

NAME : _____

CLASS : _____



JURONG PIONEER JUNIOR COLLEGE JC2 Preliminary Examination 2025

BIOLOGY Higher 2

9744/03
15 September 2025

Paper 3 Long Structured and Free-response Questions

2 hours

Additional Materials: Answer Booklet

READ THESE INSTRUCTIONS FIRST

Write your class and name in the spaces at the top of this page.

Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

Section A

Answer **all** questions in the spaces provided on the Question Paper.

Section B

Answer any **one** question on the separate Answer Booklet provided.

The use of an approved scientific calculator is expected, where appropriate.

You may lose marks if you do not show your working or if you do not use appropriate units.

The number of marks is given in brackets [] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
Section B	
Total	

This document consists of **17** printed pages and **3** blank pages.

Section A

Answer **all** questions.

- 1 Following a body injury, bone marrow stem cells migrate to the site of damage, where they undergo cell differentiation to replace damaged cells. In eukaryotes, cell growth and division are tightly regulated processes to ensure proper repair. Cells will only pass specific checkpoints in the cell cycle if certain conditions are met, one of which is the presence of growth factors.

Fig. 1.1 shows how this differentiation occurs.

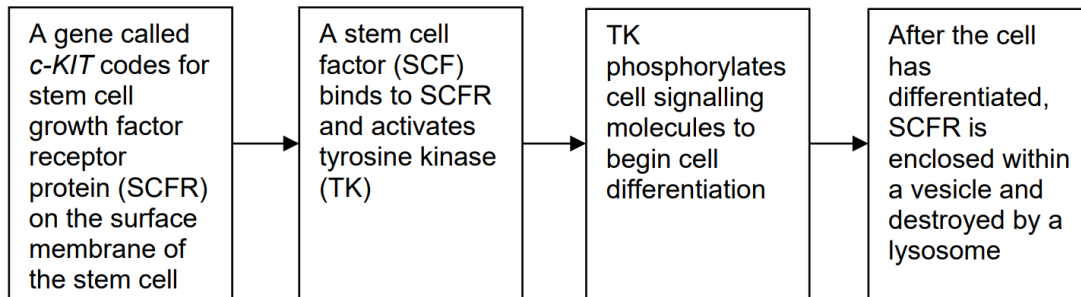


Fig. 1.1

- (a) (i) Outline how SCFR is produced and transported to the cell surface.

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..... [4]

- (ii) Suggest how SCFR is destroyed by a lysosome.

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..... [1]

Fig. 1.2 shows an example of how signals from growth factors are transduced to result in cell growth and division. The KRAS protein is a G-protein encoded by *KRAS* proto-oncogene.

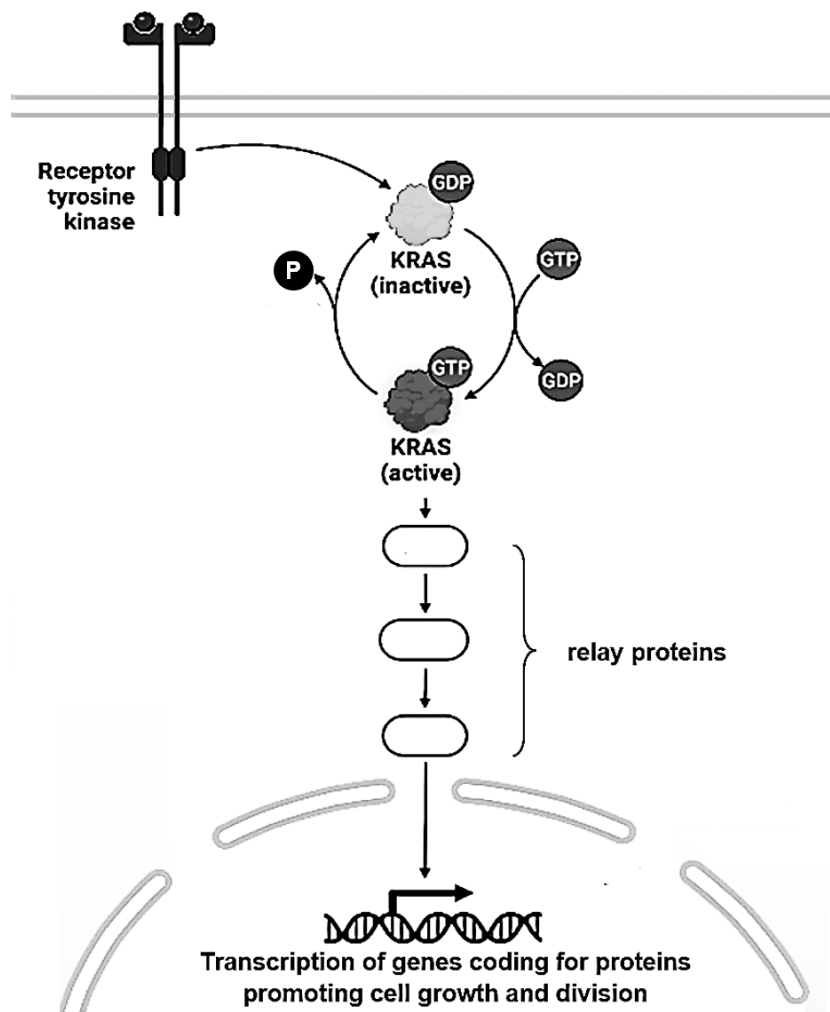


Fig. 1.2

- (b) Describe the role of the KRAS protein in the transduction of signal from growth factors.

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- (c) Mutations in *KRAS* proto-oncogene are common in colorectal (colon and rectum) cancer. The oncogene arises from the proto-oncogene by a mutation called G12D.

Fig. 1.3 shows part of the base sequence of the template strand of the *KRAS* proto-oncogene and the corresponding part of the oncogene. The corresponding parts of the primary structures of the two encoded *KRAS* proteins involved in GTPase activity are also shown.

amino acid position		6	7	8	9	10	11	12	
<i>KRAS</i> proto-oncogene	3' ...	GAA	CAC	CAT	CAA	CCT	CGA	CCA	... 5'
normal <i>KRAS</i> protein		leu	val	val	val	gly	ala	gly	
<i>KRAS</i> oncogene	3' ...	GAA	CAC	CAT	CAA	CCT	CGA	CTA	... 5'
mutant <i>KRAS</i> protein		leu	val	val	val	gly	ala	asp	

Fig. 1.3

- (i) State **one** possible environmental causative factor that increases the risk of G12D mutation shown in Fig. 1.3.

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 [1]

- (ii) With reference to Fig. 1.3, explain how the G12D mutation leads to colorectal cancer.

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 [5]

- (d) In a genetic study for colorectal cancer, two populations were screened for the G12D mutation. Table 1.1 shows the results of the study.

Table 1.1

group	total number of individuals	number of individuals with G12D mutation
without colorectal cancer (control group)	500	2
with colorectal cancer	400	120

- (i) Calculate the relative risk (RR) of G12D mutation in the cancer group compared to the control group using the formula provided.

$$RR = \frac{\text{risk of G12D in cancer group}}{\text{risk of G12D in control group}}$$

relative risk = [1]

- (ii) Discuss whether conducting screening tests to detect the G12D mutation is an effective way to screen for colorectal cancer.

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The *KRAS* oncogene, with G12D mutation, can be detected in stool samples using a technique called droplet digital Polymerase Chain Reaction (ddPCR).

ddPCR partitions DNA samples into thousands of individual droplets within which DNA samples are amplified by PCR. Fluorescent-labelled probes specific to the *KRAS* oncogene are added after which the fluorescence is measured in each droplet.

The number of droplets containing the fluorescent signal indicates the amount of *KRAS* oncogene present in the sample. The method is highly sensitive, detecting even low levels of the *KRAS* oncogene.

- (e) (i) Suggest why stool samples are appropriate for the detection of *KRAS* oncogene.

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 [1]

- (ii) Describe how DNA samples in each droplet are amplified by PCR.

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 [3]

- (iii) Explain why gel electrophoresis after PCR would not allow detection of *KRAS* oncogene.

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 [1]

- (iv) Suggest an advantage of using ddPCR in cancer screening programmes.

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 [1]

- (f) Scientists investigated a drug called MiTMAB as a treatment for cancer. MiTMAB inhibits cytokinesis.

Fig. 1.4 shows drawings of cancer cells seen with an optical microscope from a:

- sample treated with MiTMAB
- control sample.

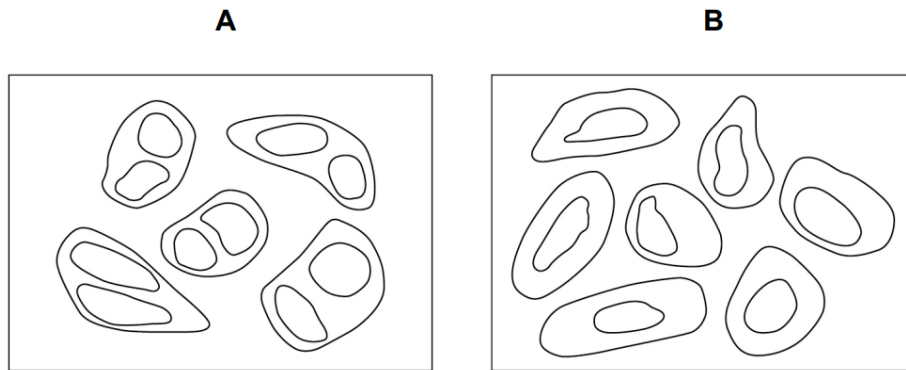


Fig. 1.4

The cells in drawing A can be identified as those treated with MiTMAB.

Explain why.

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..... [2]

(g) MiTMAB acts as a non-competitive inhibitor of an enzyme called dynamin.

When active, dynamin has two functions:

- it stimulates cytokinesis
- it inhibits cell death.

The scientists treated actively growing cultures of cancer cells with MiTMAB.

They incubated:

- one sample of 2500 cells without MiTMAB as a control
- eight samples, each with 2500 cells and a different concentration of MiTMAB.

After 72 hours, the scientists measured the number of cells in each sample.

Fig. 1.5 shows the scientists' results.

A negative value for proportion of control growth means that fewer than 2500 cells were counted after 72 hours.

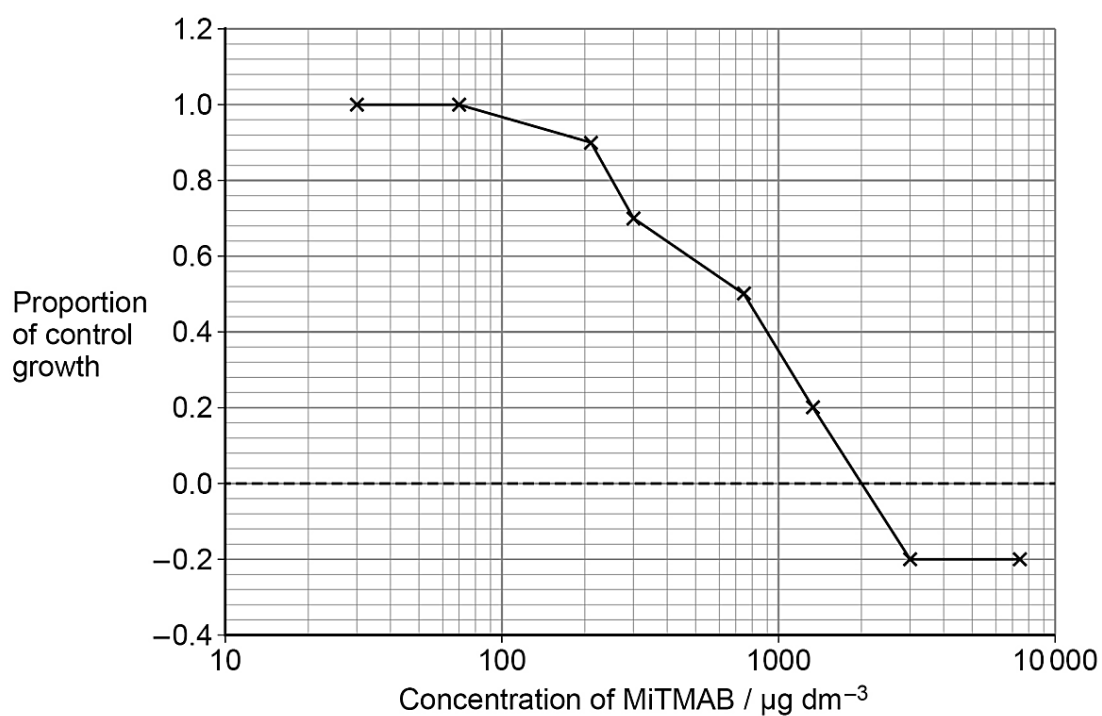


Fig. 1.5

- (i) Use all the information given to explain the results shown in Fig. 1.5.

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..... [3]

- (ii) 0.01 dm^3 of MiTMAB solution was added to the treated cells.

Calculate the increase in mass of MiTMAB added to the cells to reduce the cell growth from equal to the control to 0.0 of the control.

Show your working and give your answer to **two** significant figures.

mass = μg
[2]

[Total: 30]

- 2 *Mycobacterium tuberculosis* causes potentially fatal disease tuberculosis. With early diagnosis and the correct drug treatment, the pathogen can be eliminated from the body, especially if the infection has not progressed to active disease.

(a) Fig. 2.1 shows an electronmicrograph of *M. tuberculosis* cells.



Fig. 2.1

Identify **two** structural features that would distinguish *M. tuberculosis* from a typical eukaryotic cell.

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 [2]

- (b) During tuberculosis infection, alveolar macrophages engulf the pathogen. Some researchers are investigating the use of stem cells in treating lung tissue damaged by tuberculosis.

Explain what is meant by a stem cell and suggest **one** reason why stem cells may be useful in treating tuberculosis.

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 [3]

To help prevent the development and spread of drug resistance in *M. tuberculosis*, the World Health Organization recommends using a treatment known as combination antibiotic therapy.

This therapy involves two different types of drugs:

- a fast-acting drug such as isoniazid, which rapidly kills actively dividing *M. tuberculosis*
 - one or more longer-acting drugs such as rifampicin or pyrazinamide that eliminate any remaining pathogens, including those in a dormant state.
- (c) Suggest why using combination antibiotic therapy with two different types of drugs is more effective in preventing the development of drug resistance in *M. tuberculosis* than treatment using only one type of drug.

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..... [2]

Beside tuberculosis, other infectious diseases caused by eukaryotic pathogens, such as malaria, is also a major public health concern. Like *M. tuberculosis*, *Plasmodium falciparum* is capable of evolving drug resistance, complicating treatment strategies and eradication efforts.

P. falciparum begins its life cycle in a mosquito vector and continues its life cycle within the red blood cells of its human host. The cells of *P. falciparum* in this stage are known as trophozoites.

Fig. 2.2 is a photomicrograph of a blood smear (thin layer of cells). Some of the red blood cells contain trophozoites.

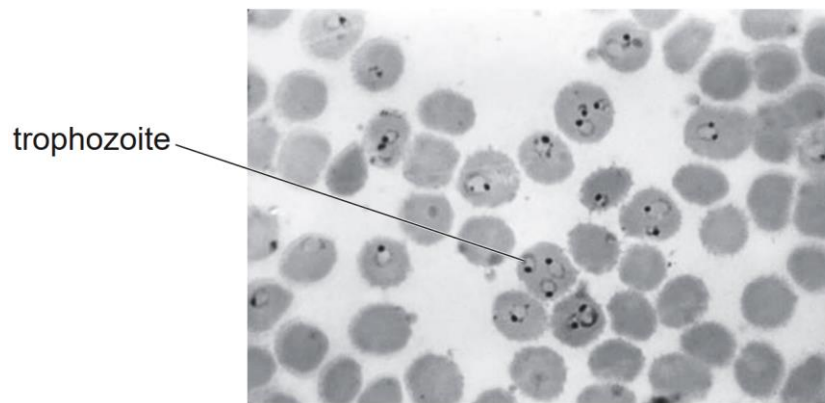


Fig. 2.2

Researchers have investigated how genetic mutations in *P. falciparum* affect the efficacy of artemisinin-based drugs. Artemisinin is a compound derived from the *Artemisia annua* plant and is commonly used to treat malaria. One such artemisinin-based drug is dihydroartemisinin (DHA).

In the following investigation, scientists measured the survival rate of trophozoites within red blood cells when exposed to two different concentrations of DHA.

Two different strains, **A** and **B** of *P. falciparum* were tested. For each strain, three different cultures were prepared:

- One with **no mutation in the *kelch13* gene** (serving as the control),
- One with the ***kelch13* F446I** mutation,
- One with the ***kelch13* C580Y** mutation.

These mutations in the *kelch13* gene have been linked to DHA resistance, making it important to study how they affect parasite survival and treatment outcomes.

Table 2.1 shows the six different cultures tested and the trophozoite survival rate for each culture.

Table 2.1

culture number	culture details	mean percentage survival rate of trophozoite	
		DHA concentration 20 nmol dm ⁻³	DHA concentration 700 nmol dm ⁻³
1	strain A no mutation	3.15	0.00
2	strain A , F446I mutation	26.00	0.73
3	strain A , C580Y mutation	33.08	0.91
4	strain B no mutation	2.86	0.00
5	strain B , F446I mutation	13.50	0.53
6	strain B , C580Y mutation	17.50	0.63

(d) State the main conclusions that can be drawn from the results shown in Table 2.1.

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..... [2]

[Total: 9]

- 3 Corals are simple marine animals and usually exist in colonies of thousands of individuals. Corals absorb calcium carbonate from the sea to build their skeletons, which help to form large coral reefs. Coral reefs are some of the most diverse ecosystems in the world.

Coral reef ecosystems are severely threatened. One of the threats include global warming, which can result in ocean warming, stressing corals and leading to coral bleaching and possible death.

- (a) Fig. 3.1 shows the changes in average global temperature and the changes in CO₂ concentration from Year 1400 to Year 2000.

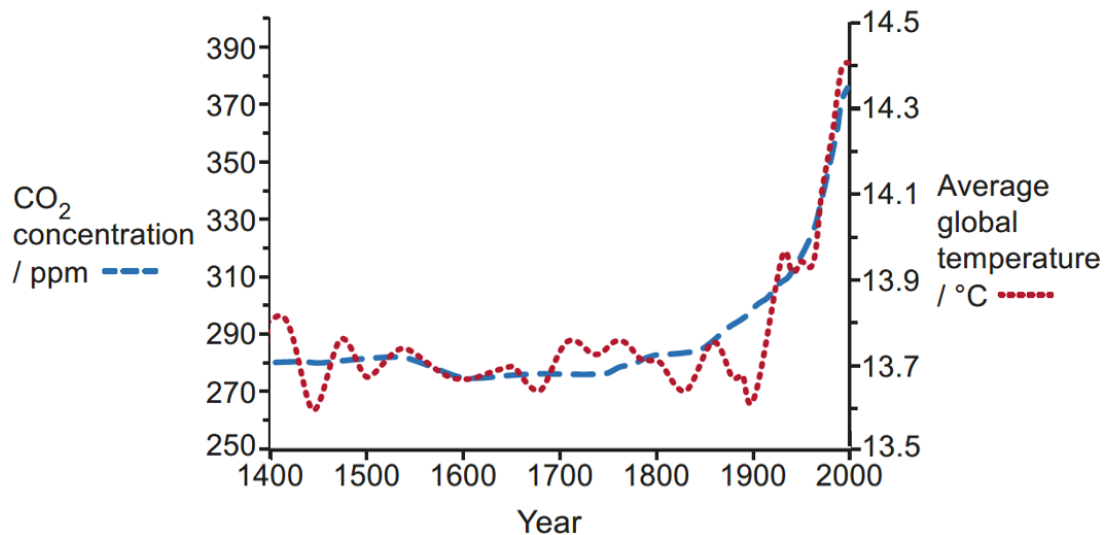


Fig. 3.1

- (i) Using Fig. 3.1 and your own knowledge, explain how global warming occurred.

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..... [4]

- (ii) Suggest **one** reason why some corals in natural reef systems might still survive despite ocean warming.

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..... [1]

- (b) The crown-of-thorns starfish (COTS) is also one of the main causes of the decline of the world's coral reefs.

Marine biologists used a choice chamber to investigate the effects of flashing and constant light on the behaviour of COTS. Table 3.1 shows their results as they presented them. The P values show results from a statistical test.

Table 3.1

behaviour of COTS	type of light used in choice chamber	
	flashing	constant
COTS moving towards the stimulus	22	12
COTS moving away from the stimulus	28	38
P value	0.69	0.02

- (i) The natural habitat of COTS is coral reefs of tropical oceans.

Suggest **two** factors that should be kept constant in the choice chambers so that COTS display normal behaviour.

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 [1]

- (ii) Evaluate the claim that either type of light could be used to cause COTS to move away from coral reefs.

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 [3]

- (iii) One of the reasons COTS can destroy coral reefs in a short time is because COTS move quickly, allowing them to move from one reef to another.

Table 3.2 shows the maximum speeds recorded of COTS in constant light.

Table 3.2

response to light	maximum speed / mm min ⁻¹
COTS moving towards constant light	259
COTS moving away from constant light	564

Calculate the shortest time one COTS would take to move up a coral reef from 66 m under water to 18 m under water in hours of daylight.

Show your working. Give your answer to the nearest hour.

time = hours
[2]

[Total: 11]

Section B

Answer **one** question in this section.

Write your answers to this question on the separate Answer Booklet provided.

Your answers should be illustrated by large, clearly labelled diagrams, where appropriate.

Your answers must be in continuous prose, where appropriate.

Your answers must be set out in parts **(a)** and **(b)**, as indicated in the question.

- 4 (a)** The accuracy of DNA replication is critical to maintaining genomic integrity across cell divisions. Multiple molecular mechanisms operate during replication to ensure fidelity, yet errors still occur and can contribute to variation, adaptation, or disease.

Describe the roles of the key proteins and enzymes involved in DNA replication and explain how errors during replication can give rise to different mutations. [13]

- (b)** Bacteria are prokaryotes that do not undergo sexual reproduction but undergo binary fission to give genetically identical daughter cells. However, genetic variation exists in bacterial populations.

Describe how genetic variation arise in bacterial populations. [12]

[Total: 25]

- 5 (a)** The reproductive cycles of enveloped viruses involve intricate interactions with host membranes and often include mechanisms that promote rapid evolution.

Describe the roles of the key proteins and enzymes involved in the reproductive cycle of influenza virus and explain how variation in its viral genome arises. [13]

- (b)** Bacteria live in environments where the supply of nutrients may change rapidly. To survive, they regulate the expression of certain genes so that enzymes are produced only when required.

Two examples of gene regulation in bacteria are the *lac* operon and the *trp* operon in *E. coli*.

Discuss how these two operons regulate gene expression when there are high levels of lactose and tryptophan, and explain the advantages of such regulation to the bacteria. [12]

[Total: 25]

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