linked recessive feature located on the X-chromosome. (1 mark)

What percentage of the female population, not being colorblind, is a carrier of alleles responsible for colorblindness?

Answer: 13 %

**Questions 53 - 54.** The *fox* operon, which has sequences A, B, C, and D, encodes enzymes 1 and 2. Mutations in sequences A, B, C, and D have the following effects, where a plus sign (+) = enzyme synthesized and a minus sign (-) = enzyme not synthesized. *Fox* is the regulator of *fox* operon.

Mutation in sequence	<i>Fox</i> absent		<i>Fox</i> present	
	Enzyme 1	Enzyme 2	Enzyme 1	Enzyme 2
No mutation	-	-	+	+
A	-	-	-	+
B	-	-	-	-
C	-	-	+	-
D	+	+	+	+

**Question 53.** Is the *fox* operon inducible or repressible? Indicate your answer by writing X in the appropriate place in the table below. (1 mark)

Inducible	X
Repressible	

**Question 54.** Which sequence (A, B, C, or D) is part of the following components of the operon? Match the correct letter against the component in the table below. (2 marks)

Component of operon	Answer
Regulator gene	D
Promoter	B
Structural gene for enzyme 1	A
Structural gene for enzyme 2	C

**Question 55.** The following is a list of mutational changes. For each of the specific mutations described, indicate which of the following terms could apply, either as a description of the mutation or as a possible cause. More than one term from the right column can apply to each statement in the left column. (6 marks)

Write your answers in the answer table below.

Code	Description of mutation	Code	Term
1.	An A-T base pair in the wild-type gene is changed to a G-C pair	a.	transition
2.	An A-T base pair is changed to a T-A pair	b.	base substitution
3.	The sequence AAGCTTATCG is changed to a AAGCTATCG	c.	transversion
4.	The sequence AAGCTTATCG is changed to a AAGCTTTATCG	d.	inversion
5.	<del>The sequence AAGCTTATCG is changed to a AATGTATCG</del>	e.	translocation
6.	The sequence AACGTCACAACACATCG changed to a AACGTCACATCG	f.	deletion
7.	The gene map in a given chromosome arm is changed from <i>bog-rad-fox1-fox2-try-duf</i> (where <i>fox1</i> and <i>fox2</i> are highly homologous, recently diverged genes) to <i>bog-rad-fox1-fox3-fox2-try-duf</i> (where <i>fox3</i> is a new gene with one end similar to <i>fox1</i> and the other similar to <i>fox2</i> ).	g.	insertion
		h.	deamination
		i.	X-ray irradiation
		j.	intercalator
8.	The gene map in a chromosome is changed from <i>bog-rad-fox1-fox2-try-duf</i> to <i>bog-rad-fox2-fox1-try-duf</i> .	k.	unequal crossingover
9.	The gene map in a given chromosome is changed from <i>bog-rad-fox1-met-qui-txu-sqm</i> to <i>bog-txu-qui-met-fox1-rad- sqm</i>		

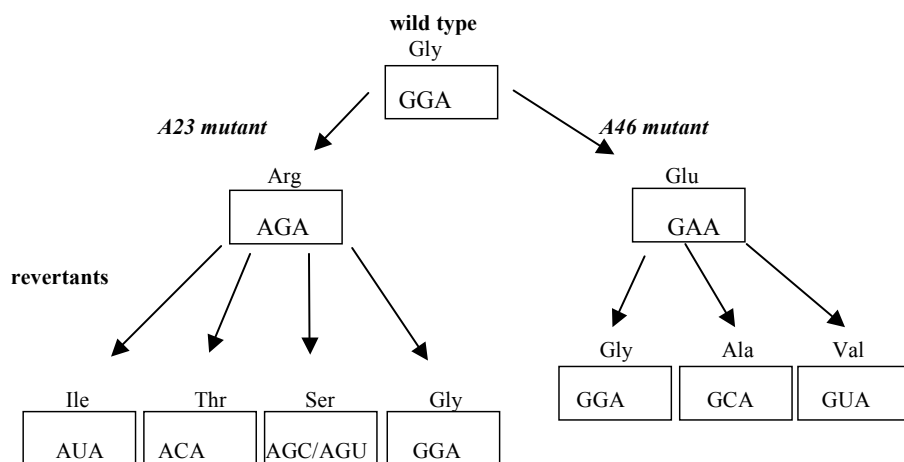
**Answer table**

1	2	3	4	5	6	7	8	9
a, b	b, c	f	g		f	k	d	d

**Question 56.** The wild type tryptophan synthetase enzyme of *E. coli* contains a glycine (Gly) at position 38. Two *trp* mutants **A23** and **A46** have been isolated which have arginine (Arg) instead of glycine at position 38 (**A23**) and glutamate (Glu) at position 38 (**A46**). Both mutants were plated on minimal medium and from **A23** four spontaneous revertants to prototrophy (i.e. are able to grow without supplements) were obtained and from **A46** three spontaneous revertants to prototrophy were obtained. The tryptophan synthetase from each of the seven revertants were isolated and the amino acids at position 38 were identified.

mutant	revertant	amino acid at position 38
<b>A23</b>	1	isoleucine (Ile)
	2	threonine (Thr)
	3	serine (Ser)
	4	glycine (Gly)
<b>A46</b>	1	glycine (Gly)
	2	alanine (Ala)
	3	valine (Val)

A summary of these data is given below. Using the genetic code table provided on the next page, deduce the codons for the wild type, mutants **A23** and **A46** and for the revertants and place each designation in the box provided. (5 marks)



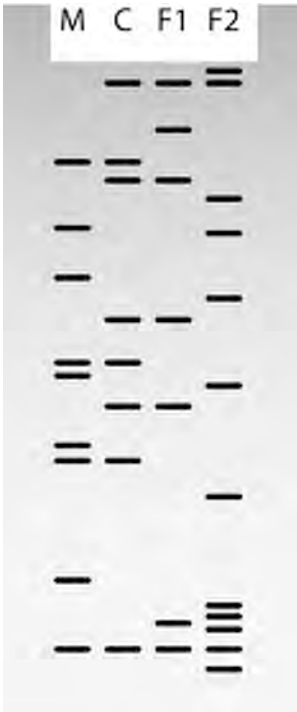
## GENETIC CODE TABLE

This table shows the 64 codons and the amino acid each codon codes for. The direction is 5' to 3'.

		2nd base			
		U	C	A	G
1st base	U	UUU (Phe/F)Phenylalanine	UCU (Ser/S)Serine	UAU (Tyr/Y)Tyrosine	UGU (Cys/C)Cysteine
		UUC (Phe/F)Phenylalanine	UCC (Ser/S)Serine	UAC (Tyr/Y)Tyrosine	UGC (Cys/C)Cysteine
		UUA (Leu/L)Leucine	UCA (Ser/S)Serine	UAA Ochre ( <i>Stop</i> )	UGA Opal ( <i>Stop</i> )
		UUG (Leu/L)Leucine	UCG (Ser/S)Serine	UAG Amber ( <i>Stop</i> )	UGG (Trp/W)Tryptophan
	C	CUU (Leu/L)Leucine	CCU (Pro/P)Proline	CAU (His/H)Histidine	CGU (Arg/R)Arginine
		CUC (Leu/L)Leucine	CCC (Pro/P)Proline	CAC (His/H)Histidine	CGC (Arg/R)Arginine
		CUA (Leu/L)Leucine	CCA (Pro/P)Proline	CAA (Gln/Q)Glutamine	CGA (Arg/R)Arginine
		CUG (Leu/L)Leucine	CCG (Pro/P)Proline	CAG (Gln/Q)Glutamine	CGG (Arg/R)Arginine
	A	AUU (Ile/I)Isoleucine	ACU (Thr/T)Threonine	AAU (Asn/N)Asparagine	AGU (Ser/S)Serine
		AUC (Ile/I)Isoleucine	ACC (Thr/T)Threonine	AAC (Asn/N)Asparagine	AGC (Ser/S)Serine
		AUA (Ile/I)Isoleucine	ACA (Thr/T)Threonine	AAA (Lys/K)Lysine	AGA (Arg/R)Arginine
		AUG (Met/M)Methionine	ACG (Thr/T)Threonine	AAG (Lys/K)Lysine	AGG (Arg/R)Arginine
	G	GUU (Val/V)Valine	GCU (Ala/A)Alanine	GAU (Asp/D)Aspartic acid	GGU (Gly/G)Glycine
		GUC (Val/V)Valine	GCC (Ala/A)Alanine	GAC (Asp/D)Aspartic acid	GGC (Gly/G)Glycine
		GUA (Val/V)Valine	GCA (Ala/A)Alanine	GAA (Glu/E)Glutamic acid	GGA (Gly/G)Glycine
		GUG (Val/V)Valine	GCG (Ala/A)Alanine	GAG (Glu/E)Glutamic acid	GGG (Gly/G)Glycine

**Question 57.** In a paternity suit the ABO phenotypes of the mother, the child and the two possible fathers (F1 and F2) were determined, and a DNA profile was made for each person.

Both the mother (M) and the child (C) are type A, Rh-negative. Father F1 is type B, Rh-negative and Father F2 is type O, Rh-negative. The DNA profiles are shown below.



Answer the following questions. (3 marks)

Question	Answer: True (1) or False (2)
a. The mother has the genotype Rr for the Rh factor	2
b. The child has the genotype I <sup>A</sup> I <sup>o</sup>	1
c. F1 cannot be the father	2



**Question 58.** “DNA repair” mechanisms can be divided into 3 categories (listed below). A list of repairing processes is also given.

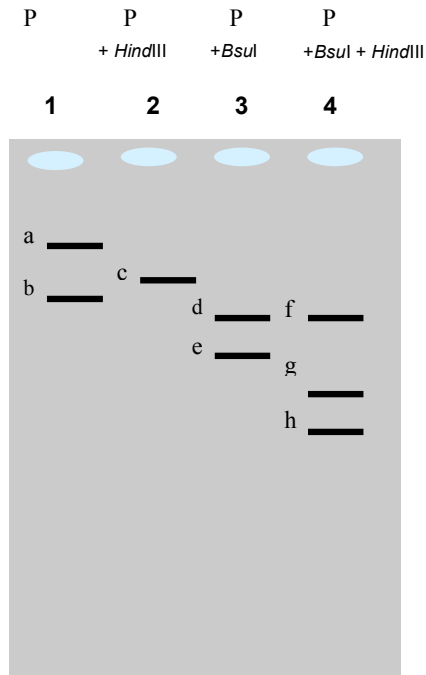
Match each DNA repair mechanisms with the names of the repairing processes. (4.5 marks)

Name of repairing process	DNA repair mechanisms
A. Mismatch repair	1. Damage reversal
B. Recombinational (daughter strand gap) repair	2. Damage removal
C. Nucleotide excision repair	3. Damage tolerance
D. Photoreactivation	
E. Mutagenic repair (trans lesion synthesis)	
F. Ligation of single strand breaks	
G. SOS repair	
H. Base excition repair	
I. Postreplicative Translesion Bypass Repair	

Answer table

DNA repair mechanism	Repairing process (list letter of all that apply)
1. Damage reversal	
2. Damage removal	
3. Damage tolerance	

**Question 59.** The pBR322 plasmid was cut with two different restriction enzymes. The patterns of ethidium bromide staining of plasmid DNA after electrophoresis on agarose gels are shown.



**Reference:**

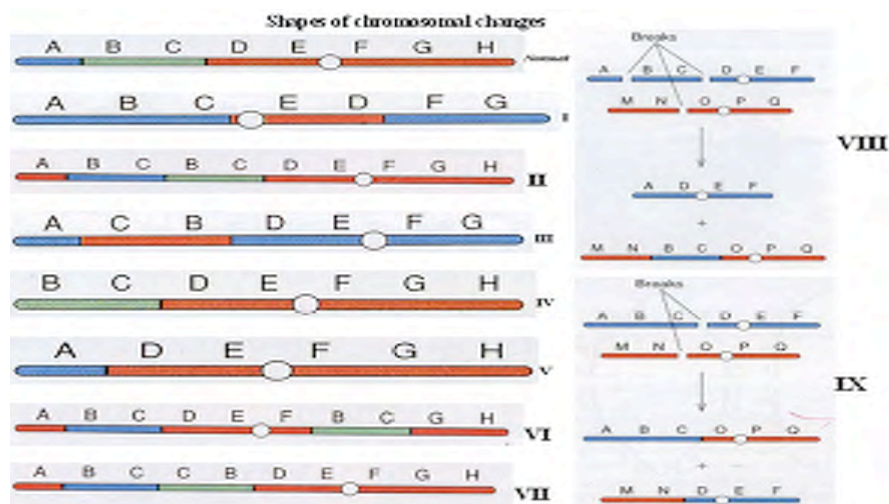
P: plasmid

Answer true or false: (2.5 marks)

- 1 ( ..T ...) The pBR322 has only one restriction site for *Hind*III.
- 2 (...F...) The restriction enzyme *Hind*III induces plasmid supercoiling.
- 3 (....T....) The pBR322 has two restriction sites for *Bsu*I.
- 4 (....T....) The migration rate of a DNA molecule in an agarose gel is inversely proportional to its size.
- 5 (....F.....) The bands in lane 4 indicate that both enzymes have the same restriction site.

**Question 60.** Information on the description and appearance of various chromosomal structural arrangements is given below.

Type of chromosomal change	Definition of chromosomal change
1. Tandem duplication	<del>A.</del> Internal fragment of chromosome is missed.
2. Reciprocal translocation	<del>B.</del> Chromosomal segment is doubled in the opposite order.
3. Interstitial deletion	<del>C.</del> Two-way exchange of a segment of chromosome.
4. Pericentric inversion	<del>D.</del> Centromere containing part of chromosome is inverted.
5. Displaced duplication	<del>E.</del> The tip of chromosome is lost because of single break.
6. Interstitial translocation	<del>F.</del> Acentromeric part of chromosome is inverted.
7. Terminal deletion	<del>G.</del> Chromosomal segment is represented twice same as the — original order.
8. Reverse duplication	<del>H.</del> Movement of a segment of chromosome from one to another — in one way.
9. Paracentric inversion	<del>K.</del> Chromosomal segment is represented twice but it is not — adjacent to original segment



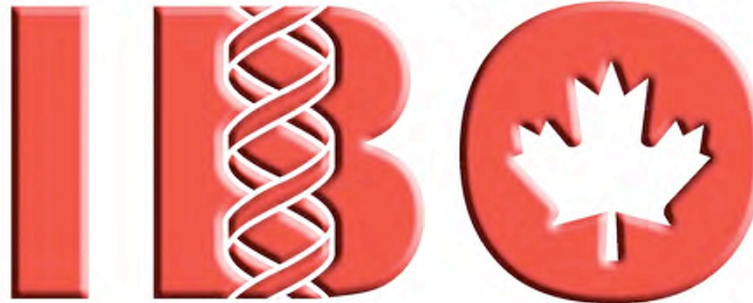
In the following table and using the appropriate letters and Roman numerals, match the correct definition and appearance to the type of chromosomal change listed. (4.5 marks)

Type of chromosomal change	Definition	Appearance
1. Tandem duplication		
2. Reciprocal translocation		
3. Interstitial deletion		
4. Pericentric inversion		
5. Displaced duplication		
6. Interstitial translocation		
7. Terminal deletion		
8. Reverse duplication		
9. Paracentric inversion		

- THE END -

**18<sup>th</sup> INTERNATIONAL BIOLOGY OLYMPIAD**  
**JULY 15 - 22, 2007**

*International Biology Olympiad*



*Saskatoon Canada 2007*

**THEORY EXAMINATION # 2**

**Total marks possible: 53.5**

**Time allowed: 120 minutes**

**WRITE YOUR 4-DIGIT STUDENT NUMBER IN THE BOX  
BELOW**

<b>STUDENT CODE</b>	
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## GENERAL INSTRUCTIONS

**Check that you have the correct examination paper and an answer sheet.**

**BE SURE TO RECORD ALL YOUR ANSWERS ON THE ANSWER SHEET**

**WHEN YOU HAVE FINISHED THE EXAM, PLACE YOUR ANSWER SHEET INSIDE YOUR QUESTION PAPER AND HAND BOTH TO THE INVIGILATOR BEFORE LEAVING THE EXAM ROOM.**

**REMEMBER TO WRITE YOUR 4-DIGIT STUDENT CODE ON THE FRONT PAGE OF THE QUESTION PAPER.**

Read each question carefully before attempting it.

### IMPORTANT

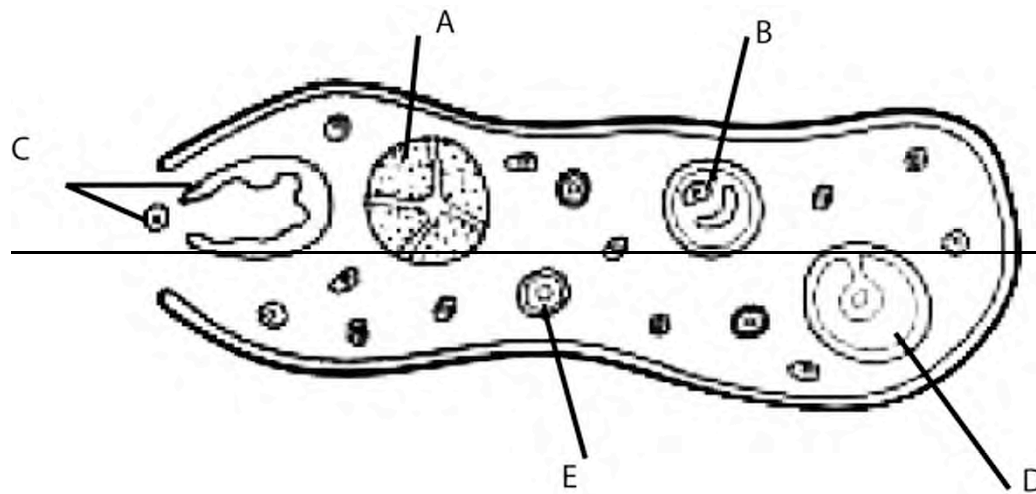
- Use the answer sheet provided to record your answers.
- **Ensure that your name and student code is PRINTED in the top margin of the front page of the answer sheet.** The markers will enter this information in the correct places on the reverse side of the answer sheet.
- Use only the HB pencil provided to mark the answer sheet. **Completely fill in the circle.**

A      B      C      D      E

**This is the correct way:**    o      •      o      o      o

- **DO NOT USE AN X OR ANY OTHER SYMBOL TO MARK YOUR ANSWER.**
- If you want to change your answer, use the eraser to completely erase your incorrect response and fill in the new circle you require.
- There is **ONLY ONE CORRECT ANSWER** to each question.
- Each question (except Question 31) is worth one mark.
- Marks will **NOT** be deducted for incorrect answers.

**Question 1.** The diagram below shows a section through a mammalian ovary.



Which one of the following is the correct sequence of the development of the structures indicated by the letters A to E?

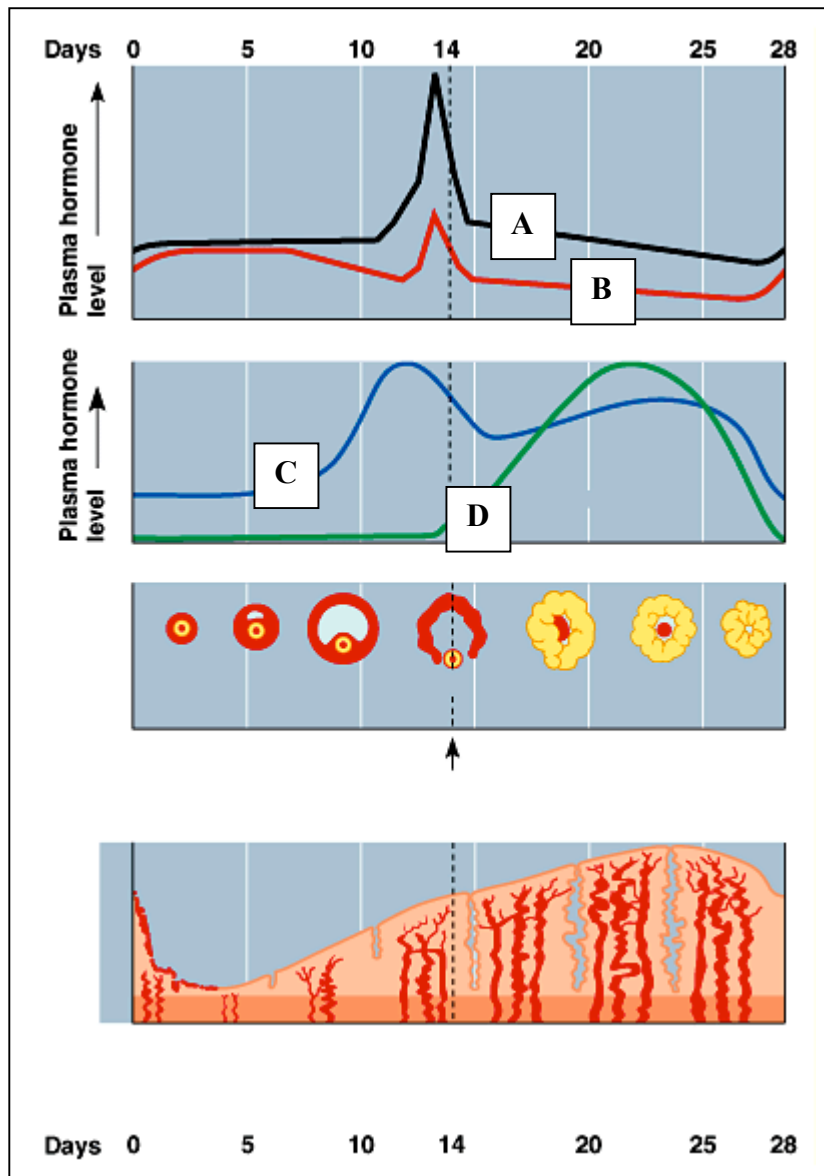
- A. A, C, D, B, E
- B. A, B, D, C, E
- C. C, B, D, A, E
- D. D, B, C, A, E
- E. E, B, D, C, A

**Question 2.** Oogenesis differs substantially from spermatogenesis. Which of the following statements concerning oogenesis is **INCORRECT**?

- A. Cytokinesis is unequal during the meiotic divisions
- B. The sequence from secondary oocyte to ovum is interrupted by a relatively long rest period**
- C. The first meiotic division is not completed unless the egg is reactivated by a hormone
- D. A mature ovum has not completed its second meiotic division
- E. The number of potential gametes is, by and large, established at birth

**Questions 3 – 7. Examine the figure below:**

**Hormone Levels during the Human Female Reproductive Cycle**



**Question 3.** Which of the following correctly lists the hormones in order from A to D?

- A. estrogen, progesterone, LH, FSH
- B. estrogen, FSH, progesterone, LH
- C. LH, FSH, progesterone, estrogen
- D. LH, estrogen, FSH, progesterone
- E. **LH, FSH, estrogen, progesterone**



**Question 4.** Which of the following statements is **INCORRECT**?

- A. **An increase in hormone B causes a decrease in hormones C and D**
- B. A steep rise in hormone C stimulates the production of hormones A and B.
- C. A low level of hormone C inhibits the production of hormones A and B.
- D. A high level of hormones C and D inhibits the secretion of hormones A and B

**Question 5.** Ovulation is triggered by a peak in the hormone whose level is shown by the

- A. **Line A**
- B. Line B
- C. Line C
- D. Line D

**Question 6.** Hormones A and B are secreted by the

- A. uterine wall
- B. ovary
- C. hypothalamus
- D. **anterior pituitary**

**Question 7.** ~~Hormones C and D are secreted by the~~

- ~~\_\_\_\_\_ A. uterine wall~~
- ~~\_\_\_\_\_ B. ovary~~
- ~~\_\_\_\_\_ C. hypothalamus \_\_\_\_\_~~
- ~~\_\_\_\_\_ D. anterior pituitary~~

**Question 8.** One hypothesis predicts that most of the CO<sub>2</sub> produced in the soil originates from microorganisms feeding on dead plant material. To which trophic level do these microorganisms belong?

- A. Primary producers
- B. Secondary producers
- C. **Decomposers**
- D. First order consumers
- E. Second order consumers

**Question 9.** Joan and Claude (neither have cystic fibrosis) come to you seeking genetic counseling. Claude was married before, and he and his first wife had a child with cystic fibrosis, an autosomal recessive condition. A brother of Joan's died of cystic fibrosis and Joan has never been tested for the gene. If they marry, what is the probability that Joan and Claude will have a son that **WILL NOT** be a carrier for, nor have cystic fibrosis?

- A. 1/12
- B. 1/8
- C. 1/6**
- D. 1/4
- E. 1/2

**Question 10.** Chromosomal crossing over occurs in which of the following stages of cell division?

- A. Prophase of mitosis.
- B. Metaphase of mitosis.
- C. Prophase I of meiosis.**
- D. Metaphase II of meiosis.
- E. Telophase I of meiosis.

**Question 11.** A man whose blood group is Type A has two boys. The plasma of one of the boys agglutinates the red cells of his father, but the plasma from the other son does not. Which statement is **incorrect**?

- A. The father must be heterozygous for the A blood type allele.
- B. The mother of the son that agglutinates his father's blood can be type AB.
- C. The boy that agglutinates could have type O blood.
- D. The mother of the son that agglutinates must possess a type O allele.**
- E. The boy that doesn't cause agglutination can be type AB.

**Question 12.** In peas, the allele for smooth seed coat (S) is dominant to wrinkled (s), Tall plant (T) is dominant to short (t) and yellow coloured seed (Y) is dominant to green (y).

A plant with the genotype SsTt yy was test crossed and 145 progeny survived to maturity. Approximately how many of these progeny are expected to be tall plants with green wrinkled seeds?

- A. 9
- B. 18
- C. 36**
- D. 72

**Question 13.** ~~B chromosomes are additional chromosomes possessed by some, but not all, individuals in a population. Which combination of statements is correct?~~

~~I. They occur only in plants.~~

~~II. While they are common in plants, they occur also in fungi, insects and animals.~~

~~III. They arise from normal chromosomes by fragmentation.~~

~~IV. They are normal, but short, chromosomes.~~

~~V. In plants they are associated with reduced viability.~~

~~\_\_\_\_\_ A. I, III and V~~

~~\_\_\_\_\_ B. I, IV and V~~

~~\_\_\_\_\_ C. II, III and V~~

~~\_\_\_\_\_ D. II, IV and V~~

**Question 14.** Often the frequency of a particular deleterious allele is very different in neighbouring populations. For example, the frequency of the allele causing cystic fibrosis is 0.02 in Population A and 0.006 in Population B. Such a difference in allele frequencies between two close populations is probably the result of

**A. The occurrence of the founder effect in an earlier generation**

B. More effective repair of DNA damage caused by mutation

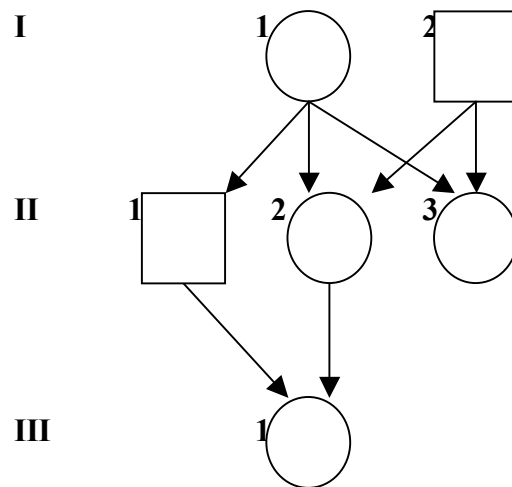
C. Selective advantage of the allele in one population but not the other

D. Recurring migration between the populations

E. Non-random mating.

**Question 15.** The coefficient of relatedness is a theoretical value determined by the number of alleles that would be the same between two organisms.

The diagram below shows the relationships between some honeybees. What is the coefficient of relatedness between II-2 and II-3; and between II-2 and III-1?



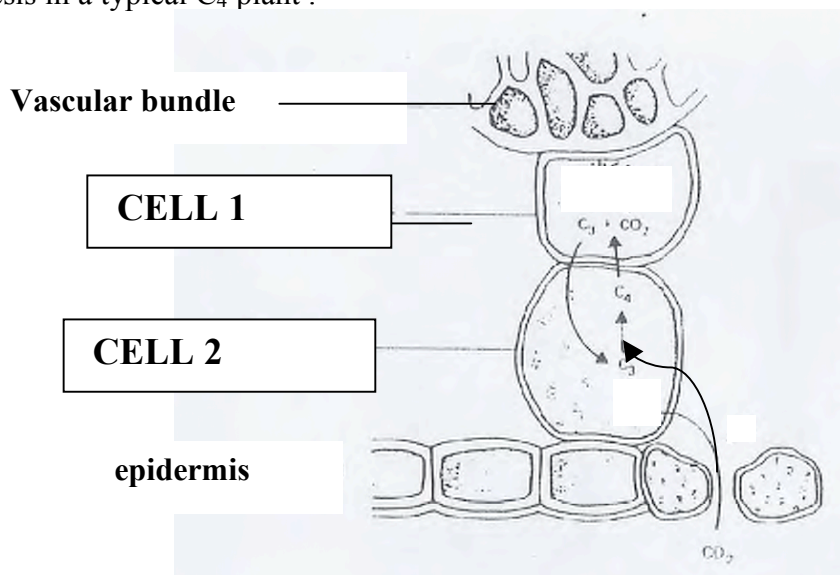
ANSWER	Between II-2 and II-3	Between II-2 and III-1
A.	0.50	0.50
<b>B.</b>	<b>0.75</b>	<b>0.50</b>
C.	0.75	1.00
D.	0.25	1.00
E.	0.50	0.75

**Question 16.** Collenchyma and sclerenchyma are plant support tissues. Which combination of the following statements correctly differentiates these two types of plant tissue?

- I. Collenchyma occurs only in Dicotyledons; sclerenchyma is an elastic tissue that is found in both Monocotyledons and Dicotyledons.
- II. Collenchyma cells are developed during growth; sclerenchyma cells generally occur in organs that have concluded their longitudinal growth.
- III. Collenchyma and sclerenchyma may arise from the same cell type.
- IV. Collenchyma cells have primary walls only while sclerenchyma cells have secondary walls.
- V. Collenchyma originates from the protoderm; sclerenchyma is formed by the procambium.

- A. I, II, III.
- B. II, III, IV**
- C. II, IV, V
- D. IV, V

**Question 17.** The following figure shows the carbon fixation reactions during photosynthesis in a typical  $C_4$  plant :



Which of the following answers indicate the dominant carbon fixation enzyme in each of the two cells?

Answer	Cell 1	Cell 2
A.	Malate dehydrogenase	Sucrose synthase
B.	PEP Carboxylase	Rubisco
<b>C.</b>	<b>Rubisco</b>	<b>PEP Carboxylase</b>
D.	Aspartate aminotransferase	Malate dehydrogenase
E.	Malic enzyme	Pyruvate dehydrogenase

**Question 18.** Suppose that an illuminated suspension of *Chlorella* (a photosynthetic alga) was actively carrying out photosynthesis when the light was suddenly switched off. How would the levels of 3-phosphoglycerate and ribulose 1,5-bisphosphate change during the next minute?

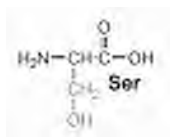
- A. The concentration of 3-phosphoglycerate would increase and that of ribulose 1,5-bisphosphate would increase.
- B. The concentration of 3-phosphoglycerate would increase; the concentration of ribulose 1,5-bisphosphate would decrease.**
- C. The concentration of 3-phosphoglycerate would decrease; the concentration of ribulose 1,5-bisphosphate would increase.
- D. The concentration of 3-phosphoglycerate would decrease; the concentration of ribulose 1,5-bisphosphate would decrease.
- E. The concentration of 3-phosphoglycerate would remain the same; the concentration of ribulose 1,5-bisphosphate would decrease.

**Question 19.** Which of the following statements shows the difference between the reaction sites of photosystem I and II?

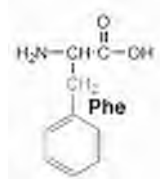
- A. Chlorophyll *a* is only found in photosystem I; chlorophyll *b* is found in photosystem II.
- B. Each preferentially absorbs slightly different wavelengths of light.**
- C. One is located in the thylakoid membrane; the other occurs in the stroma.
- D. Only photosystem I is found in the thylakoid membranes.
- E. None of these statements are correct.

**Question 20.** You are a biotechnologist designing novel eukaryotic enzymes that are regulated by phosphorylation. Which amino acid residues shown below would you most likely use at the regulatory site?

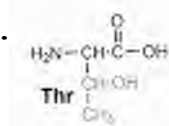
I.



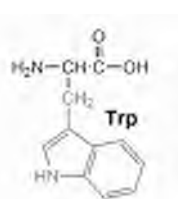
II.



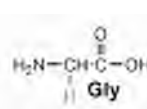
III.



IV.



V.



- A. I, III**
- B. I, IV
- C. I, II, III
- D. II, IV, V
- E. III, IV, V

**Question 21.** A biologist has discovered two new species of micro-organisms. Micro-organism A was isolated from a hot spring whereas micro-organism B was obtained from a tropical forest. DNA was isolated from both organisms and an analysis of the melting profile of each DNA sample was carried out. The melting temperature ( $T_m$ ) was 80 °C for DNA from micro-organism A, and 70 °C for DNA from micro-organism B.

Which statement best describes the reason for this difference in values?

- A. DNA of micro-organism A has higher A+T content
- B. DNA of micro-organism A has higher G+A content
- C. DNA of micro-organism A has higher G+C content**
- D. DNA of micro-organism A has higher T+G content
- E. DNA of micro-organism A has a higher proportion of TGA codons

**Question 22.** ~~Which of the following cofactors is not redox active?~~

- ~~A. Coenzyme A~~
- ~~B. Flavin coenzyme~~
- ~~C. NADH~~
- ~~D. Vitamin D~~
- ~~E. Coenzyme A and Vitamin D~~

- ~~A. I~~
- ~~B. II~~
- ~~C. III~~
- ~~D. IV~~
- ~~E. I, III~~

**Questions 23-24.** Two cells have the following characteristics:

Characteristic	Cell I	Cell II
Cell wall	Present	Present
Ribosomes	Present	Present
Nucleus	Absent	Present
Ability to photosynthesize	Present	Absent
Cell respiration	Present	Present

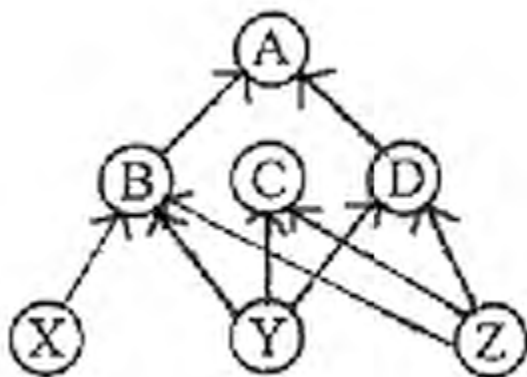
**Question 23.** From the characteristics presented in the table, which statement is correct?

- A. Cell I is more complex in its organization than cell II
- B. Cell I is a prokaryote**
- C. Cells with all characteristics of cell II appeared earlier in the fossil record than cells with all characteristics of cell I.
- D. Cell II does not have a cell membrane
- E. Both groups of cells are from fungi

**Question 24.** Cell II is a

- A. plant cell**
- B. eubacterium
- C. archaebacterium
- D. animal cell
- E. cyanobacterium

**Question 25.** Suppose Species B disappears from an ecosystem in which the interrelationship among the component species can be described by the food web below.



Which of the following will be a consequence of its elimination?

- A. Species X loses its only prey.
- B. Species A loses its only prey.
- C. Species D benefits because it is most distant from Species B.
- D. Species C benefits because the competition between species B and species C is reduced.**
- E. The disappearance of species B has no effect on species C or species D.



**Question 26.**—You have been asked by an international organization to initiate a biodiversity conservation project on a tropical island off the south coast of Java, and far from any large continental land. For this purpose, you must identify from three islands the island that has the highest number of species.

The following information is provided:

Island Name	Size/Area	Distance from Java
Boa	418 km <sup>2</sup>	220 km
Ibo	500 km <sup>2</sup>	800 km
Bio	420 km <sup>2</sup>	450 km

Which of the following statements describes your decision?

- A. — Bio Island
- B. — Boa Island
- C. — Ibo Island
- D. — Either Boa Island or Bio Island
- E. — Insufficient information is provided to allow you to make a decision.

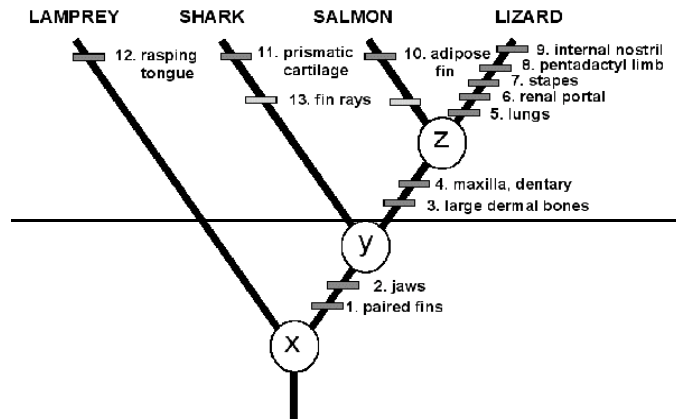
**Question 27.** Marine bony fishes have much lower internal osmotic concentration than the seawater around them. Which of the following statements DOES NOT EXPLAIN the osmotic regulation of marine bony fishes:

- A. They lose water by osmosis and gain salt by diffusion
- B. They drink seawater
- C. **They actively absorb sodium chloride across gills**
- D. They absorb sodium chloride from stomach
- E. They absorb water from stomach

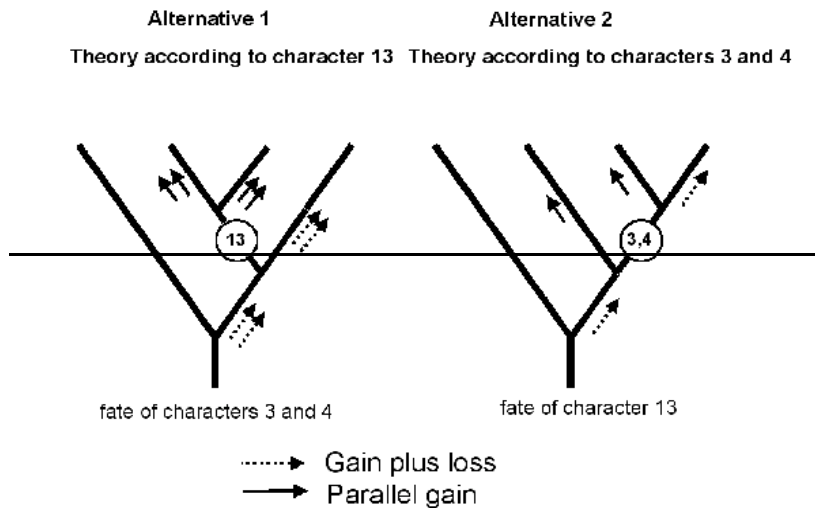
**Question 28.**—The best description of the relationships between fundamental niches (FN) and realized niches (RN) of two competing species A and B that coexist is:

- A. —  $FN_A = RN_A$ ;  $FN_B = RN_B$
- B. —  $FN_A > RN_A$ ;  $FN_B = RN_B$
- C. —  $FN_A < RN_A$ ;  $FN_B < RN_B$
- D. —  $FN_A > RN_A$ ;  $FN_B > RN_B$
- E. —  $FN_A = RN_A$ ;  $FN_B > RN_B$

~~Question 29.—Use the information given in Figures 1 and 2 to answer this question.~~



**Figure 1.** ~~An example of a phylogeny showing characters by which taxa are recognised. Characters 1—4 are synapomorphies, 5—12 are autapomorphies and 13 is an attribute seen in the salmon and the shark.~~



**Figure 2.** ~~Two possible ways to organize the data from Figure 1.~~

~~Which of the following statements best describes the information presented in Figures 1 and 2?~~

- ~~— A. The tree shown in Figure 1 is the most parsimonious tree possible using these characters.~~
- ~~— B. The Lamprey and the Lizard are the oldest because they have the longest line.~~
- ~~— C. The four groups shown in Figure 1 are equally related because they are all at the same horizontal level.~~
- ~~— D. X, Y and Z are characteristics common to all groups.~~
- ~~— E. The Lamprey is more closely related to the Shark than to the Salmon or the Lizard.~~

**Question 30.** A woman visits her doctor after noticing several changes in her body over a period of 6 (six) months. She has noticed weight loss, intolerance to temperature variations, irregular menstrual cycles, insomnia, and general weakness. Based on these symptoms, you would expect the doctor to test her for:

- A. Diabetes mellitus
- B. Hyperthyroidism**
- C. Hypothyroidism
- D. Hypoglycemia

**Question 31.** Endocrine glands

- A. Produce hormones that are only secreted into the digestive tract
- B. Release most hormones into the bloodstream**
- C. Release hormones that generally act as rapidly as nerve impulses
- D. Are present only in vertebrates

**Question 32.** Long corolla length in tobacco is inherited as a recessive monogenic characteristic. If in a natural population 49% of the plants have a long corolla, what is the probability that the result of test crossing a randomly selected plant with a short corolla from this population in  $F_1$  will have uniform progeny?

- A. 100%
- B. 50%
- C. 30%
- D. 18%**
- E. 0%

**Question 33.** From an evolutionary viewpoint, which of the five following individuals is the most fit?

- A. A child who does not become infected with any of the usual childhood diseases, such as measles or chicken pox.
- B. A woman of 40 with seven adult offspring**
- C. A woman of 80 who has one adult offspring
- D. A 100-year old man with no offspring
- E. A childless man who can run a mile in less than five minutes

**Question 34.** A study of a grass population growing in an area of irregular rainfall found that plants with alleles for curled leaves reproduced better in dry years, whereas plants with alleles for flat leaves reproduced better in wet years. Curled and flat leaves are controlled by different alleles at the same gene locus.

This situation tends to

- A. cause genetic drift in the grass population
- B. cause gene flow in the grass population
- C. lead to directional selection in the grass population
- D. preserve variability in the grass population**
- E. lead to uniformity in the grass population

**Question 35.** The cohesion-tension (C-T) theory of sap ascent states that in plants sap is transported against gravity by bulk flow through the xylem vessels or chains of tracheids. Which of the following statements correctly describes the main factors affecting this bulk flow?

- A. Hydrogen bonds within the water, hydrogen bonding to the hydrophilic walls of the xylem cells, and the gradient of solute potential ( $\psi_s$ ).
- B. The gradient of the pressure potential ( $\psi_p$ ), and solute concentration
- C. The gradient of water potential ( $\psi$ ), hydrogen bonds within the water and solute concentration.
- D. Hydrogen bonds within the water, hydrogen bonding to the hydrophilic walls of the xylem cells, and the gradient of pressure potential ( $\psi_p$ ).**

**Questions 36-38.** Plants maintain most Indole Acetic Acid (IAA) (an auxin) in conjugated forms, which complicates IAA quantification.

**Question 36.** ~~These forms can exist in forms such as IAA-amino acid conjugates~~

- ~~\_\_\_\_\_ A. AA-amino acid conjugates~~
- ~~\_\_\_\_\_ B. IAA-hydrolase conjugates~~
- ~~\_\_\_\_\_ C. IAA-glycerol conjugates~~
- ~~\_\_\_\_\_ D. IAA-peroxide conjugates~~

**Question 37.** These forms can exist in forms such as IAA-amino acid conjugates. Before analysis in order to measure total IAA in a particular tissue, these conjugates must be

- A. dehydrated
- B. dehydrogenized
- C. hydrolyzed**
- D. synthesized

**Question 38.** Therefore free IAA, thought to be the active form of the hormone, is measured

- A. in the same sample without enzymes
- B. in the same sample with enzymes
- C. in a parallel sample without enzymes**
- D. in a parallel sample with enzymes

**Question 39.** You find a mutant bacterium that synthesizes lactose-digesting enzymes whether or not lactose is present. Which of the following statements or combination of statements might explain this?

- I. The operator has mutated such that it is no longer recognised by the repressor.
- II. The gene that codes for the repressor has mutated and the repressor is no longer effective.
- III. The gene or genes that code for the lactose-digesting enzymes have mutated.

- A. Only I
- B. Only II
- C. Only I, II**
- D. Only I, III
- E. I, II, III

**Question 40.** What mechanism is responsible for the acidification of the lysosome?

- A. A lysosome fuses with acidic vesicle derived from Golgi apparatus
- B. A pump transports protons from the cytosol into the lysosome**
- C. A pump transports protons from the lysosomal lumen to the cytosol
- D. A lysosome fuses with acidic endocytosed material
- E. A pump transports  $\text{OH}^-$  ions from the cytosol to the lysosomal lumen

**Question 41.** Which of the following is an example of active transport?

- A.  $\text{K}^+$  through a voltage-gated  $\text{K}^+$  channel
- B.  $\text{Ca}^{2+}$  through a voltage-gated ion channel
- C.  $\text{Na}^+$  through ligand-gated ion channel
- D. 3  $\text{Na}^+$  in exchange for 2  $\text{K}^+$  across the plasmalemma**
- E. All of the above

**Question 42.** The transport of glucose into the mammalian red blood cell is accomplished by

- A. simple diffusion through the phospholipid bilayer
- B. a  $\text{Na}^+ - \text{K}^+$  ATPase
- C. esterifying the glucose to phosphatidate
- D. first converting glucose into lactose
- E. **facilitated diffusion through a glucose transporter**

**Question 43.** Isopods are one of the few crustacean groups that have successfully invaded terrestrial habitats. Which of these statements is INCORRECT?

- A. **They live in dry conditions.**
- B. They must live in moist conditions.
- C. Their abdominal appendages bear gills.
- D. They do not have an efficient cuticular covering to conserve water.

~~**Question 44.** Hormones are essential to maintaining homeostasis mainly because~~

- ~~\_\_\_\_\_ A. they catalyze specific chemical reactions in brain cells.~~
- ~~\_\_\_\_\_ B. the body requires them for digesting food.~~
- ~~\_\_\_\_\_ C. they cause specific responses in specific targets.~~
- ~~\_\_\_\_\_ D. they act faster than nerve impulses.~~

~~**Question 45.** Compared to nerve impulses, hormones are generally~~

- ~~\_\_\_\_\_ A. released more slowly and have longer lasting effects.~~
- ~~\_\_\_\_\_ B. released faster and have longer lasting effects.~~
- ~~\_\_\_\_\_ C. release more slowly and have effects of a shorter duration.~~
- ~~\_\_\_\_\_ D. released faster and have effects of shorter duration.~~

**Question 46.** Someone who has suffered damage to the pancreas might

- A. have difficulty maintaining normal cortisol levels
- B. have abnormal blood calcium levels.
- C. **have periods of very low energy.**
- D. experience fluctuating blood pressure

**Question 47.** The hypothalamus

- A. **sends nerve impulses and also makes hormones.**
- B. directly stimulates the adrenal gland to produce glucocorticoids
- C. belongs to both the nervous and circulatory systems.
- D. regulates circadian rhythms in vertebrates.

**Questions 48 - 49.** Ten grams of plant material were homogenized in 50 ml buffer and the homogenate was centrifuged. Protein from 10 ml of the supernatant was precipitated by addition of ammonium sulphate and the protein precipitated was collected by centrifugation and re-suspended in 1 ml of buffer. The re-suspended protein was diluted 10 times for protein determination.

**Question 48.** ~~The amount of protein in 1 ml of the diluted sample was 0.4 mg. What is the total amount of protein recovered from 10 ml of the supernatant?~~

- ~~— A. 2 mg~~
- ~~— B. 4 mg —~~
- ~~— C. 6 mg~~
- ~~— D. 8 mg~~

**Question 49.** The amount of protein in 1 ml of the diluted sample was 0.4 mg. What is the amount of protein extracted from 100 g tissue?

- A. 0.2 g
- B. 0.4 g
- C. 0.6 g
- D. 0.8 g

**Question 50.** Prion diseases are characterized by:

- A. cellular DNA damage.
- B. misfolded proteins that are much more soluble than the regular form of the protein.
- C. **misfolded proteins that are prone to aggregation and are very stable.**
- D. abnormal enzyme activity.
- E. protein chaperones in cells.

**Question 51.** Why are some proteinases synthesized as inactive precursors known as zymogens (proenzymes)?

- A. Because they don't degrade a cell's starch supply.
- B. Zymogens have a higher degree of substrate specificity than most enzymes.
- C. **Zymogen synthesis ensures that proteinase activity is kept to a minimum inside the cell where they are synthesised.**
- D. Zymogens are better at interconverting energy than regular enzymes.
- E. Zymogens are more resistant to protein denaturation than the regular proteinase.

**Question 52.** ~~Negative feedback is a process that~~  
~~Which of the following statements is INCORRECT? Negative feedback:~~

- ~~A. always reduces the amount of a hormone present in the blood.~~
- ~~A. is the main mechanism maintaining endometrial blood supply during pregnancy~~
- ~~\_\_\_\_\_ B. keeps conditions near their normal state.~~
- ~~\_\_\_\_\_ B. is responsible for varying urine osmolarities over the period of a day~~
- ~~\_\_\_\_\_ C. lowers the body temperature below normal.~~
- ~~\_\_\_\_\_ C. results in small fluctuations in physiological parameters~~
- ~~\_\_\_\_\_ D. none of the above are correct.~~
- ~~\_\_\_\_\_ D. is used in regulation of sympathetic and parasympathetic functions~~

**Question 53.** What is the role of the “second messenger” in hormone action?

- A. it signals a cell to secrete a hormone.
- B. it informs a gland as to whether its hormones are having an effect.
- C. it relays a hormone’s message inside a target cell.**
- D. it carries a hormone while it is in the blood.

**Question 54.** ~~It takes much longer for sex hormones and other steroids to produce their effect than it takes nonsteroid hormones. Why?~~

- ~~\_\_\_\_\_ A. Steroids are bigger, slower moving molecules.~~
- ~~\_\_\_\_\_ B. Steroids usually must be carried longer distances by the blood.~~
- ~~\_\_\_\_\_ C. Steroids generally cause target cells to make new proteins, which take time.~~
- ~~\_\_\_\_\_ D. Steroids relay their message via a second messenger.~~

**Questions 55 - 57.** To test the origin of CO<sub>2</sub> available in the soil, two experiments were conducted on trees in a *Pinus* forest.

**Question 55.** In the first experiment, a 20 cm-wide strip of bark around the stem was removed from trees mid-way between the ground and the lowest branch.

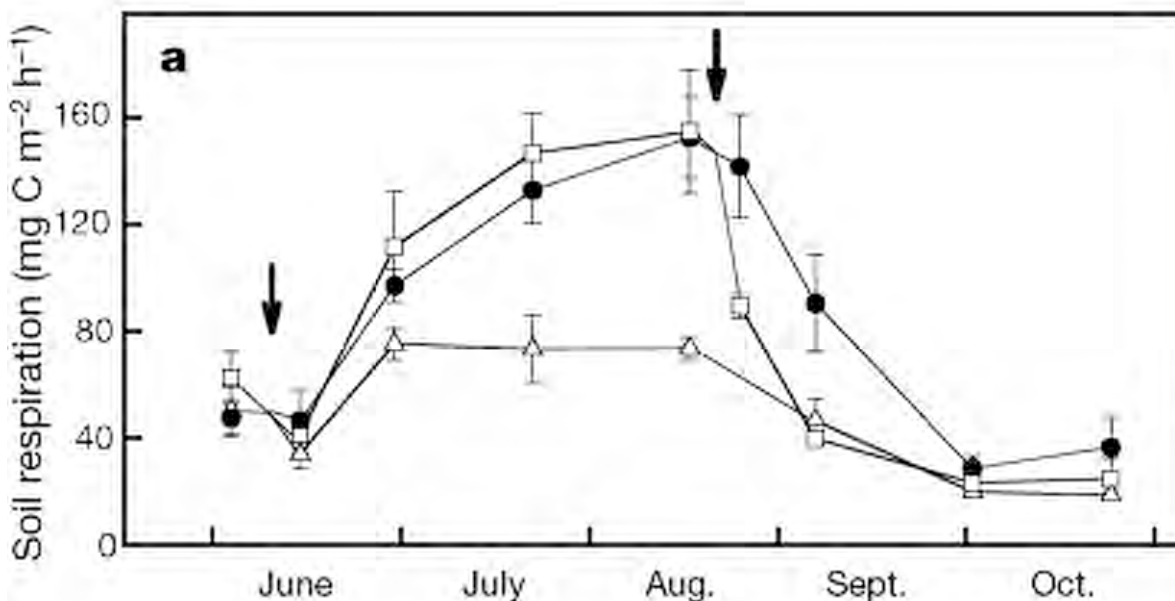
Which of the following statements correctly describes the effect of this treatment on the trees?

- A. Transpiration will cease. As a result, the tree will lose all its needles.
- B. Transport of auxin in the xylem is prevented. This will cause increased auxin concentration in the roots and root growth will be stimulated.
- C. Phloem transport is prevented causing the roots to become deficient in nitrogen.
- D. Transport of sugars to the roots ceases and the roots will die.**
- E. Transport of potassium and calcium from the roots to the needles will cease.



**Question 56.** In the second experiment, the amount of CO<sub>2</sub> released from the soil at the base of trees was measured on several days during the growing period. The bark-removal experiment was repeated on a total of 9 trees, three trees per treatment. In the first treatment, the bark was removed in early June (white triangles); in the second treatment, the bark was removed in late August (white squares); the third treatment was the control treatment where the bark was not removed (black circles).

The data from this experiment are shown in the following graph. The black arrows indicate the time of bark removal.



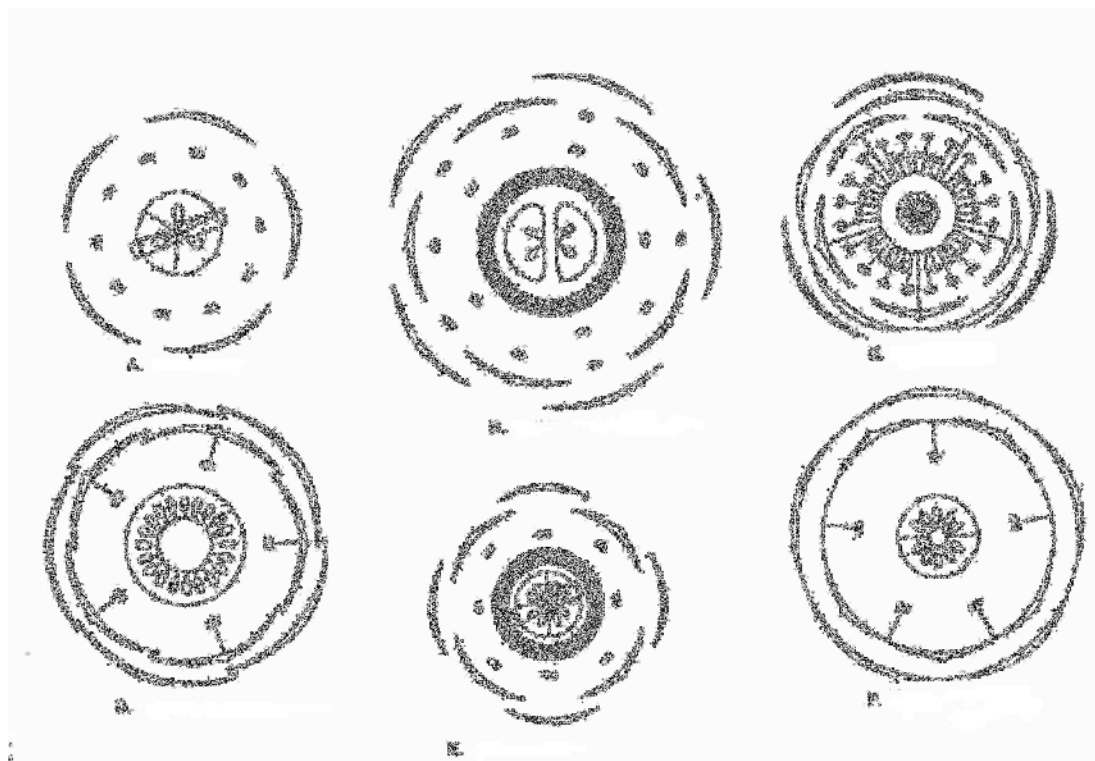
Which combination of the following statements best describe the results of this experiment?

- I. The variability of the different treatments overlap and any effect of bark removal is due to chance.
  - II. The production of CO<sub>2</sub> in the soil shows seasonal variation.
  - III. Bark removal in June had a much smaller effect on the total CO<sub>2</sub> production in the soil during the whole season than bark removal in August.
  - IV. The decrease in the CO<sub>2</sub> production in the soil in the treatments where bark was removed cannot be explained by seasonal variations alone.
  - V. The production of CO<sub>2</sub> in the soil is always smaller for trees with bark removed than for undamaged trees.
- A. Only I, II and V
  - B. Only I, II and IV
  - C. **Only II, IV and V**
  - D. Only II, III and IV
  - E. Only I, III and V

**Question 57.** Which of the following statements is a valid conclusion for the results of the second experiment?

- A. Most  $\text{CO}_2$  produced in the soil is due to the decomposition of dead roots.
- B. Most  $\text{CO}_2$  produced in the soil is due to cellular respiration of root cells.**
- C. The amount of  $\text{CO}_2$  produced in the soil is not influenced by photosynthesis.
- D. When most of the roots die, the production of  $\text{CO}_2$  in the soil is greatest.
- E. The amount of  $\text{CO}_2$  produced in the soil depends on the soil temperature.

**Questions 58 - 59.** Below are six floral diagrams, labelled A to F.



**Question 58.** From the following, choose the combination in which the floral diagram is associated with the correct family.

- A. A = Brassicaceae
- B. B = Fabaceae
- C. C = Liliaceae
- D. D = Malvaceae
- E. E = Rosaceae

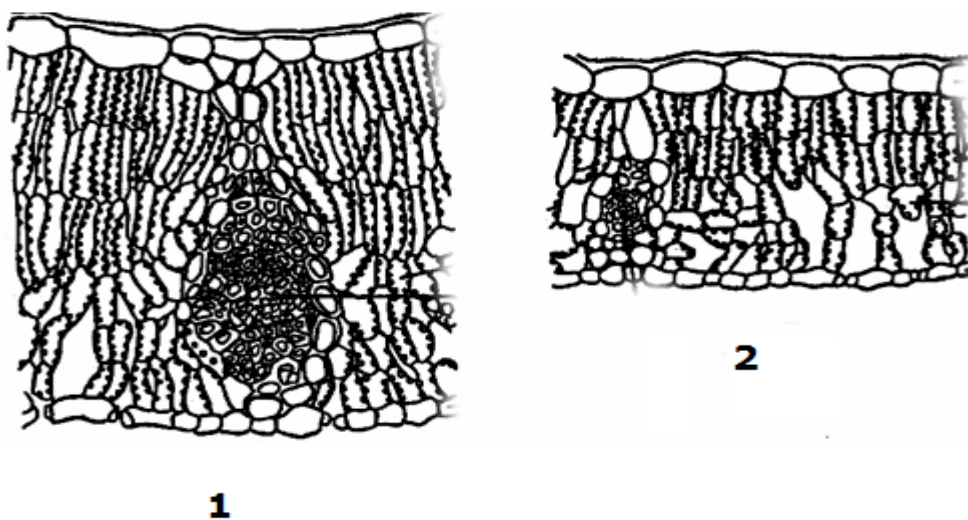
**Question 59.** In which floral diagram do the all the floral characteristics listed below occur?

- X Zygomorphic flower, fused sepals
- X Axile placentation.
- X Epipetalous stamen

- A. B
- B. C
- C. D
- D. E
- E. F**

**Question 60.** Students made cross-sections of leaves collected from two different oak trees. When they examined the sections under a microscope, they were surprised to see that the leaves were different.

The following diagrams show cross-sections of leaves from Oak tree 1 and Oak tree 2.



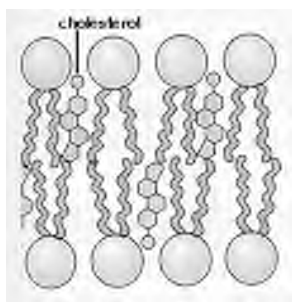
Which of the following statements best explains the difference in leaf structure that the students observed?

- A. Oak tree 1 grows in a swampy area; Oak tree 2 grows in sandy soil.
- B. Oak tree 1 is a young tree; Oak tree 2 is a mature tree.
- C. Oak tree 1 grows in fertile soil; Oak tree 2 grows in poor soil.
- D. Oak tree 1 is exposed to sun for most of the day; Oak tree 2 grows in a shaded area.**
- E. Oak tree 1 is infected by fungi, which induced the cell proliferation; Oak tree 2 was not infected.

**Question 61.** Cloning of a new DNA fragment into a circular plasmid/vector always requires:

- A. Complementary base pairing
- B. DNA ligase activity**
- C. The presence of the same restriction site in the insert and the vector
- D. Selectable markers and autonomous replicating sequences
- E. All of the above

**Question 62.** Below is a diagram representing cholesterol in the phospholipid bilayer.



Cholesterol mixes with phospholipids in a cell membrane because cholesterol molecules are:

- A. amphipathic**
- B. steroid derivatives
- C. entirely hydrophobic
- D. phospholipids derivatives
- E. bound with glycoproteins

**Question 63.** Which of the following molecules can diffuse through the mammalian phospholipid bilayer without using a channel/transporter?

- I.  $O_2$
- II. glucose
- III. steroid hormones
- IV.  $K^+$
- V. amino acids

- A. I, III**
- B. I, IV
- C. II, III, V
- D. II, III, IV, V
- E. All of the above.

**Question 64.** What is the net charge of aspartic acid when the pH of the solution in which it is prepared is the same as its pI value? Note the three pKa values of aspartic acid are as follows:  $-\text{COOH}$  pKa = 2.1;  $-\text{NH}_3^+$  pKa = 9.8; R group pKa = 3.9

- A. one net positive charge
- B. two net positive charges
- C. one net negative charge
- D. two net negative charges
- E. **no net charge**

**Question 65.** A quantitative amino acid analysis reveals that bovine serum albumin (BSA) contains 0.58% tryptophan residues by weight. The molecular mass of the tryptophan molecules is 204 daltons. The molecular mass of bovine serum albumin is known to be approximately 66000 daltons. What number of tryptophan residues is present in each BSA molecule?

- A. **2**
- B. 3
- C. 4
- D. 5
- E. 6

**Question 66.** What essential function does gastrulation perform for the developing embryo?

- A. It results in the dorsal-ventral axis formation.
- B. **It gives rise directly to the germ layers of the embryo.**
- C. It gives rise to neural crest cells.
- D. It gives rise directly to endocrine cells.
- E. It gives rise directly to the trophectoderm.

**Question 67.** Which of the following is not true about the lymphatic system?

- A. It helps maintain the volume and protein concentration of the blood.
- B. It helps defend the body against infection.
- C. It transports fats from digestive tract to circulatory system.
- D. Lymph composition is similar to that of interstitial fluid.
- E. **Lymph drains directly into the excretory system.**

**Question 68.** The most direct consequence on amphibian development upon removal of the grey crescent would be:

- A. Inability to develop from the 2-cell stage to the 4-cell stage.
- B. Inability to develop from the 4-cell stage to the 8-cell stage.
- C. Inability to form a blastocoel.
- D. Inability to form dorsal structures.**
- E. Inability to form ventral structures.

**- THE END -**

### EXAM SUMMARY STATISTICS – IBO 2007

Marks	Practical Exams									Theoretical Exams			
	Animal Biology		Plant Biology		Biochemistry		Genetics			Exam 1		Exam 2	
	Raw scores	%	Raw scores	%	Raw scores	%	Raw scores	%		Raw scores	%	Raw scores	%
Maximum possible	63	100	77	100	44	100	43	100		99	100	53.5	100
Maximum	62.6	99.4	74.0	96.1	44.0	100.0	39.0	90.8		92.5	93.4	50.5	94.4
Minimum	18.3	29.0	17.5	22.7	12.0	27.3	7.0	16.3		34.6	35.0	14.0	26.2
Mean	49.2	78.2	59.3	77.1	36.7	84.1	22.8	53.2		69.9	70.6	38.2	71.3
Standard deviation	8.7	13.8	9.9	12.8	6.7	15.1	5.7	12.9		11.2	11.3	7.2	13.5
CV (%)	17.6		16.6		18.0		24.2			15.9		18.9	

**MEAN SCORE**  
**DISCRIMINATING INDEX**

73.1%  
 19.1

71.0%  
 17.4

**DISTRIBUTION OF THEORETICAL EXAM QUESTIONS BY SUBJECT AREA**  
**IBO 2007**  
(before Jury revision)

Subject Area	Recommended distribution (%)	No. of questions	% distribution	Over/ under	Mark value of questions	% distribution	Over/ under
Cell Biology	20	30	24	+4%	42.5	23	+3%
Plant Anatomy and Physiology	15	19	15	=	37.5	20	+5%
Animal Anatomy and Physiology	25	34	27	+2%	39.5	21	-4%
Ethology	5	2	2	-3%	4	3	-2%
Genetics and Evolution	20	24	20	=	42.5	23	+3%
Ecology	10	7	6	-4%	11.5	6	-4%
Biosystematics	5	9	7	+2%	9	5	=

**DISTRIBUTION OF THEORETICAL EXAM QUESTIONS BY SUBJECT AREA**  
**IBO 2007**  
(after Jury revision)

Subject Area	Recommended distribution (%)	No. of questions	% distribution	Over/ under	Mark value of questions	% distribution	Over/ under
Cell Biology	20	26	25	+5%	35.0	23	+3%
Plant Anatomy and Physiology	15	18	18	+3%	31.5	21	+6%
Animal Anatomy and Physiology	25	25	25	=	31.5	21	-4%
Ethology	5	1	1	-4%	4.0	3	-2%
Genetics and Evolution	20	21	21	+1%	36.0	24	+4%
Ecology	10	4	4	-6%	7.0	5	-5%
Biosystematics	5	7	7	+2%	7.5	5	=



# **IBO 2007 Theoretical Exam 1 Item Analysis**

Question	Difficulty index (p-score)	Point Serial correlation (Rit)	Discrimination Index*	% Correct response	
				Upper 27%	Lower 27%
1	0.59	0.38	0.481	44	19
2	0.65	0.48	0.615	48	16
3	0.66	0.41	0.442	46	23
4	0.87	0.25	0.192	51	41
5	0.70	0.43	0.481	47	22
6	0.92	0.28	0.154	51	43
7	Skipped				
8	0.47	0.15	0.212	28	17
9	0.39	0.49	0.558	36	7
10	Skipped				
11	Skipped				
12	0.40	0.28	0.327	28	11
13	0.53	0.41	0.481	42	17
14	0.87	0.31	0.212	51	40
15	Skipped				
16	0.63	0.18	0.231	36	24
17	0.59	0.24	0.212	38	27
18	0.20	0.23	0.231	20	8
19	Skipped				
20	0.64	0.25	0.288	41	26
21	0.74	0.39	0.365	48	29
22	0.74	0.34	0.442	51	28
23	0.50	0.32	0.327	34	17
24	0.75	0.44	0.423	45	23
25	0.89	0.40	0.269	52	38
26	0.48	0.49	0.615	44	12
27	0.47	0.55	0.808	47	5
28	0.63	0.34	0.385	42	22
29	0.68	0.39	0.404	46	25
30	0.72	0.38	0.365	48	29
31	0.81	0.33	0.288	52	37
Mean	0.64	0.35	0.38		
SD	0.17	0.10	0.16		

\* A measure of the effectiveness of the question in discriminating between high and low scorers.

# IBO 2007 Theoretical Exam 2 Item Analysis

Question	Difficulty index (p-score)	Point Serial correlation (Rit)	Discrimination Index*	% Correct response	
				Upper 27%	Lower 27%
1	Skipped				
2	0.37	0.43	0.46	32	8
3	0.79	0.40	0.37	50	31
4	0.67	0.25	0.23	38	26
5	0.71	0.25	0.29	46	31
6	0.80	0.47	0.44	52	29
7	Skipped				
8	0.98	0.24	0.06	52	49
9	0.30	0.40	0.44	30	7
10	0.95	0.23	0.12	52	46
11	0.65	0.39	0.48	48	23
12	0.86	0.29	0.21	49	38
13	Skipped				
14	0.55	0.20	0.29	35	20
15	0.37	0.19	0.29	28	13
16	0.63	0.20	0.23	41	29
17	0.71	0.33	0.37	46	27
18	0.39	0.33	0.46	35	11
19	0.84	0.31	0.31	50	34
20	0.76	0.44	0.46	51	27
21	0.89	0.18	0.15	50	42
22	Skipped				
23	0.96	0.30	0.12	52	46
24	0.46	0.34	0.44	36	13
25	0.78	0.21	0.21	50	39
26	Skipped				
27	0.55	0.45	0.56	41	12
28	Skipped				
29	Skipped				
30	0.56	0.18	0.23	33	21
31	0.96	0.28	0.08	52	48
32	0.64	0.42	0.50	45	19
33	0.87	0.31	0.29	52	37
34	0.65	0.28	0.29	42	27
35	0.60	0.24	0.33	40	23
36	Skipped				
37	0.88	0.33	0.23	49	37
38	0.32	0.27	0.27	23	9
39	0.86	0.52	0.44	52	29
40	0.84	0.36	0.23	47	35
41	0.81	0.37	0.35	50	32
42	0.80	0.33	0.33	51	34
43	0.73	0.36	0.42	47	25
44	Skipped				

45	Skipped				
46	0.75	0.34	0.31	43	27
47	0.82	0.29	0.35	48	30
48	Skipped		0.00		
49	0.68	0.51	0.62	48	16
50	0.76	0.38	0.40	50	29
51	0.91	0.56	0.31	52	36
52	Skipped				
53	0.91	0.46	0.27	52	38
54	Skipped				
55	0.87	0.44	0.29	51	36
56	0.79	0.44	0.35	47	29
57	0.82	0.31	0.25	47	34
58	Skipped				
59	0.68	0.34	0.42	46	24
60	0.72	0.37	0.44	48	25
61	0.06	0.23	0.13	7	0
62	0.49	0.35	0.46	37	13
63	0.68	0.36	0.42	46	24
64	0.68	0.36	0.42	46	24
65	0.87	0.30	0.19	52	42
66	0.82	0.20	0.25	49	36
67	0.88	0.39	0.27	51	37
68	0.63	0.25	0.29	41	26
Mean	0.72	0.33	0.31		
SD	0.19	0.10	0.14		

\* A measure of the effectiveness of the question in discriminating between high and low scorers.