THE 19TH INTERNATIONAL BIOLOGY OLYMPIAD

13TH – 20TH JULY, 2008
MUMBAI, INDIA

REPORT

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INTRODUCTION

The 19th International Biology Olympiad (IBO) was held in Mumbai, India from July 13 to July 20, 2008. It was an honour for Homi Bhabha Centre for Science Education (HBCSE), Tata Institute of Fundamental Research (TIFR) to have been the organizing institution of the 19th IBO. Something like 550 persons were involved in this event – 220 students and 178 leaders and observers, 55 student guides and about 100 organizers. That an event of this scale came to a successful conclusion is indeed a matter of great satisfaction to all those involved in it.

The hosting of 19th IBO by our country was made possible because of the generous funding of three Departments/Ministries of the Government of India: Department of Atomic Energy (DAE), Department of Science & Technology (DST) and Ministry of Human Resource Development (MHRD). I express my grateful thanks to Dr. Anil Kakodkar, Chairman, Atomic Energy Commission and Secretary DAE, Dr. P. Rama Rao, Chairman, Board of Research in Nuclear Sciences (DAE), Dr. T. Ramasami, Secretary, DST and Shri Arun Kumar Rath, Secretary, MHRD not only for their financial support but also for their keen interest in the event and encouragement. I should also like to sincerely thank the senior officials of these sponsoring departments : Dr. C.V. Ananda Bose and Dr. P. Mukherjee of DAE, Dr. Markandeya of BRNS (DAE), Dr. Rao Aiyagari of DST and Shri S. Khuntia of MHRD. I record my gratitude to Prof. S. Bhattacharya, former Director TIFR and Prof. Mustansir Barma, current Director TIFR for their advice and support and also for ensuring all possible assistance from TIFR main campus whenever we turned to them for help.

The National Academic Committee (NAC), chaired by the eminent biologist Dr. S.K. Apte of Bhabha Atomic Research Centre, consisting of some of the leading biologists and biology educationists of the country, played a decisive role in ensuring the academic standards of 19th IBO. It was a pleasure hosting a large number of meetings at HBCSE, wherein these people put their heads together and designed excellent theoretical and experimental tasks for the event. Dr. Rekha Vartak, In-charge Biology Olympiad Cell of HBCSE and the Academic Coordinator of 19th IBO, carried the entire event on her shoulders as it were, ably assisted as she was by Ms. Anupama Ronad as also a number of other younger members of the biology cell. Prof. Anindya Sinha of National Institute of Advanced Studies, Bangalore did a superb job as the Jury Chair of 19th IBO. It is a pleasure to record my deep gratitude to the members of NAC for the wonderful job carried out by them.

For HBCSE, the 19th IBO was an unforgettable exhilarating experience that reminded us of a similar event hosted by HBCSE (the 33rd International Chemistry Olympiad) seven years ago in 2001. The entire Centre rose as one to discharge the great responsibility involved in organizing this mega event. I should like to express my sincere appreciation of all the members of HBCSE staff headed by Ms. M.D. Gaitonde for the tremendous spirit and solidarity they showed throughout. But above all it is the participants, especially our guests from abroad who made us feel so good. Throughout the event and even before it, it was the unstinted cooperation of leaders as well as students from different countries that made the 19th IBO happen the way it did. Thank you all.

Prof. Arvind Kumar
Organizing Chair, 19th IBO

October 2008.

The draft outline of the report was ready before Prof. Arvind Kumar, former Centre Director, HBCSE, retired on October 31, 2008. HBCSE is pleased to bring out this final report and records its appreciation of all those who made the event a success.

June 2009.

Prof. H. C. Pradhan
Centre Director, HBCSE

ABOUT THE INTERNATIONAL BIOLOGY OLYMPIAD (IBO)

The International Biology Olympiad is a unique competition for students at pre-university level. The international biological competition between Czechoslovakia and Poland from 1985 to 1989 provided ground for the future IBO. Positive experience during international olympiads in other natural sciences and mathematics led to the idea of starting an international biology olympiad. So UNESCO asked the former Czechoslovakia to take the initiative.

Six interested countries (Belgium, Bulgaria, Czechoslovakia, German Democratic Republic, Poland and the Soviet Union) founded the IBO in 1989 (Prague and Brno) and participated in the first IBO which was held in Olomouc, Czechoslovakia in July 1990. Notwithstanding some initial difficulties, this olympiad was a great success and it was decided to continue with the IBO. In subsequent olympiads the number of participating countries increased rapidly and the strength now stands at 55 participating countries.

The unique feature of this competition lies in two things: one is its strong experimental component along with the theoretical and secondly the exceptionally high quality of the questions that test the students' analytical abilities, reasoning and problem solving capacities.

The competition is a mode of bringing together highly talented students across the globe, allowing bonding amongst them through friendship and exposing them to varied cultures. It is also a platform where teachers, scientists and educationists share the same platform and exchange ideas about curricula which in turn could help improve Biology Education the world-over.

Fifty five countries from all over the world participated in the contest of the 19th IBO held in Mumbai while two countries participated as observing delegations. Each contesting country sent four students who were the winners of the respective national Olympiad and two mentors. Some countries sent additional observers who could help them in the major task of translation of the text. Also, the two future host countries namely Japan and Korea sent additional observers to get familiar with the various organizational aspects of the event.

BIOLOGY OLYMPIAD ACTIVITY IN INDIA

India's participation in Science Olympiad is fairly recent though it has been participating in the International Mathematical Olympiad since 1989. In 1997-98, Homi Bhabha Centre for Science Education (HBCSE) (a national Centre of Tata Institute of Fundamental Research, Mumbai) and the Indian Association of Physics Teachers (IAPT) took initiative in starting the Physics Olympiad Programme. A year later HBCSE extended the programme to chemistry and biology. Indian participation at the International Biology Olympiad started in the year 2000. IAPT came forward to offer its wide network for help in organizing the chemistry and biology examinations also. These initiatives received strong support and encouragement from the Department of Atomic Energy (DAE), the Department of Science and Technology (DST) and the Ministry of Human Resource Development (MHRD) of the Government of India. The good performance of the Indian teams right in the initial years of participation helped in the consolidation of the programme.

The National Olympiad Programme in physics, chemistry and biology is overseen by a National Steering Committee constituted by DAE under its Board of Research in Nuclear Sciences (BRNS).

The programme is financially supported by BRNS (DAE), DST and MHRD. Currently, the selection of the Indian team for the International Biology Olympiad involves three stages:

Stage I: National Standard Examination in Biology (NSEB)
The first screening test consists of multiple-choice questions in areas related to general biology. Any student from the higher secondary science stream can appear for the examination. Administrative help for this examination is provided by the Indian Association of Physics Teachers (IAPT) and Indian Association of Chemistry Teachers (IACT). For the last couple of years the test paper for this examination is set by the newly-formed Indian Association of Teachers in Biological Sciences (IATBS). The examination is held at a large number of centres throughout the country and about 10,000 students appear for this examination. This number is likely to grow substantially as the science Olympiad activity becomes more widely known in the country.

Stage II: Indian National Biology Olympiad (INBO)
The top 300 students selected on the basis of their performance in the NSEB are eligible to appear for INBO that is organized at about fifteen centres across the country. The INBO examination is also a theoretical examination of a higher difficulty level than the first stage exam. Patterned along the lines of IBO, the INBO paper consists of both A-type as well as B-type questions.

Stage III: Orientation cum Selection Camp (OCSC) at HBCSE
The top 35 students selected on the basis of their performance in the INBO attend an Orientation cum Selection Camp at HBCSE. The total duration of this camp is about one week, in accordance with the IBO regulations. The top four students who represent India at the International Biology Olympiad are selected based on their performance in the theoretical and experimental tests given during the camp. For the year 2008, the OCSC could not be held at HBCSE since it was the organizing institution for the19th IBO. This responsibility was taken over by the Indian Association of Teachers in Biological Sciences (IATBS). Dr. P. G. Kale, Secretary of this organization was the Academic Co-ordinator for the OCSC camp for 2008. The venue of the camp was R. Jhunjhunwala College, Ghatkopar, Mumbai.

PERFORMANCE OF INDIAN TEAMS AT IBOS

Despite a late start, the performance of the Indian teams at the IBO has been creditable. The first Indian team that participated in the IBO at Antalya, Turkey in the year 2000 received 2 silver and 2 bronze medals. In the year 2007, at the 18th IBO held at Saskatoon, Canada, the Indian team received 1 gold and 3 silver medals. At the 19th IBO at Mumbai, India in 2008, the team received 1 gold, 2 silver and 1 bronze medals. The Indian team for the 19th IBO was led by Dr. P. G. Kale, Reader, Department of Biological Sciences, Jhunjhunwala College, Mumbai and Dr. Sasikumar Menon, Assistant Director, Therapeutic drug Monitoring Lab, Mumbai.

THE 19TH INTERNATIONAL BIOLOGY OLYMPIAD

BACKGROUND:

In the year 2003, at the 13th International Biology Olympiad at Minsk, Belarus, India offered to host the IBO, during one of the forthcoming years. The IBO committee suggested that the slots available were either 2008 or 2010. In the year 2004 in Australia it was suggested that India would host the 19th International Biology Olympiad in the year 2008. In due course, the Govt. of India formally accepted the proposal to host the 19th IBO. Homi Bhabha Centre for Science Education, (HBCSE), TIFR, was designated as the organizing institution for the event. The venue selected for the event was Mumbai. The decision to host the 19th International Biology Olympiad by the Government of India was welcomed by all the participating countries.

FUNDING OF THE 19TH INTERNATIONAL BIOLOGY OLYMPIAD:

The 19th International Biology Olympiad was funded by the Board of Research in Nuclear Sciences, Department of Atomic Energy (BRNS, DAE), Department of Science & Technology (DST) and Ministry of Human Resource Development (MHRD), of the Government of India.

ORGANIZING COMMITTEE:

Hosting an International Olympiad is an academic as well as an organizational challenge.
To meet the organizational demands, an Organizing committee, with Prof. Arvind Kumar, Centre Director HBCSE, as chairperson, was constituted. The core members of this committee were, Prof H. C. Pradhan, Prof Vijay Singh, Dr Rekha Vartak, and Ms Madhavi Gaitonde. Several sub-committees were formed to formulate the details of the various aspects of the program, and ensure speedy & smooth implementation of various administrative responsibilities. Initiation of the organizational tasks was done about a year prior to the actual event. However the work gained momentum as the actual IBO drew closer.

NATIONAL ACADEMIC COMMITTEE:

A National Academic Committee (NAC) was constituted for carrying out the academic responsibility by devising the theoretical and experimental tests for the competition.
Dr S. K. Apte, eminent biologist from the Bhabha Atomic Research Centre (BARC) chaired the NAC. Dr Rekha Vartak, Head of the Biology Cell at HBCSE, was the Academic Coordinator of the 19th IBO. The committee held its first meeting in April 2007. Throughout the year, the committee met every month to generate a question bank and eventually after thorough deliberations, the final theoretical paper was set. The Questions sent to the host country by the participating countries were also screened before including some of them in the final paper. The NAC also formulated the experimental tests in the 4 lab areas: 1) Plant Anatomy and Physiology 2) Animal Anatomy and Physiology 3) Biochemistry and 4) Animal Behaviour.
A Scientific task committee comprising of the members of the Biology cell of HBCSE, carried out the standardization, procurement & collection of the materials and biological samples and other background tasks involved in conducting the lab tests for 220 students.
Prof Anindya Sinha of National Institute of Advanced Studies, NIAS, Bangalore was the jury chairperson, who presented the theoretical and experimental test papers before the International jury. Dr. Olga Waksmann and Dr. Alexander Friedmann from Germany were invited a week prior to the event so as to carry out the Russian translation of the test papers and also help in computer

related work of the 19th IBO jury sessions.

ABOUT THE EXAMINATION:

Since the Homi Bhabha Centre for Science Education was the host organization and all standardizations were conducted here, it was decided that the venue for the test would be HBCSE. About 10 rooms- Labs, seminar & lecture rooms as well as the library were converted into class-room set-ups for conducting these tests for 220 students. All the rooms and labs were air-conditioned to provide a comfortable environment for the foreign students coming from across the globe. Maintaining uniformity in terms of workspace and environment was of prime concern in the arrangements done for the tests.

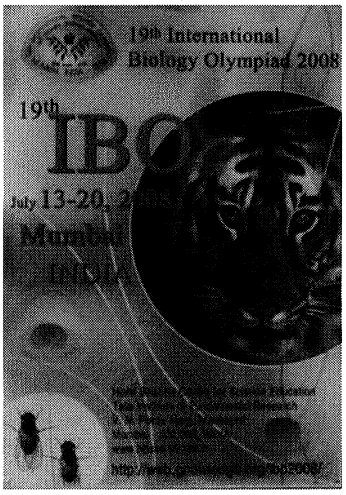
The major purchases done for the lab, apart from the glassware and plastic ware (mainly of Borosil and Tarson make) were Olympus binocular compound microscopes, Kanad Vidyut colorimeters, and Erba Biohit micropipettes. Additionally about 65 Laptops were rented for the students to view the animal behaviour video files, as a part of the tests. A major procurement for the lab tests was the foam fibre models of animal skeletons and assembling of the same was another huge task. The lab tests were of one hour duration each. The 220 students were split into four batches of 55 each and they appeared for the lab tests in rotation over four hours.

Keeping in the mind the requirement of quick overnight photocopying after the Jury sessions, a total of 6 photocopying machines were procured, by way of purchasing 3 high end machines (30 cpm with compilation facility) and renting 3 machines (15 cpm). The theory test was a four and a half hour test comprising of part A and part B.
Evaluation of the answer scripts was carried out by the evaluation team at the venue of the exam itself.

THE LOGO OF THE 19TH IBO:

The logo of the 19th IBO represented the flora and fauna of India:
the leaf of the native Neem (*Azadirachta indica*) tree and
the paw of the tiger (*Panthera tigris*).
The text in the logo was written in the English as well as the Devanagri script used to write in Hindi which is the national language of India.

THE POSTER OF THE 19TH IBO:



A poster to publicize the 19th IBO was prepared and distributed to the participating countries a year prior to the event. The poster had a representation of the genetically popular fly ie the *Drosophila* as well as the face of a tiger with the feathers of the national bird of India, the peacock in the background. This poster was also distributed to various colleges in India since it gave information regarding the 19th IBO, the venue and the website.

THE WEBSITE OF THE 19TH IBO:

The official website for the 19th IBO, 'http://web.gnowledge.org/ibo2008/' was created by July 2007 and was continuously kept updated by Mr. Manoj Nair of HBCSE. This website facilitated the participating countries with online registrations of students, leaders observers etc. and also conveyed the latest updates to them. It had hyperlinks to the official IBO Website, various useful information regarding travel helps, guides, and maps etc.
The website also hosted the event photographs, final results, and the official Newsletter for IBO, named 'Paw Prints'.
A dedicated email id (iboindia@hbcse.tifr.res.in) allowed communication between the participating teams and the organizers.

19TH IBO NEWSLETTER:

The fun-filled and lively newsletter for the 19th IBO was titled 'Paw Prints'. A total of seven issues of the newsletter were brought out and distributed among the jury members and students at breakfast time. The issues gave various kinds of information – about the flora and fauna in India, Mumbai and HBCSE, interesting local information, anecdotes and historic events related to both biology and otherwise. It also made the participants familiar with a few words and phrases in the official language of India which is Hindi. It carried views and moods of the student participants and leaders. The interesting crosswords and riddles were a good breather every morning for the participants from the hectic schedule of the event. The issues are good keepsakes of the event.

ACCOMMODATION OF THE PARTICIPANTS:

The student participants and mentors were accommodated at two different hotels about 1 km.apart. No communication among them was permitted till the examinations were over. After considering the various options, the hotel Intercontinental the Grand located at a distance of about one km.from the International airport at Sahar, Mumbai was chosen for the accommodation of leaders and

observers. All jury sessions were held at the Banquet Hall of this hotel. 65 computers were arranged in the jury rooms and three projection screens were also set up.

The participating students alongwith their team guides were accommodated at the hotel Vits at Sahar, Mumbai. Air conditioned buses were arranged for the travel of students from the hotel to the examination venue as well as for all excursions of participants.
Close proximity to the airport was considered while selecting the accommodation so as to avoid problems of airport tranfers in case of heavy rains. Both the hotels also accommodated the delegation members who arrived early or departed later than the actual dates of the IBO.

THE EVENT:

The 19th IBO was held from the 13th to 20th July, 2008. All 55 member teams who registered online could actually participate in the event. Armenia and Sri Lanka were the two observing countries. Thus, a total of 220 students and 178 jury members and observers participated. Two countries who conveyed that they could not participate due to administrative problems at their end were Peru and Leichtenstein. Three other countries who were to attend as observers – Yemen, Chile and Bangladesh also could not attend.

The delegation members were received at the Sahar International Airport at Mumbai on the 13th of July, 2008 by the student & jury guides and were taken to their respective hotels. Round the clock registration desks were set up at both hotels. The team registration fee of INR 60,000/- and Observer fee of INR 60,000/- were collected at the registration desk of the jury hotel. Since Japan and Korea were to host the consecutive IBOs in the year 2009 and 2010, they were allowed to bring along two observers at no extra fee. Registration bags consisting of a specially printed writing pad, brochures about the host organization and tourist information about Mumbai, IBO booklet, T-shirt, cap, pouch containing writing materials, a scientific calculator and a gemstone-painted ethnic Indian diary as a gift were distributed to every participant. Additionally, students were given their respective lab coats and safety goggles to be used during the lab tests.

The Opening Ceremony was held in the Banquet Hall of Intercontinental the Grand on the morning of 14th July, 2008. The programme started with the lighting of the traditional Indian lamp by Prof. Mustansir Barma, Director, Tata Institute of Fundamental Research (TIFR) which is the parent institute of HBCSE. Most teams were traditionally dressed for the event. Prof. Vijay Singh, National Co-ordinator of Science Olympiads in India conducted the proceedings and introduced the teams with interesting information about every country. As they were introduced, every team came on stage headed by their respective team guide carrying the flag. The flags were then lined up near the backdrop of the stage. Prof. Arvind Kumar, Chairperson, Organizing Committee, Prof. Mustansir Barma and Dr. Hans Morelis, President, IBO Co-ordinators were speakers during the ceremony. Dr. Rekha Vartak proposed the vote of thanks. The Oath of Fair Play was taken by Dr. Eckhard Lucius on behalf of the jury members and by a student from the Indian team (Siddharth Iyengar) on behalf of the student participants. The programme ended with a classical Kathak performance by Nandita Puri and her group. The Indian classical music accompanying the performance was headed by Pandit Kalinath Mishra at the tabla.

The Opening Ceremony was followed by the jury session for discussing the experimental test while the students were taken for lab visit to HBCSE. While the students appeared for the lab tests on the 15th of July, the jury members and observers were taken on a day-long city tour around Mumbai which included places of tourist interes such as Mani Bhavan, Marine Drive, Flora Fountain and so on. A meeting of the students with the jury was arranged at the Jury Hotel at the end of the day.

The students were taken for a day of relaxation to the amusement park, Esselworld and to Water Kingdom on the 16th of July. The jury session to discuss the theoretical test was held on this day. The students appeared for the theoretical test on the 17th of July at HBCSE. On the completion of the test, the students met their team leaders at HBCSE where a Village Haat (Fair) was arranged. The Haat had a set up of Indian villages and representative displays and activities from various Indian states such as the puppet show and dance from Rajasthan, application of henna on the palms, making of lacquer bangles were a part of this event. Several stalls selling ethnic wares were also put up so that the participants could choose to buy from a large collection of items, under one roof. A jury session for viewing the experimental answer scripts of students was held on the night of 17th July.

The 18th July was a day when the students and jury were all taken for an enriching visit to the Nehru Centre, Nehru Planetarium and the Nehru Science Centre while the organizers were busy with the evaluation of theory answer scripts and preparation of score slips. A jury meeting to view the theory answer scripts as well as the score slips of their students as also to arbitrate the same was held at the jury hotel post dinner. The Co-ordinators meeting was also held on this same night.

A final jury meeting was held on the morning of 19th July where the statistics was presented to the jury by the statistician Ms. Leena Kulkarni and the final medal cut-offs were decided on the basis of the t-scores. After this meeting, the jury members interested in shopping were taken to Colaba and World Trade Centre.

The Closing Ceremony was held from 3:30 pm onwards on the 19th July. This ceremony was held at the Nehru Centre at Worli, Mumbai. The dignitaries present were Dr. T. Ramasami, Secretary, Department of Science and Technology and Dr. Anil Kakodkar, Chairman, Atomic Energy Commission. The Ceremony started with 'An Evening of Indian Folk Dances' by the students of Dr. Kanak Rele from the Nalanda Dance Institute. Prof. Vijay Singh was the master of ceremonies for the programme. Dr. Rekha Vartak, Academic Co-ordinator gave an overview of the 19th IBO. Dr. S. K. Apte, Chairman of National Academic Committee of 19th IBO, Dr. T. Ramasami, Dr. Anil Kakodkar and Dr. Hans Morelis addressed the gathering. Dr. Tomas Soukup, Secretary of the IBO Co-ordinating Centre, handed over a cup to Dr. Arvind Kumar as a memento to be retained by the organizers. The presentation of medals was organized by Ms. Anupama Ronad. 23 gold medals, 47 silver medals and 68 bronze medals and certificates were given away by the members of the National Academic Committee. The medals to the students who topped the competition were given away by Dr. Ramasami and Dr. Anil Kakodkar. The IBO Trophy was then handed over by Prof. Arvind Kumar, Chairperson of 19th IBO Organizing Committee, India to Dr. Hideo Mohri, Chairperson of 20th IBO Organizing Committee, Japan. Dr. Hideo Mohri invited the participating countries to the 20th IBO to be held in Tsukuba, Japan in July, 2009. Certificates of participation were distributed to every participating member of all delegations. The Closing Ceremony ended with a vote of thanks by Prof. H. C. Pradhan, Dean of Faculty, HBCSE. A Closing Dinner was arranged after the Ceremony at The Hyatt. Departure of most teams on the 20th of July, 2008 marked the end of the 19th IBO.

SPEECHES

Dr T Ramasami
Secretary, Department of Science and Technology
Government of India
Guest of Honour at the Closing Ceremony, 19th International Biology Olympiad

Distinguished dignitaries, participants of this wonderful programme, the student guides, representatives from the media and my very dear students, a very good evening to you all.

It was said that I was a guest of honour, but truly the guests of honour are the participants and the people who have added meaning to this programme. I am only a representative of the Government who has a responsibility to connect resources with useful causes. Dr. Vartak, you have done a great job for us. Thank you very much.

Of course, as my friends were describing how difficult it had been to set questions and pass the jury. I said, look ultimately the students have to answer and I'm told that you have done extremely well and I think some time probably in future, you will be the question setters or the jury. I look upon this as a special occasion. Olympiads are truly a movement, essentially to unite cultures and create a seamless world – a seamless world where the boundaries of nations disappear. There have been occasions on which I used to argue in my younger days that India is not a country, it's a civilization and I believe what we have seen today in the Olympiad is indeed a kind of global civilization in which 55 countries have participated. Incidentally, for chemists, 55 is a magic number and I believe there are about 220 student participants and 110 teacher leaders! See it is essentially a convergence of diverse cultures here and as for the students, it's the cream of the cream of the cream. Therefore, all the hard work that the National Academic Committee did to set questions I think, you have made it a light job by performing so well. I am sure this occasion is a cause for celebration. I don't think it is an occasion where we only talk about winning medals. It is a celebration of learning, a celebration of unity and friendship.

And it turns out that if you come to India, you have to hear a little bit of cricket even if you don't like it! There was a cricketer by the name W. G. Grace, a fantastic player in England. But in one of those matches in one of the small tournaments, he was out for zero. And the umpire gave him out. He refused to go out and he said, "look here, all these people out there have come to see me play and not to see you give me out. So I will not go out". All of you are here today to receive those medals and therefore, I am not going to stand here for a very long time.

No doubt, the Government of India is seized of the responsibility of making science education attractive so that the talented students are motivated into research and I think a programme of this kind is one such measure and I think on this occasion, we should thank the Homi Bhabha for Science Education that they have organized it and they have done a great job. I thank them on behalf of all of you. Thank you very much.

Dr Anil Kakodkar
Chairman, Atomic Energy Commission, and Secretary, Department of Atomic Energy
Chief Guest at the Closing Ceremony, 19th International Biology Olympiad

Prof. Arvind Kumar, Dr. Ramasami, Prof. Mustansir Barma, distinguished members of the National Academic Committee, distinguished members of the jury, all the participating teams, student guides, team managers, my colleagues from various institutions across the country who are associated with the Biology Olympiad and friends,

I realize that just as long speeches before the distribution of medals were raising tension, now that the medals have been announced, for all of you who have won the medals, prolonged speeches will do much the same even more, so I am going to be very brief!

I am here essentially to thank the Homi Bhabha Centre for Science Education, very ably led by Prof. Arvind Kumar for the excellent efforts that they have been taking, not only in the matter of organizing the 19th International Biology Olympiad but also in all aspects of science education particularly at the pre-university and the undergraduate level. Being very closely familiar with the programmes and the work of the institution, I have nothing else but admiration for the work that the Homi Bhabha Centre for Science Education has been doing and it was very gratifying to hear from all of you, several speakers who one after another spoke to recall and testify the level of excellence that the Homi Bhabha Centre for Science Education has displayed in organizing a programme of this kind.

The Department of Atomic Energy along with of course all the other Government departments interested in science and education and in this case, the Department of Science and Technology and the Ministry of Human Resource Development have been very conscious about the need to create interest among the younger community in science. An International Olympiad like the International Biology Olympiad being hosted here is one very important activity or part of a programme in creating such interest, certainly for us in India but I am equally conscious that this is true all over the world.

I think it would be no exaggeration to say that science has had a very important role in our evolution as human beings, in our ability to understand things around us, in our ability to use that understanding in enhancing the quality of life and, to the extent that we can, minimize human suffering. And I believe science would continue to contribute so in the future. . It is from this perspective that I think that the greater the attraction among young talented students to take a career in science, greater would be our progress in realizing the beneficial role of science for humanity.

An Olympiad, as has been said, is a meeting of cultures, an opportunity for developing new bonds. It is a competition no doubt, but a healthy competition aimed at developing universal friendships and promoting universal brotherhood.

And I think any science Olympiad has an additional dimension in terms of mobilizing the younger community of this world in making our world a better place and I only wish that the Olympiad movement, whether it is in biology or any other subject of science, would

make a great contribution towards ensuring that the problems that the humanity faces today are better understood and better resolved.

I wish to once again congratulate all those who have won the medals but I want to equally congratulate all others who have participated in this movement called 'International Biology Olympiad'.

As you get back home, I'm sure you will carry with you the spirit of the International Biology Olympiad, you will carry with you fond memories about new friends you have made here, fond memories of India and also a bit of resolve to dedicate yourself to the larger cause that I just mentioned. All the best to you! Thank you!

(*The text above is based on audio recordings of the speeches.*)

ORGANIZATION

Organizing Chair 19th IBO: Prof. Arvind Kumar, Centre Director, HBCSE

Members of Core Organizing Committee:

Prof. H. C. Pradhan, Dean, HBCSE
Prof. Vijay Singh, National Co-ordinator, Science Olympiads
Dr. Rekha Vartak, Head, Biology Olympiad Cell, HBCSE
Ms. Madhavi Gaitonde, Head, Administration, HBCSE

The National Academic Committee:

Dr. S. K. Apte, BARC, Mumbai **Chairperson**
Dr. Rekha Vartak, HBCSE, Mumbai **Academic Co-ordinator**
Prof. Anindya Sinha, NIAS, Bangalore **Jury Chairperson**
Prof. Madan Mohan Chaturvedi, Delhi University
Prof. Bharat Chatoo, MS University, Baroda
Prof. N. S. Punekar, IIT Mumbai
Dr. P. V. Balaji, IIT Mumbai
Dr. Bimalendu B. Nath, University of Pune
Dr. Krishanu Ray, TIFR, Mumbai
Prof. Santosh K. Kar, JNU Delhi
Prof. Rabindranath Nayak, IISER, Bhubaneshwar
Dr. Ansuman Chattopadhyay, Shanti Niketan, Kolkata
Dr. Ajit Dange, Wilson College, Mumbai
Prof. Vijay Singh, HBCSE, Mumbai
Mr. V. G. Gambhir, HBCSE, Mumbai

The Scientific Task Committee:
From Biology Cell, HBCSE, Mumbai

Dr. Rekha Vartak

Ms. Anupama Ronad

Ms. Sandhya Kasivishwanathan

Ms. Swati Katre

Mr. Vikrant Ghanekar

Computing for Experimental tasks and Website maintenance:

Mr. Manoj Nair, HBCSE, Mumbai

The various sub committees and the core members of each sub-committee were as follows:

1. Registration at Jury Hotel: Ms. Sumana Amin, Ms. Smita Burli and Mr. Gajanan Mestry.
2. Registration materials: Dr. Sugra Chunawala, Dr. Rekha Vartak, Ms. Madhavi Gaitonde, Mr. C. S. Pawar, Mr. A. D. Ghaisas and Ms. Anupama Ronad.
3. Registration at Students' Hotel: Ms. M. M. Mastakar, Ms. V. N. Purohit, Ms. Sandhya Rajashekar, Ms. Smita Patil and Mr. V. D. Lale.
4. Arrangements at Student hotel: Ms. M. M. Mastakar, Ms. Sucheta Penkar and Ms. Swapnila Modak.
5. Accounts: Mr. V. P. Raul, Mr. Mahesh Bamne, Ms. Manisha Deshmukh and Mr. D. R. Mhapsekar.
6. Airport transfers: Mr. U. V. Shenoy, Mr. A. W. Joshi, Mr. Manish Thakur, Mr. K. T. Hambir, Mr. S. L. Rasam, Mr. J. J. Tambe, Mr. D. R. Mhapsekar and student as well as jury guides.
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8. Secretariat: Prof. Arvind Kumar, Ms. Sumana Amin, Dr. Rekha Vartak and Ms. Anupama Ronad
9. Procurement of various licences: Mr. A. W. Joshi
10. Hotel accommodation: Prof. Arvind Kumar, Ms. Madhavi Gaitonde, Ms. Smita Burli and Ms. Sumana Amin.
11. Food Arrangements: Ms. Madhavi Gaitonde, Mr. D. D. Pednekar and Mr. C. S. Pawar.
12. Transport: Mr. U. V. Shenoy and Mr. A. W. Joshi.
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14. Stage and jury meeting room arrangements: Mr. N. Y. Tribhuwan, Mr. V. C. Jacob, Mr. H. H. Rane, Mr.B. S. Bhagit, Mr. V. P. Ahire and personnel from Grey Technologies Ltd.

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18. Posters, flags and banners: Mr. S. D. Pardeshi.
19. Invigilation: Mr. R. S. Korgaonkar, Mrs. M. M. Mastakar, Mr. K. T. Hambir, Mr. P. K. Nawale, Mr. V. C. Sonawane, Ms. Rashmi Shrotri, Mr. A. D. Ghaisas, Dr. K. K. Mishra, Praveen Patha Ms. Indrani Sen, Mr. Shirish Pathare, Ms. Swapnila Modak, Ms. Manisha Deshmukh, National Academic Committee members and the project staff of HBCSE Praveen Pathak
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9. Denmark
10. Estonia
11. Finland
12. France
13. Germany
14. Greece
15. Indonesia
16. Ireland
17. Japan
18. Korea
19. Latvia
20. Lithuania
21. Moldova
22. Netherlands
23. New Zealand
24. Pakistan
25. Poland
26. Romania
27. Russia
28. Singapore
29. Slovakia
30. Slovenia
31. Spain
32. Sweden
33. Switzerland
34. Thailand
35. Turkey
36. Ukraine
37. United Kingdom
38. United States of America

THE OPENING CEREMONY
14TH JULY, 2008 (9:30 AM – 1:00 PM)
AT
INTERCONTINENTAL THE GRAND

9:30 am	Entry of the IBO cup and Welcome address by Prof. Arvind Kumar, Organizing Chair, 19th IBO
9:35 am	Introduction of participating teams by Prof. Vijay Singh, National Co-ordinator, Science Olympiads
10:15 am	Lighting of the traditional lamp Inaugural Address by Prof. Mustansir Barma, Director, Tata Institute of Fundamental Research
10:30 am	Address by Dr. Hans Morelis, Chair, IBO Co-ordinators
10:35 am	Oath by participating students
10:40 am	Oath by participating team leaders
10:45 am	Vote of thanks by Dr. Rekha Vartak, Academic co-ordinator, 19th IBO
	Tea / Coffee Break
11:30 am	Kathak performance by Nandita Puri and her troupe

THE CLOSING CEREMONY
19TH JULY, 2008 (3:30 PM – 8:00 PM)
AT
NEHRU CENTRE

3:30 pm - 5:00 pm	Indian Classical & Folk Dances By Nalanda Dance Research Centre
5:00 pm - 5:30 pm	Tea / Coffee Break
	AWARD FUNCTION
5:30 pm	Welcome address by Prof. Vijay Singh, National Co-ordinator, Science Olympiads
5:50 pm	About the 19th IBO by Dr. Rekha Vartak, Academic Co-ordinator, 19th IBO
6:00 pm	Address by Dr. S. K. Apte, Chair, National Academic Committee, 19th IBO
6:10 pm	Address by the Guest of Honour, Dr. T. Ramasami, Secretary, Dept. of Science and Technology, Government of India
6:15 pm	Address by Dr. Hans Morelis, Chair, IBO Co-ordinators
6:20 pm	Announcement of awards and the presentation of medals
7:15 pm	Address by the Chief Guest, Dr. Anil Kakodkar, Chairman, Atomic Energy Commission
7:25 pm	Handing over the IBO cup by Prof. Arvind Kumar to Chair, 20th IBO (Japan)
7:30 pm	Vote of thanks by Prof. H. C. Pradhan, Dean, HBCSE Faculty

THE EVENT SCHEDULE

Days/Dates	Students	Jury
Sunday, 13 July	Arrival at VITS, registration, lunch and dinner at VITS, free time in the afternoon.	Arrival at The GRAND, registration, lunch and dinner at The GRAND, free time in the afternoon.
Remarks: Teams were split into students and jury at the airport. Registration desks were open for 24 hours (July 13, 9.00 am to July 14, 9.00 am) at VITS and The GRAND.		
Monday, 14 July	Breakfast at 8.00 a.m. at VITS, departure at 9.00 a.m. for The GRAND, opening ceremony at The GRAND (9.30 a.m. to 11.30 a.m.). Cultural programme (11.45 am to 1.00 p.m.), lunch at The GRAND, departure at 2.00 p.m. for HBCSE, visit to HBCSE labs at 3.00 p.m., departure at 4.00 p.m. for VITS, dinner at VITS.	Breakfast at 8.00 a.m. at The GRAND, opening ceremony at The GRAND (9.30 a.m. to 11.30 a.m.) Cultural programme (11.45 to 1.00 p.m.), lunch at The GRAND, jury session for practical tasks begins at 2.00 p.m. at The GRAND, dinner at The GRAND, discussion continues
Tuesday, 15 July	Breakfast at 7.00 a.m. at VITS, departure at 7.30 a.m. for HBCSE, practical test (9.30 - 10.30, 11.00 – 12.00, lunch at HBCSE, 1.00 – 2.00, 2.30 – 3.30), departure at 4.00 p.m. for Juhu beach, meeting with jury at Juhu beach, departure at 6.30 pm for dinner at VITS.	Breakfast at 7.30 a.m. at The GRAND, departure at 8.00 a.m. for city tour (packed lunch), arrival at Juhu beach at 5.30 p.m., meeting with students at Juhu beach, departure at 6.30 pm for dinner at The GRAND.
Wednesday, 16 July	Breakfast at 8.00 a.m. at VITS, departure at 9.00 a.m. for Amusement Park (packed lunch), return to VITS in the evening, dinner at VITS	Breakfast at 8.00 a.m. at The GRAND, jury session for theoretical tasks begins at 9.00 a.m. at The GRAND, lunch at The GRAND, discussion continued, dinner at The GRAND, discussion continued.
Thursday, 17 July	Breakfast at 7.00 a.m. at VITS, departure at 7.30 a.m. for HBCSE, theory test (9.00 a.m. - 2.00 p.m.) with refreshment at 11.00 am, lunch at HBCSE at 2.00 p.m., meeting jury at HBCSE at 2.30 p.m., village fair (Haat) at HBCSE, departure at 4.30 p.m. for VITS, dinner at VITS.	Breakfast at The GRAND, free time, lunch at The GRAND, departure at 1.30 p.m. for HBCSE, meeting with students at HBCSE, village fair (Haat) at HBCSE, departure at 4.30 p.m. for The GRAND, dinner at 7.00 p.m at The GRAND, jury session and co-ordinators' meeting at 8.00 p.m.

Friday, 18 July	Breakfast at 7.30 a.m. at VITS, departure at 8.00 a.m. for Nehru Science Centre, departure at 11.00 a.m. for Nehru Centre (Discovery of India Exhibition) (packed lunch), visit to Planetarium, departure at 4.00 p.m. for VITS, dinner at VITS.	Breakfast at 7.30 a.m. at The GRAND, departure at 8.00 a.m. for Nehru Science Centre, departure at 11.00 a.m. for Nehru Centre (Discovery of India Exhibition) (packed lunch), visit to Planetarium, departure at 4.00 p.m. for The GRAND, jury session at 6.00 p.m. at The GRAND (distribution of answer sheets and score slips, finalization of medal cut offs), dinner at The GRAND, discussion continued.
Saturday, 19 July	Breakfast at 7.30 a.m. at VITS, departure at 8.00 a.m. for TIFR, visit to TIFR (9.30 a.m. – 11.00 a.m.), shopping in South Mumbai (packed lunch) /return to VITS (lunch), departure from South Mumbai/VITS at 2.00 p.m. for Nehru Centre, closing ceremony and cultural programme at Nehru Centre (3.30 p.m. to 7.30 p.m.), departure for closing dinner at Hotel Hyaat.	Breakfast at 7.30 a.m. at The GRAND, jury session at 8.00 a.m. at The GRAND, lunch at The GRAND, departure at 2.00 p.m. for Nehru Centre, closing ceremony and cultural programme at Nehru Centre (3.30 p.m. to 7.30 p.m.), departure for closing dinner at Hotel Hyaat.
Sunday, 20 July	Breakfast at VITS, departure.	Breakfast at The GRAND, departure.

THE EXPERIMENTAL TESTS

PRACTICAL TEST 1: PLANT ANATOMY AND PHYSIOLOGY

(47 points, 60 minutes)

Task 1 (33 points)

Study of factors affecting the activity of stomata

You should try and complete this task in 30 minutes.

Materials and equipment	**Quantity**
1. Specimens labeled 1 to 8 (in red capped vials)	8
2. Compound binocular microscope	1
3. Glass microslides	8
4. Box of coverslips	1
5. Watchglass	1
6. Forceps	1
7. Brush	1
8. Wash bottle containing distilled water	1
9. Permanent marker pen	1
10. Tissue paper roll	1
11. Container for washing and discard	1

Introduction

Stomata are specialized microscopic structures found in all vascular plants.
These microscopic pores allow exchange of gases between the environment and the plant cells. Stomata are also the sites from where water evaporates from the plant. Various environmental factors such as temperature, humidity and light intensity can affect the opening or closing of the stomata.

Q. 1.1. (3 points) Some statements about stomata are given below. Indicate whether the statements are true or false by putting a tick mark (√) **in the appropriate boxes in Q. 1.1. in the Answer Sheet.**

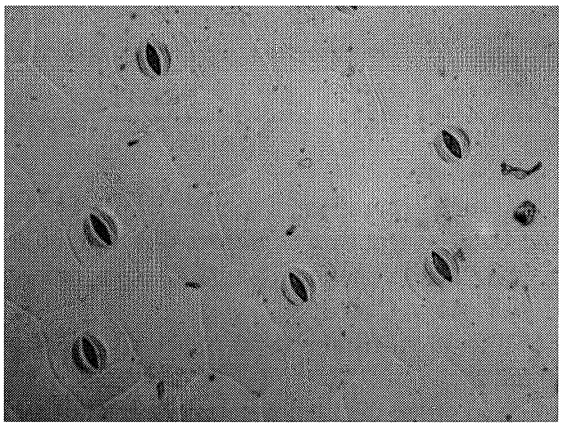
	Statement	True	False
a.	Guard cells are the only epidermal cells that contain chloroplasts.		
b.	The Stomatal Index of any plant species is the ratio of number of stomata in a given area of the leaf to the total number of stomata and other epidermal cells in that same area.		
c.	Stomata are characteristic of angiosperms alone.		
d.	Larger the stomatal pore, greater is the rate of transpiration per unit area of the pore.		
e.	The Stomatal Index is always constant for a given species.		
f.	A plant with stomata only on the upper surface of its leaves is most likely to be a submerged hydrophyte.		

Stomata can be observed by taking an epidermal peel of a leaf. Alternatively, an imprint of the stomata can be obtained, without damaging the leaf tissue, as follows:

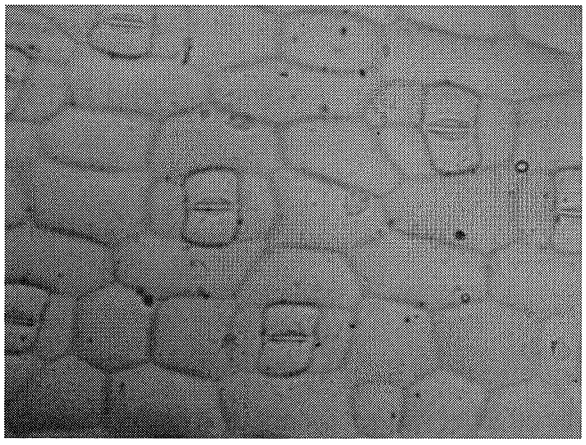
A thin coat of transparent colourless nail polish is applied on the leaf surface. The coat is allowed to dry and peeled off using a pair of forceps. This imprint is placed on a microslide with a drop of water, a coverslip is placed on it and it is observed under the microscope.

Open and closed stomata can be easily distinguished from these imprints. Representative microscopic images of the imprints are given below.

OPEN stomata: (10X)



CLOSED stomata: (10X)



In this task, you will study the effect of various factors on the opening and closing of the stomata. These experiments are conducted by immersing leaves in solutions of different chemicals under specified conditions.

Q. 1.2. (0.5 point) The best choice for such an experiment would be:

a. a mesophyte
b. a hydrophyte
c. a xerophyte
d. a halophyte

Put a tick mark (√) in the appropriate box **in Q. 1.2. in the Answer Sheet.**

a.	b.	c.	d.

Q. 1.3. (2 points) In one such experiment, a solution of pH 4.0 containing 100 mM K^+ and 0.1 mM Ca^{++} is required. Choose the correct way to prepare this solution from the following options and calculate the amount of KCl and volume of 10mM $CaCl_2$ solution you have to add.
Atomic mass of K is 39.1 and of Cl is 35.5.

a. Dissolve X g of KCl in 40 ml citrate buffer of pH 4.0, add Y ml of 10 mM $CaCl_2$, and make up the volume to 50 ml.
b. Dissolve X g of KCl in 40 ml distilled water. Add Y ml of 10 mM $CaCl_2$ to 5 ml distilled water. Mix both the solutions and adjust the pH to 4.0 with HCl. Make up the volume to 50 ml.
c. Dissolve X g of KCl in 40 ml distilled water. To this, add Y ml of 10 mM $CaCl_2$. Make up the volume to 50ml. Adjust the pH to 4.0 with HCl.

Put a tick mark (√) in the appropriate box and give the correct answer for X and Y **in Q. 1.3. in the Answer Sheet**.

a.	b.	c.

X = _____ g KCl

Y = _____ ml 10mM $CaCl_2$

Experiment

In order to study the effect of various factors on stomata, leaves of a plant were treated in eight different ways. The imprints obtained after each of these treatments (1 to 8 given below) are provided in red-capped vials labeled 1 to 8, respectively.
Please note that these treatments have also been described in the following table for your convenience.

Treatment 1: Leaves were immersed in a solution containing 100 mM KCl, 0.1 mM $CaCl_2$, pH 7.0 and kept in light for 2 h.

Treatment 2: Leaves were immersed in a solution containing 10 mM KCl, 0.1 mM $CaCl_2$, pH 7.0 and kept in dark for 2 h.

Treatment 3: Leaves were immersed in a solution containing 0.5 M mannitol, 100 mM KCl, 0.1 mM $CaCl_2$, pH 7.0 and kept in light for 2 h.

Treatment 4: Leaves were immersed in a solution containing 10 mM KCl, 0.1 mM $CaCl_2$, pH 4.0 and kept in dark for 2 h.

Treatment 5: Leaves were immersed in solution containing 10 mM KCl, 0.1 mM $CaCl_2$, pH 7.0 containing an Unknown Chemical and kept in dark for 2 h.

Treatment 6: Leaves were immersed in a solution containing 100 mM KCl, 0.1 mM $CaCl_2$, pH 4.0 and kept in light for 2 h.

Treatment 7: Leaves were immersed in a solution containing 100 mM KCl, 0.1 mM $CaCl_2$, 10 µM abscisic acid, pH 7.0 and kept in light for 2 h.

Treatment 8: Leaves were immersed in a solution containing 100 mM KCl, 0.1 mM $CaCl_2$, 10 µM abscisic acid, pH 4.0 and kept in light for 2 h.

Treatment	**KCl**	**$CaCl_2$**	**pH**	**Light**	**Abscisic Acid**	**Mannitol**	**Unknown Chemical**
1	100mM	0.1mM	7.0	2 h Light	-	-	-
2	10mM	0.1mM	7.0	2 h Dark	-	-	-
3	100mM	0.1mM	7.0	2 h Light	-	0.5 M	-
4	10mM	0.1mM	4.0	2 h Dark	-	-	-
5	10mM	0.1mM	7.0	2 h Dark	-	-	Yes
6	100mM	0.1mM	4.0	2 h Light	-	-	-

7	100mM	0.1mM	7.0	2 h Light	10µM	-	-
8	100mM	0.1mM	4.0	2 h Light	10µM	-	-

Q. 1.4. (8 points): Observation of the imprints

(i) Pick up the imprint gently from the container using a brush. You may need to gently swirl the vial in order to locate the imprint.
(ii) Place the imprint in a drop of water on a glass microslide.
(iii) Place a coverslip and observe under the 10X objective of the microscope. **Note that you will be observing unstained specimens. Hence, make appropriate adjustments in the microscope.**
(iv) Note down the observations **in Table 1.4. in the Answer Sheet**. You need to count at least 20 stomata per imprint.

Table 1.4.

Treatment	Total number of stomata counted	Number of open stomata	Number of closed stomata
1			
2			
3			
4			
5			
6			
7			
8			

Interpretations

Q. 1.5. (10 points)
Based on the results obtained from the given set of experiments, answer the questions **Q. 1.5.A to Q. 1.5.D in the Answer Sheet**. Fill in the blanks with the appropriate serial numbers from the options given below. Use all options, but each option only once.

A. The factor/s that clearly lead to stomatal closure is/are: _____
B. The factor/s that clearly lead to stomatal opening is/are: _____
C. The factor/s that clearly have no effect on stomatal opening/closing is/are: ____
D. The factor/s whose effect cannot be clearly established in this experiment is/are: _____

Options:

1. Light alone
2. Darkness alone
3. Acidic pH
4. Mannitol
5. Unknown Chemical
6. 10 mM KCl alone
7. 100 mM KCl alone
8. $CaCl_2$
9. Abscisic acid alone
10. Abscisic acid and acidic pH

Q. 1.6. (2.5 points) The correct explanation for the observations in Treatments 7 and 8 is:

a. Acidification of guard cells leads to opening of K^+ channels of the plasma membrane. This results in entry of K^+ and water molecules to the guard cells.
b. As the pKa of abscisic acid is close to 5.0, most of the molecules remain undissociated at pH 4.0. This hastens their entry into the guard cells.
c. No effect was observed in either treatment because there was no water stress.
d. Abscisic acid is a strong acid and works best at highly acidic pH.

Put a tick mark (√) in the appropriate box **in Q. 1.6. in the Answer Sheet**

a.	b.	c.	d.

Q. 1.7. (2.5 points) Which of the following correctly explains the effect of mannitol on the stomatal aperture?

a. Mannitol is a highly hydrophilic substance and restricts the entry of water molecules into the guard cells.
b. High concentration of mannitol in the extracellular fluid forces K^+, Cl^- and Ca^{++} to enter the guard cells. This leads to entry of water molecules into the cells as well.
c. Entry of mannitol into guard cells increases their solute potential leading to uptake of water.
d. High solute concentration of mannitol results in withdrawal of water from guard cells.

e. Entry of mannitol in the guard cells is counter-balanced by the efflux of K^+ and Ca^{++} leading to the withdrawal of water from the guard cells.

Put a tick mark (√) in the appropriate box **in Q. 1.7. in the Answer Sheet**

a.	b.	c.	d.	e.

Q. 1.8. (2.5 points) You have already observed the effect of the Unknown Chemical on stomata (Treatment 5. Leaves were immersed in solution containing 10 mM KCl, 0.1 mM $CaCl_2$, pH 7.0 containing an Unknown Chemical and kept in dark for 2 h.). These results suggest that the chemical could be useful for:

a. weed control by increasing the rate of respiration.
b. keeping plant cuttings fresh over long periods by preventing water loss.
c. weed control by acting as a wilting toxin.
d. increasing crop yield in arid lands by increasing rate of photosynthesis.
e. increasing plant growth by reducing photorespiration.

Put a tick mark (√) in the appropriate box **in Q. 1.8 in the Answer Sheet.**

a.	b.	c.	d.	e.

Q. 1.9. (2 points) In this task, you studied the effect of various factors on the opening and closing of the stomatal aperture. Similar experiments were performed by scientists and they discovered that light activates zeaxanthin molecules, present in the guard cells, which in turn, activate an ATP-powered proton pump of the guard cell membrane. With this background information and the observations made by you in this task, you have to arrange the sequence of events involved in the response of stomata to light. Fill in the correct options against each step **in Q. 1.9. in the Answer Sheet**.

Mechanism:
Step I: 1
Step II: 2
Step III: _____
Step IV: 6
Step V: _____
Step VI: _____
Step VII: _____

Options:
1) Activation of zeaxanthin by light
2) Activation of ATP-powered proton pump

3) Closing of the stomata
4) Influx of K^+
5) Efflux of K^+
6) Change in membrane potential
7) Efflux of Ca^{++}
8) Efflux of protons
9) Influx of water molecules
10) Efflux of water molecules
11) Opening of the stomata

Task 2 (14 points)
Study of plant anatomy and its correlation with the habitat

You should try and complete this task in 30 minutes.

Materials and equipment	**Quantity**
1. Fresh plant specimens	
(i) Leaf in a Petri dish (labeled X)	1
(ii) Stem in a Petri dish (labeled Y)	1
2. Compound binocular microscope	1
3. Razor blades	2
4. Glass microslides	2
5. Box of coverslips	1
6. Watchglasses	3
7. Safranin staining solution (labeled S)	1
8. Brush	1

Introduction

Plants growing in different habitats exhibit various adaptations. These adaptations can be studied macroscopically as well as microscopically and correlated to their habitats.

In this task, you will study the anatomy of the given specimens using the following method. Both specimens X and Y belong to the same plant.

Method

1. Take thin transverse sections of the leaf specimen X.
2. Stain with Safranin staining solution for about 30 to 60 seconds.
3. Wash the section with distilled water and mount on a clean glass microslide in a drop of water.
4. Place a coverslip and observe under 10X objective of the microscope.
5. Repeat Steps 1- 4 for the stem specimen Y.

Observations on the leaf specimen X:

Observe the leaf section and answer **Questions Q. 2.1. and Q. 2.2.**

Q. 2.1. (4 points) Choose the appropriate letters from the Dichotomous Keys 1 and 2 given in **Annexure 2.1.** and fill in **Q. 2.1.I. and Q. 2.1.II. in the Answer Sheet.**

Note: Schematic representations of some of the plant structures are given in **Annexure 2.2.** for your reference.

I. Trichomes ☐

II. Stomata ☐

Q. 2.2. (4 points) Based on your observations on the leaf section, put a tick mark (√) in the appropriate boxes **in Q. 2.2. in the Answer Sheet**.

	Present	Absent
1. Cuticle	☐	☐
2. Sclerenchyma	☐	☐
3. Collenchyma	☐	☐
4. Aerenchyma	☐	☐
5. Water storage tissue	☐	☐
6. Glands:		
a. Oil gland	☐	☐
b. Salt gland	☐	☐
c. Digestive gland	☐	☐

Observations on the stem specimen Y:
Observe the stem section and put a tick mark (√) in the appropriate boxes in **Q. 2.3. in the Answer Sheet**.

Q. 2.3. (3.5 points)

	Present	Absent
1. Cuticle	☐	☐
2. Sclerenchyma	☐	☐
3. Collenchyma	☐	☐
4. Aerenchyma	☐	☐
5. Water storage tissue	☐	☐
6. Vascular bundle:	Open	Closed
	☐	☐
	Collateral	Bicollateral
	☐	☐

Q. 2.4. (2.5 points) Based on your observations of specimens X and Y, identify the type of plant to which they belong.

a. Mesophyte
b. Succulent xerophyte
c. Submerged hydrophyte
d. Floating hydrophyte
e. Insectivorous mesophyte
f. Parasitic mesophyte
g. Halophyte
h. Freshwater hygrophyte

Put a tick mark (√) in the appropriate box in **Q. 2.4. in the Answer Sheet.**

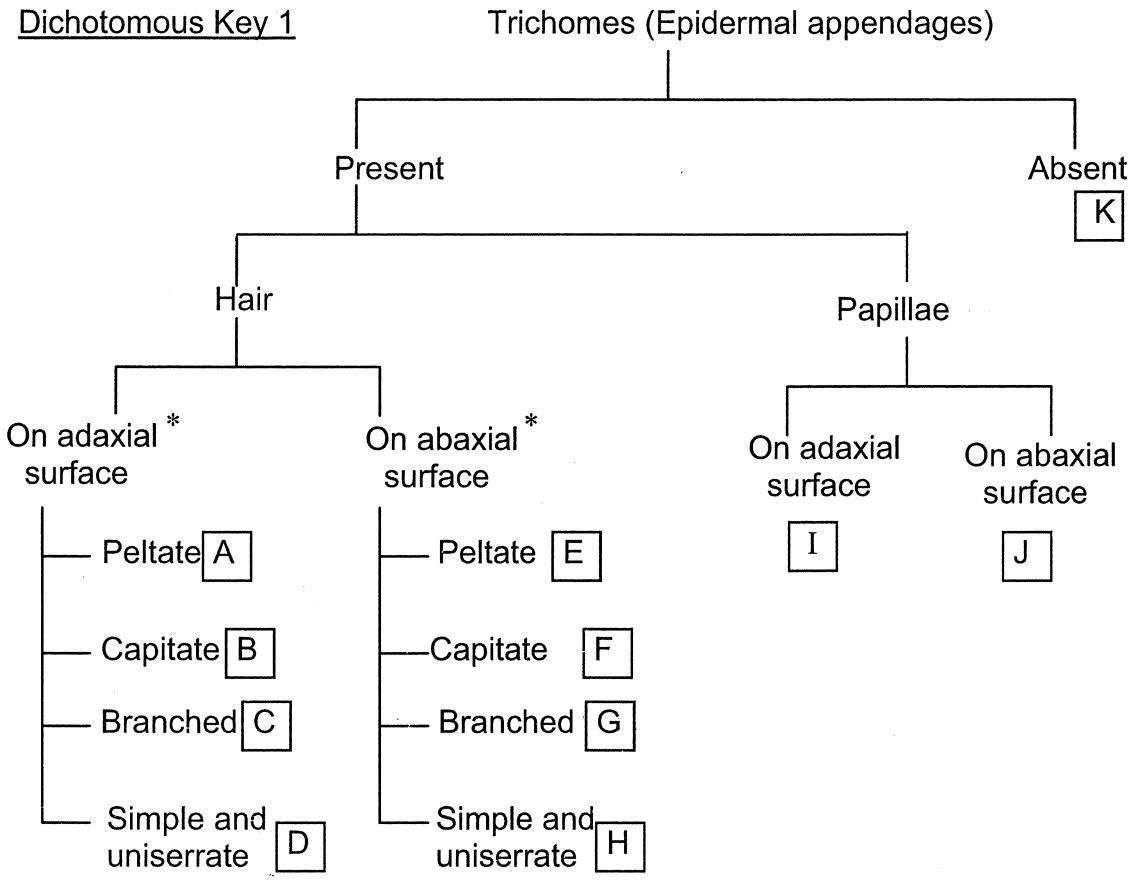
(In this question, the correct interpretation will be given points if it is consistent with your observations.)

a.	b.	c.	d.	e.	f.	g.	h.

****

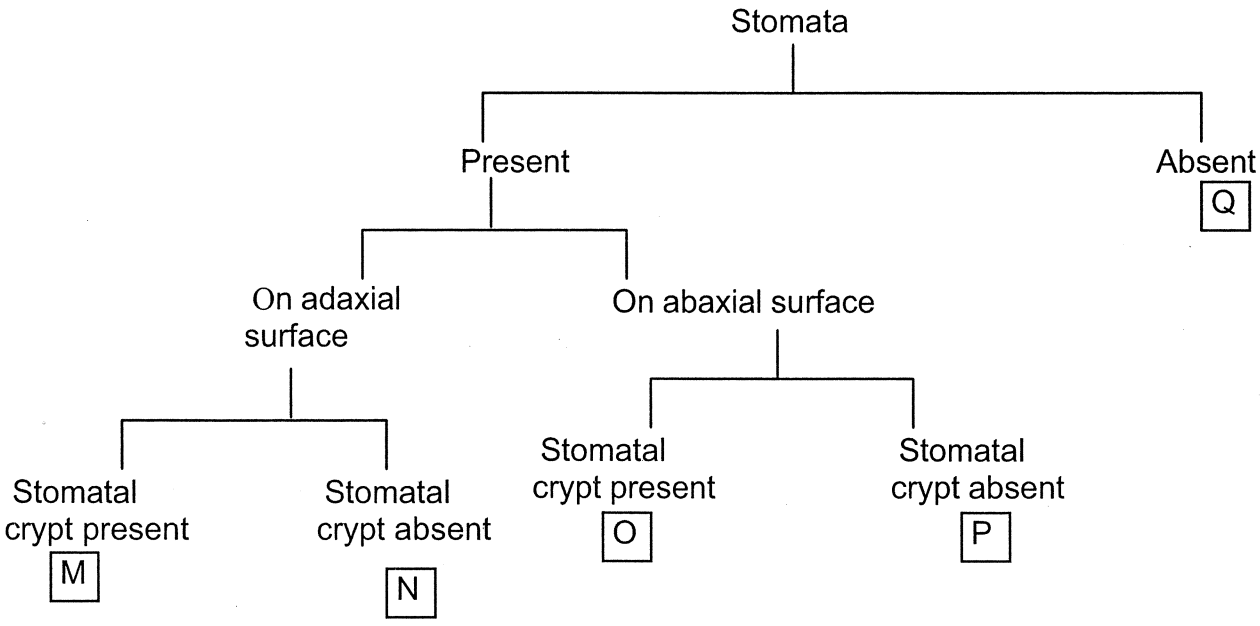
ANNEXURE 2.1

Dichotomous Key 1



* NOTE: Adaxial: facing the stem; abaxial: facing away from the stem

Dichotomous Key 2



ANNEXURE 2.2.

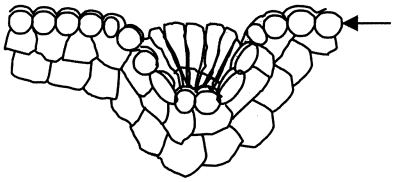


Figure 1: Salt Gland

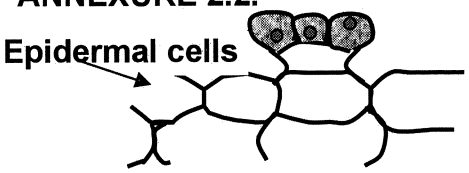


Figure 2: Digestive Gland

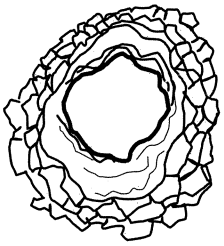


Figure 3: Oil Gland

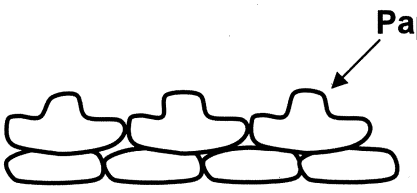


Figure 4: Papillose Epidermis

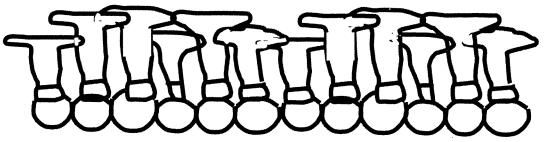


Figure 5: Peltate Hair

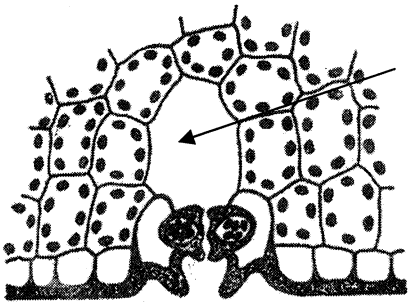


Figure 6: Sunken Stoma

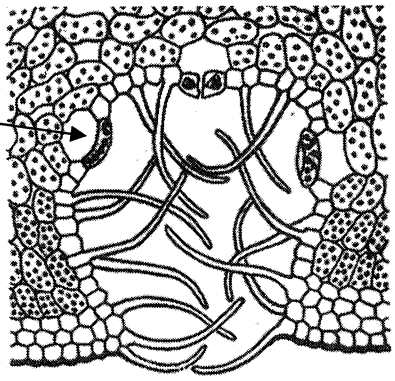


Figure 7: Stomatal Crypt

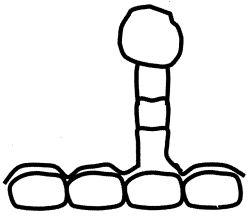


Figure 8: Capitate Hair

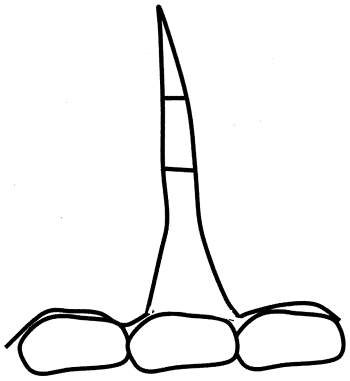


Figure 9: Uniserrate Trichome

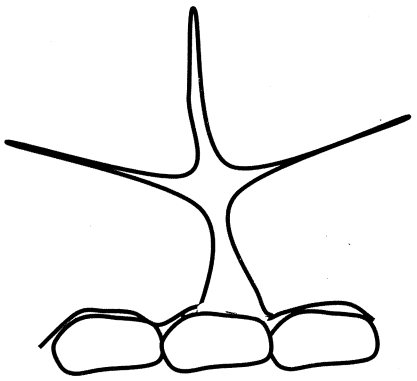


Figure 10: Branched Trichome

**********END OF PRACTICAL TEST 1**********

PRACTICAL TEST 2: ANIMAL ANATOMY AND PHYSIOLOGY

(66 points, 60 minutes)

Task 1 (54 points)

Study of animal skeletal systems

You should try and complete this task in 45 minutes.

Materials and equipment	**Quantity**
12. Set of skeletal specimens labeled 1 to 9 in sealed boxes **(Please do not open the boxes!)**	9
13. A set of photographs of three skulls labelled 1A, 2A and 3A	1
14. Magnifying hand-lens	1

Introduction

The skeletal system provides physical support and a scaffold for the body and defines its architecture in animals. The three types of skeletal systems include an external (exoskeleton), internal (endoskeleton) and a fluid-based (hydrostatic skeleton) system.

The internal skeleton in vertebrates determines its body shape, provides support for its weight and offers sites for muscle attachment. Although structural modifications in the skeleton may occur in different groups of animals, the basic plan by and large remains the same.

In this task, you will observe and compare the internal skeletal systems of three present-day vertebrates. The models of the skeletal parts provided to

you include the skull, the vertebral column and the limb bones. At the end of the task, you will match these parts to form the complete skeletal system of each of the three vertebrates.

Part A: Comparative study of skulls

(i) Types of skull:

The skull of vertebrates is a bony structure that serves as the general framework for the head. Structurally, the skull comprises four regions – frontal, parietal, occipital and temporal (Figure 1). There are various openings in different regions of the skull, including the nostrils, eye sockets and the temporal openings. The placement of the eyes with respect to each other determines the field of vision of the animal.

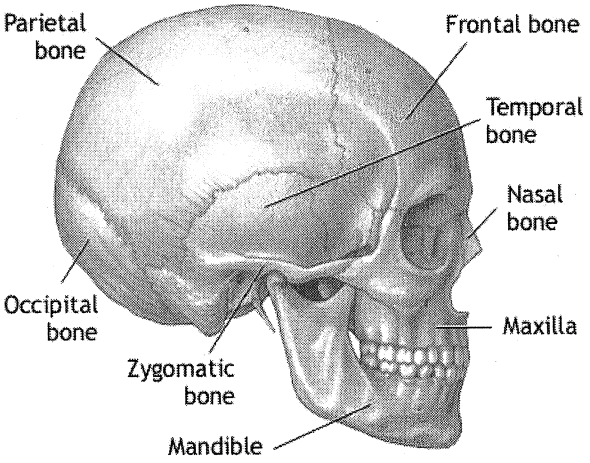


Figure 1

The number of temporal fenestrae (openings) and the position of these openings are used to broadly classify vertebrate skulls into the following four major categories:

(A) Anapsid skull: Anapsids get their name from the fact that they have no additional openings in their skulls apart from their eye sockets and nostrils. The temporal region is covered completely by bone. This type of skull is characteristic of fishes, amphibians, and early reptiles (Figure 2).

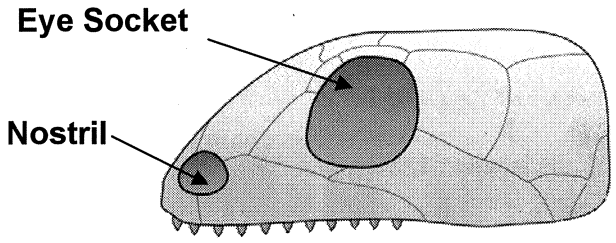
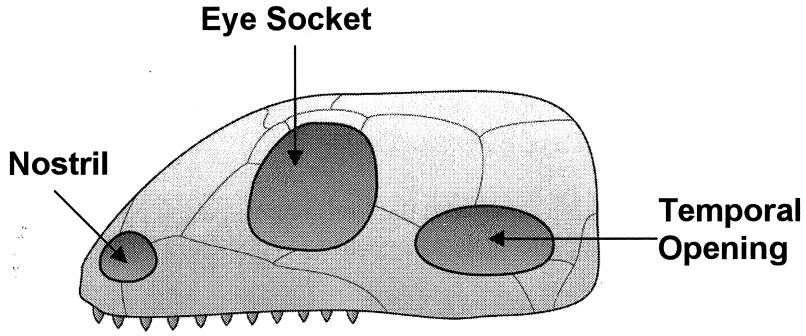


Figure 2

(B) Synapsid skull: It has a single pair of temporal openings. It was found in mammalian ancestors and represented an early divergence from the anapsids. The skull of present day mammals represents a modified synapsid pattern (Figure 3).



(C) Diapsid skull: It is characterized by two pairs of temporal openings. This type diverged from the anapsids and has undergone extensive modification. It is found in pterosaur and dinosaur fossils, as well as in birds and all living reptiles. One of the highly modified forms of the diapsid skull is found in lizards, where the lower temporal opening is not as distinct as the upper one (Figure 4).

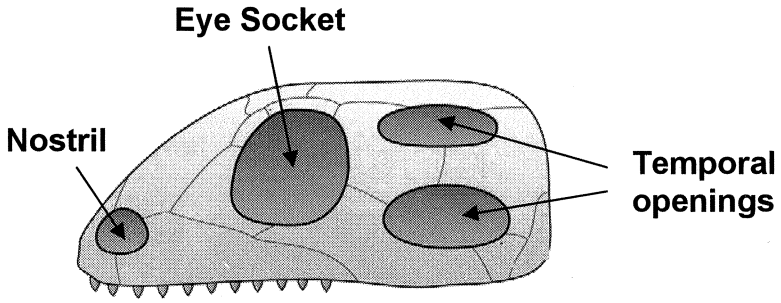


Figure 4

(D) Euryapsid skull: It has a single pair of temporal openings. The euryapsid skull seems to be derived from diapsid ancestors by loss of the lower temporal openings. Two groups of Mesozoic marine reptiles (plesiosaurs and ichthyosaurs) possessed this type of skull (Figure 5).

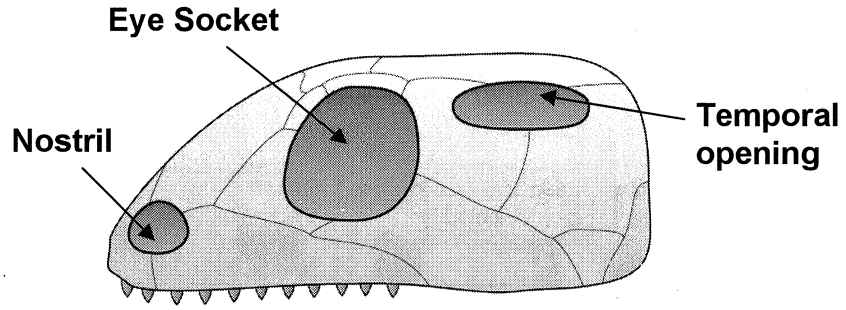
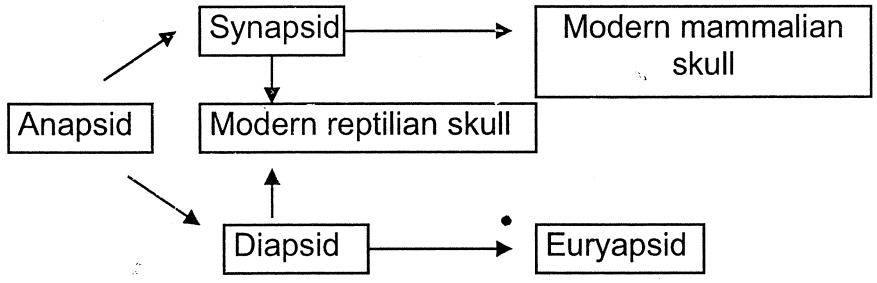


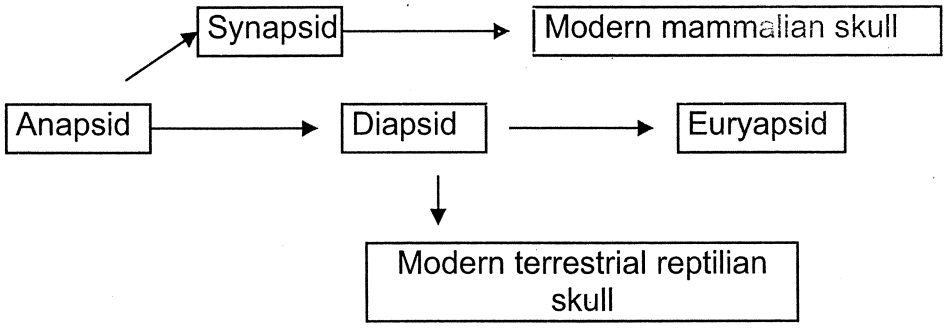
Figure 5

Q. 1.A.1. (2 points): Based on the information provided earlier, choose the cladogram that most likely depicts the evolution of skulls by putting a tick mark (√) in **Q. 1.A.1. in the Answer Sheet**.

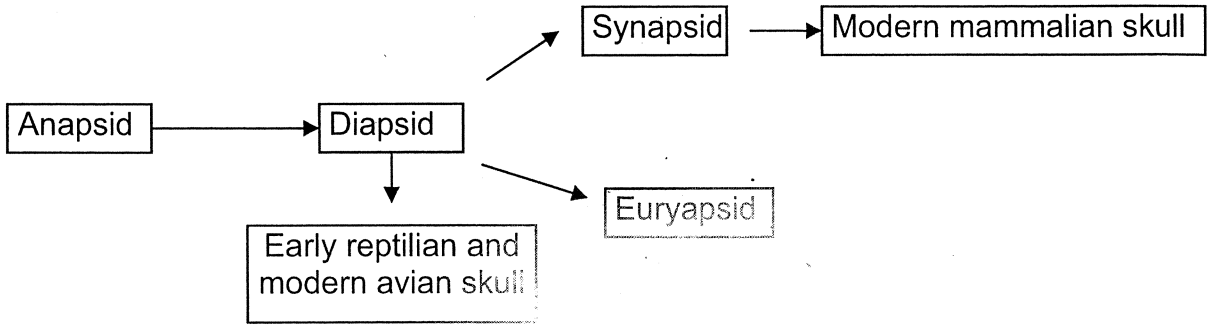
a.



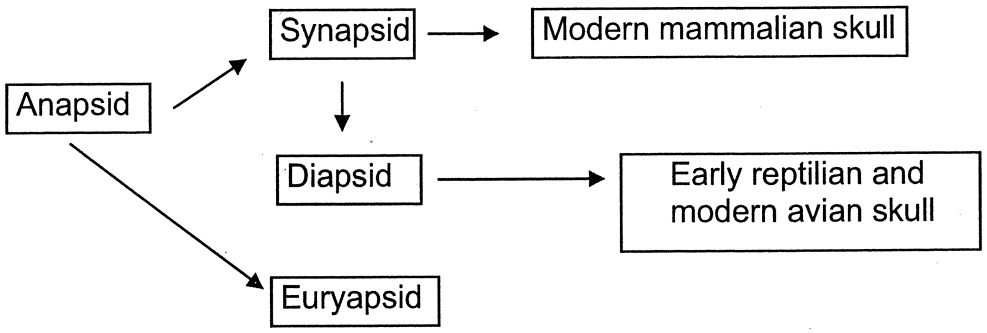
b.



c.



d.



a.	
b.	
c.	
d.	

(ii) Dentition: Dentition refers to the type and arrangement of teeth in an animal and is an adaptation to its feeding habit. Based on the dentition, vertebrates can be broadly classified as homodont or heterodont. Depending on the number of times the teeth are replaced during the life span of an animal, they can be further classified as diphyodont or polyphyodont.

Q. 1.A.2. (6 points) Observe the Specimens 1, 2 and 3 for the type of skull and the respective photographs 1A, 2A, and 3A for their dentition. Put tick marks (√) in the appropriate boxes in **Table 1.A.2. in the Answer Sheet**.

Table 1.A.2.

Character		1	2	3
Type of skull	Anapsid			
	Diapsid			
	Synapsid			
	Euryapsid			
Type of dentition	Homodont			
	Heterodont			

Q. 1.A.3. (6 points) Observe the specimens for position of orbit (the eye sockets), and for types of teeth. Fill in the **Table 1.A.3. in the Answer Sheet** by putting tick marks (√) in the appropriate boxes.

Table 1.A.3.

Features		1	2	3
Vision	Predominantly stereoscopic vision			
	Predominantly non-stereoscopic vision			
Feeding habit	Predominantly carnivorous			
	Predominantly herbivorous			

Part B: Comparative study of vertebral columns and ribs

The vertebral column and ribs are components of the axial skeletal system.

The vertebral column defines the major body axis and comprises a series of separate bones (vertebrae) joined to form a backbone (Figure 6).

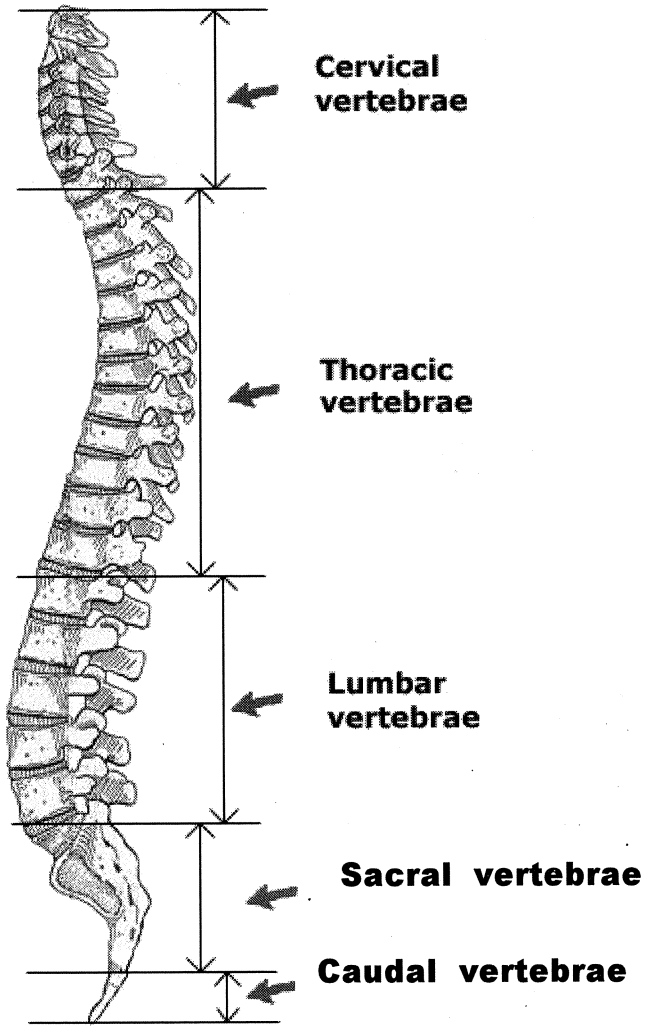


Figure 6

Cervical vertebrae, the first set of vertebrae, are characterized by highly reduced transverse processes in contrast to the following set of vertebrae, the thoracic vertebrae. The number of cervical vertebrae is usually correlated with the degree of neck movement.

In higher animals, the thoracic vertebrae are important because they articulate with the ventral sternum and ribs to form a rib cage.

Ribs also provide sites for secure muscle attachment, help suspend the body, form a protective case around the viscera and sometimes serve as accessory breathing devices (Figure 7).

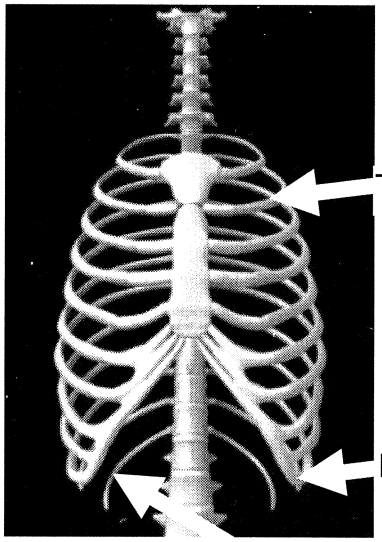


Figure 7

The sternum is a mid-ventral skeletal structure that offers a site of origin for chest muscles and secures the ventral tips of true ribs to complete the protective rib cage. A well-developed rib cage is characteristic of mammals.

The classification of ribs in tetrapods is based on the type of association they establish with the sternum. The three kinds of ribs are:

True ribs – these ribs meet ventrally with the sternum.
False ribs – these ribs articuiate with each other but not with the sternum.
Floating ribs – these ribs do not articulate with the sternum or any other structure. These ribs, when present in large numbers offer flexibility to the body during locomotion.

Q. 1.B.1. and Q.1.B.2. (8 + 3 = 11 points) Observe the Specimens 4, 5 and 6 and put tick marks (√) in the appropriate boxes in **Tables 1.B.1. and 1.B.2. in the Answer Sheet**.

Table 1.B.1.

Characters		4	5	6
Ribs	Present			
	Absent			
Major type of ribs	True			
	False			
	Floating			
Tail	Present			
	Reduced /Absent			

Table 1.B.2.

Feature		4	5	6
Neck movement	Restricted			
	Free			

Part C: Comparative study of limb bones

The transition of vertebrates from aquatic to terrestrial and from terrestrial to aerial has had an impact upon the design and redesign of the appendicular system. The appendicular skeleton includes the paired fins or limbs and the
girdles. Schematic figures of representative limb arrangements are given below (Figures 8 and 9).

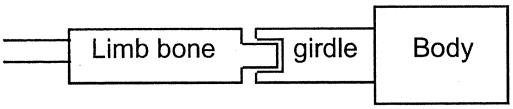


Figure 8: Schematic representation of the articulation of a sprawled limb

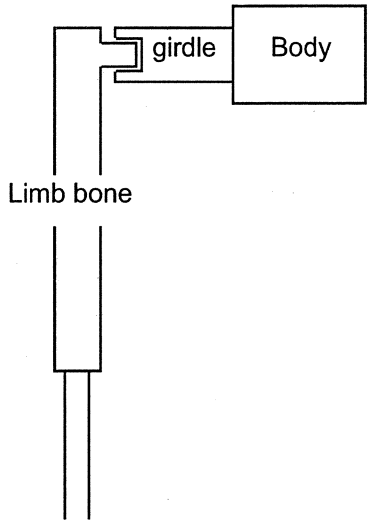


Figure 9: Schematic representation of the articulation of an underneath limb

Q. 1.C.1. (12 points) Carefully study the Specimens 7, 8 and 9, and fill in **Table 1.C.1. in the Answer Sheet** by putting tick marks (√) in the appropriate boxes.

Characters		7	8	9
Position of limb with respect to body	Sprawled			
	Underneath			
Length of fore- and hindlimbs	Similar			
	Fore limbs longer			
	Hind limbs longer			
Claws	Present			
	Absent			
Modifications	Tibia and fibula completely fused			
	Tibia and fibula partially separate			

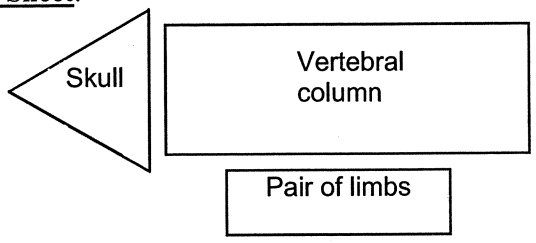
Q. 1.C.2. (8 points) Based on your observations, fill in **Table 1.C.2. in the Answer Sheet** by putting tick marks (√) in the appropriate boxes.

Table 1.C.2.

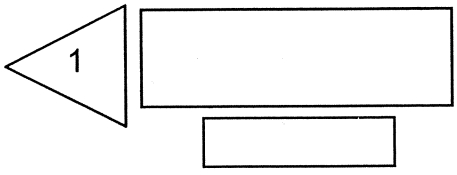
Features		7	8	9
Limb movement during locomotion	Swinging (rotational movement)			
	Pendulum-like			
Habit of the animal	Saltatorial (jumping)			
	Cursorial (walking)			
	Fossorial (digging)			

Part D: Assembly of the skeletal systems

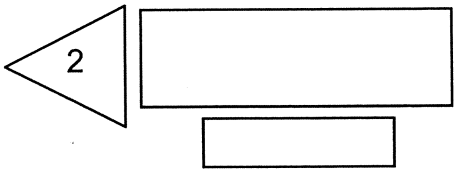
Q. 1.D.1 (6 points) The nine specimens (three skulls, three vertebral columns and three sets of limb bones) belong to three different animals (I, II, and III). In the schemes given below, write the respective specimen numbers (4 to 9) in the appropriate boxes to construct the three animals in **Q. 1.D.1. in the Answer Sheet**.



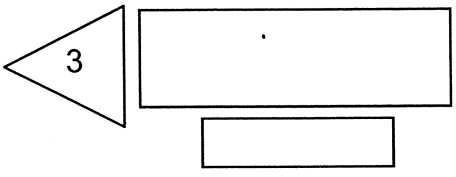
Animal I



Animal II



Animal III



Q. 1.D.2 (3 points): Assign each of the three animals to the most probable class. Choose from the options given below and write appropriate letter in **Q. 1.D.2. in the Answer Sheet.**

Animal I: Class: _____

Animal II: Class: _____

Animal III: Class: _____

Options:
A. Mammalia
B. Reptilia
C. Aves
D. Amphibia
E. Pisces

Task 2 (12 points)
Semi-quantitative estimation of nitrogenous waste products

You should try and complete this task in 15 minutes.

	Materials	**Quantity**
1.	Porcelain spot plates, each with 6 cavities	3
2.	Toothpicks	20
3.	Permanent marker pen	1
4.	Tissue paper roll	1
5.	Container for wash and discard	1
6.	Reagents (given in a plastic box)	1 bottle each

Label	**Reagent**
A	Phosphotungstic acid
B	Sodium carbonate (20% w/v)
C	Uric acid (standard solution)
D	Ehrlich's reagent (mildly corrosive)
E	Urea (standard solution)
F	Sodium nitroprusside
G	Oxidizing solution
H	Phenol solution (mildly corrosive)
I	Ammonia (standard solution)
S1	Simulated Sample 1
S2	Simulated Sample 2
S3	Simulated Sample 3
H_2O	Distilled water

Introduction

Vertebrates have evolved different modes of excretion of nitrogenous wastes, which are mostly derived from degradation of proteins and nucleic acids. They use different ways of excretion of these wastes during their transition from an aquatic to terrestrial mode of life. The three major forms of these wastes are ammonia, urea and uric acid. While ammonia is highly soluble in water, uric acid is the least soluble. Ammonia, being most toxic, needs to be excreted in a highly diluted form. Uric acid is mostly excreted as semisolid crystals.

Three simulated samples (S1, S2 and S3), representing nitrogenous wastes from three groups of animals, are provided. Follow the protocols given below to find out the relative levels of uric acid, urea and ammonia in these samples.

General Instructions

1. ***For each test, run a positive control and a negative control using the standard solutions and distilled water, respectively.***
2. ***Grade the colour of positive control as '+++' and that of negative control as ' – '.***
3. ***Please note that the recording of the results for the positive and negative controls carries NO points.***

Protocols for estimation

1. Estimation of uric acid by phosphotungstic acid reduction method

Principle

Under alkaline conditions, uric acid reduces phosphotungstic acid to give a blue- coloured product.

Method

(i) Put three drops each of Samples S1, S2 and S3 in separate cavities of a given spot plate.

(ii) Add one drop each of solutions A followed by B to each cavity. Mix with separate toothpicks and observe the developed colour.

(iii) Grade the colour of the positive control as '+++' and that of the negative control as ' – '.

Q. 2.1.1. (3 points) Record the results in **Table 2.1. in the Answer Sheet** by putting '+++', '++' or '+' for positive results depending on the intensity of the colour developed and '–' for negative results.

2. Estimation of urea using Ehrlich's reagent

Principle

Under strong acidic conditions, urea reacts with Ehrlich's reagent (*p*-dimethylaminobenzaldehyde) to form a yellow-coloured dye (protonated Schiff's base).

Method

(i) Put three drops each of Samples S1, S2 and S3 in separate cavities of a given spot plate.

(ii) Add one drop of solution D to each cavity. Mix with separate toothpicks.

Q. 2.1.2. (3 points) Record your results **immediately** in **Table 2.1. in the Answer Sheet** by putting '+++', '++' or '+' for positive results depending on the intensity of the colour developed and '-' for negative results. For comparison, grade the colour of the positive control as '+++' and that of the negative control as ' – '.

3. Estimation of ammonia by indophenol blue method

Principle

In an alkaline solution, ammonium ions react with oxidizing solution to form monochloramine. In the presence of phenol and an excess of oxidizing solution, the monochloramine forms a blue-coloured product, indophenol, when nitroprusside is used as a catalyst.

Method

(i) Put three drops each of Samples S1, S2 and S3 in separate cavities of a given spot plate.

(ii) Add one drop each of solutions F, followed by G and finally H to each cavity. Mix with separate toothpicks.

Q. 2.1.3. (3 points) Record your results **after two minutes** in **Table 2.1. in the Answer Sheet** by putting '++++', '+++', '++' or '+' for positive results depending on the intensity of colour developed and '-' for negative results. For comparison, grade the colour of positive control as '+++' and that of negative control as ' – '.

Table 2.1.

Samples	Uric acid test	Urea test	Ammonia test
S1			
S2			
S3			
Positive control			
Negative control			

Q. 2. 2. (3 points): Based on the results obtained, match each of the samples with the appropriate class of vertebrates listed below. Fill in your answer by putting the appropriate letter in **Q. 2.2. in the Answer Sheet**.

Answer: _____

a.	S1: Pisces	S2: Mammalia	S3: Reptilia
b.	S1: Amphibia	S2: Aves	S3: Pisces
c.	S1: Mammalia	S2: Reptilia	S3: Aves
d.	S1: Mammalia	S2: Pisces	S3: Aves
e.	S1: Aves	S2: Pisces	S3: Mammalia
f.	S1:Reptilia	S2: Amphibia	S3: Mammalia
g.	S1: Aves	S2: Reptilia	S3: Amphibia

********** END OF PRACTICAL TEST 2 **********

PRACTICAL TEST 3: BIOCHEMISTRY AND CELL BIOLOGY

(43 points, 60 minutes)

Task 1

PART A (35 points)

Study of β-lactamase activity and its inhibition

Materials and equipment	Quantity
1. Colorimeter, with a set of seven cuvettes	1
2. Test tubes	8
3. Test tube stand	1
4. Micropipette (10 – 100 µl capacity)	1
5. Micropipette (100 – 1000 µl capacity)	1
6. Micropipette tips (10 – 100 µl capacity)	20
7. Micropipette tips (100 – 1000 µl capacity)	20
8. Photographs of Petri plates	6
9. Permanent marker	1
10. Tissue paper roll	1
11. Wash bottle containing distilled water	1
12. Container for wash and discard	1
13. Graph paper	1

Reagents (please see the next page)

Label	Reagent	Container
A	β – Lactamase enzyme (1.85 mg/ml)	Vial
B	Inhibitor (100 mM)	Vial
C	Penicillin G (0.54 mM)	Blue-stoppered tube
D	Sodium phosphate buffer, pH 7.0 (10 mM)	Blue-stoppered tube
E	$CuSO_4$-Neocuproine reagent	Blue-stoppered tube
F	HCl (2 M)	White-stoppered tube

Handling of micropipette:

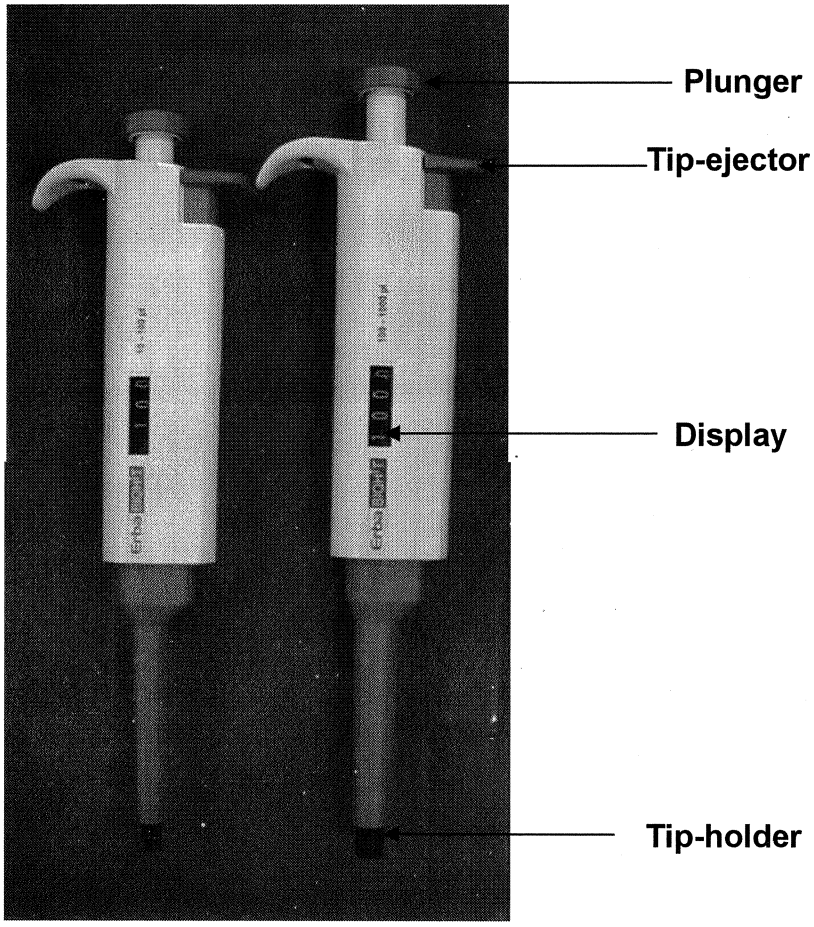


Figure 1

Adjustment method

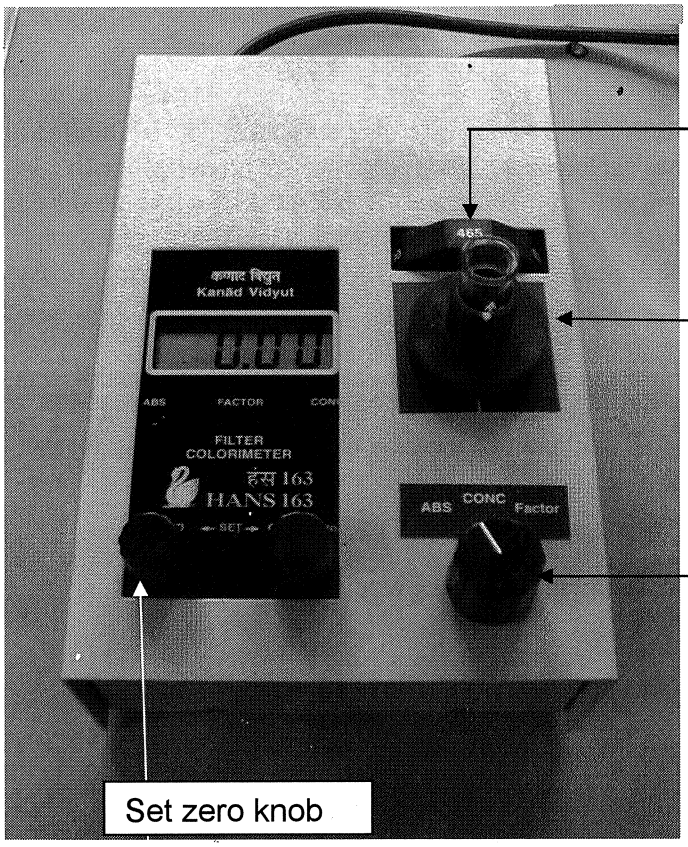
Turn the plunger (Figure 1) to set the value to the desired volume, which can be seen in the display.

Remember that each micropipette has a fixed range of volumes as indicated on the pipette. DO NOT CROSS THE LIMITS OF THIS RANGE.

Usage method

Secure the pipette tip to the tip holder (Figure 1). Gently push down the plunger to the first stop, hold, and dip the tip into the solution vertically to a depth of 2 - 4 mm. Release the plunger slowly and make it return to the original position. Remove the pipette from the liquid and transfer the contents to the desired tube. Make sure that the tip is close to the inner wall of the tube. Push the plunger to the first stop and then push further to discharge the solution completely from the tip. Remove the pipette from the tube. Eject the used tip into the discard container by pressing the tip-ejector.

Operating Instructions for the colorimeter



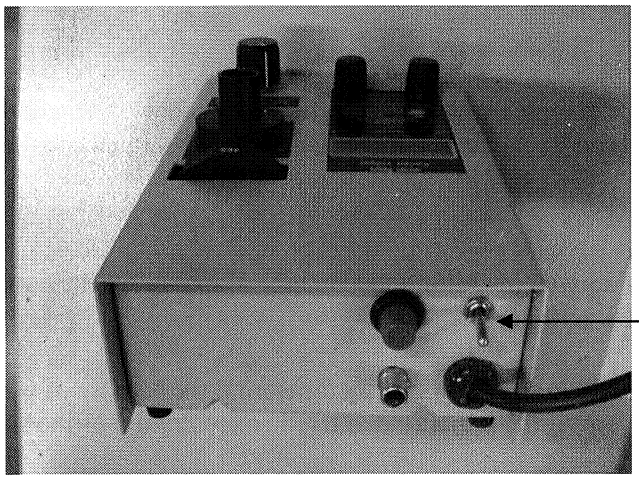


Figure 2: Rear view of colorimeter

1) Turn the power switch (Figure 2) of the colorimeter ON.
2) Set the instrument to Absorbance mode ("ABS") using the mode selector.

3) Set the wavelength to 465 nm using the wavelength selector.
4) Put the blank solution in a cuvette. Clean the outside surface of the cuvette with tissue paper and insert it into the cuvette holder. Gently push the cuvette all the way down.
5) Rotate the 'set zero' knob to set the reading to zero. The instrument is now ready for measuring the absorbance of the test solutions.

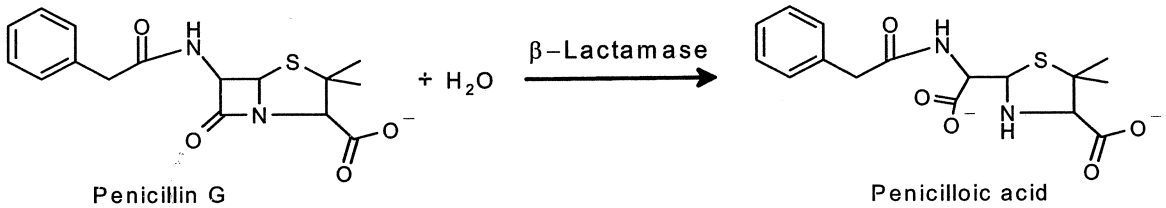
Introduction

Penicillins are antibiotics with a characteristic β-lactam ring in their structure. This antibiotic kills bacteria by inhibiting the cell wall synthesis. However, these molecules are rendered inactive by some bacteria, which synthesize an enzyme called β-lactamase. These bacteria, which produce β-lactamases, are resistant to penicillins. Due to this, penicillin treatment is ineffective in patients infected with such resistant bacteria. One approach to overcome this problem is to develop effective β-lactamase inhibitors.

The effectiveness of a β-lactamase inhibitor can be evaluated by determining its IC_{50} and K_i values. The IC_{50} of an inhibitor is defined as the concentration of the inhibitor required to inhibit the enzyme activity by 50 percent. The K_i of an inhibitor is a measure of its binding affinity for the enzyme.

Principle of β-lactamase assay

β-Lactamase inactivates penicillin by catalyzing the following reaction:



Penicillin G

Penicilloic acid

The penicilloic acid generated is complexed with $CuSO_4$ in the presence of neocuproine. The yellow-colored product formed can be monitored by measuring its absorbance at 465 nm using a colorimeter.

In this task, you will:

- determine the IC_{50} value of a given inhibitor by generating a dose-response curve, and
- calculate the K_i value for the inhibitor.

A dose-response curve for the inhibitor is generated by measuring the activity of β-lactamase in the presence of varying concentrations of the inhibitor at a fixed concentration of the substrate.

Q. 1.A.1. (18 points) Follow the protocol given below and enter the absorbance values **in Table 1.A.1. in the Answer Sheet**.

I. Prepare the following reaction mixtures:

Test tube	Sodium phosphate buffer, pH 7.0	Inhibitor (100 mM)	β-lactamase enzyme	Distilled water
1	1.48 ml	-	20 µl	-
2	1.46 ml	20 µl	20 µl	-
3	1.44 ml	40 µl	20 µl	-
4	1.42 ml	60 µl	20 µl	-
5	1.40 ml	80 µl	20 µl	-
6	1.38 ml	100 µl	20 µl	-
Blank	1.43 ml	50 µl	-	20 µl

II. Mix gently and incubate at room temperature for 5 minutes. **You may use the wall clock or your wrist watch to keep track of the incubation time.**
III. Add 1 ml of penicillin G (0.54 mM) to each tube and mix gently. Incubate at room temperature for 10 minutes.
IV. Add 1.5 ml of the $CuSO_4$-neocuproine reagent to each tube and mix gently. Incubate at room temperature for 5 minutes.
V. Stop the color development by adding 100 µl of HCl to each tube and mix gently.
VI. Set the colorimeter to 465 nm.
VII. Use the Blank to set the absorbance to zero.
VIII. Measure the absorbance values of the solutions in Test tubes 1 to 6, and enter these values in the table. **You should get any one absorbance reading countersigned by the supervisor. To call the supervisor, raise the yellow card.**

Table 1.A.1.

Test tube	Absorbance
1	
2	
3	
4	
5	
6	

Data analysis and interpretation

Q. 1.A.2. (6 points)

I. Calculate the concentrations (in mM) of the inhibitor [I] in 2.5 ml of the enzyme reaction in Test tubes 1 to 6 and enter these values **in Table 1.A.2. in the Answer Sheet.**

II. Consider the absorbance values to be the rates of hydrolysis of penicillin G. Now calculate v_i/v_0, where:

v_0 is the rate of hydrolysis of penicillin G by β-lactamase in the absence of the inhibitor, and v_i is the rate of penicillin G hydrolysis in the presence of the inhibitor. Note that for Test tube 1, $v_i = v_0$.

Enter these values (up to two decimals) **in Table 1.A.2. in the Answer Sheet.**

Table 1.A.2.

Test tube	[I] (mM)	v_i/v_0
1		
2		
3		
4		
5		
6		

Q. 1.A.3. (5 points) Plot a graph of v_i/v_0 versus [I] in the **Graph Paper attached to the Answer Sheet**.

Determination of the IC_{50} and K_i value of the inhibitor

Q. 1.A.4. (3 points) Determine the IC_{50} value by interpolation of the data points in the graph. Write the value (up to two decimals) in the box **in the Answer Sheet**.

IC_{50} = _____ mM

Q. 1.A.5. (3 points) Calculate the dissociation constant K_i of the inhibitor using the equation:

$$IC_{50} = K_i\left(1+\frac{[S]}{K_m}\right)$$

where K_m is the Michaelis-Menten constant of β-lactamase for penicillin G and [S] is the initial concentration of substrate (penicillin G) present in the enzyme reaction mixture.
Assume the K_m of β-lactamase for penicillin G to be **0.05 mM**. Write down your answer (up to two decimals) in the box **in the Answer Sheet**.

K_i = _____ mM

PART B (4 points)

Correlating β-lactamase expression to resistance

When penicillin-resistant bacteria are grown in liquid culture media, β-lactamase is secreted into the medium. The supernatant of such a medium can be assayed for β-lactamase activity. Culture supernatants from four different organisms (P, Q, R and S), which are suspected to be penicillin-resistant, were obtained and 20 µl of each was assayed for β-lactamase activity. The corresponding absorbance values were measured at 465 nm and are given in the table below.

Organism	Absorbance
P	0.090
Q	0.450
R	0.075
S	0.220

These four organisms were tested for their resistance to penicillin G by the disc diffusion plate assay as follows:

1. Each organism was separately inoculated into warm growth medium and poured into a sterile Petri plate. On cooling, the medium solidified.
2. Filter paper discs impregnated with varying concentrations of penicillin G were then placed on the surface of the medium.
3. The plates were incubated allowing penicillin to diffuse and organisms to grow.
4. Organisms sensitive to penicillin will not be able to grow in the vicinity of the antibiotic disc and hence, a clear zone will be obtained around the disc.

You have been given labeled photographs of six plates I - VI.

Plate I is a control plate showing uniform mat growth of organisms in the absence of penicillin G.
Plate II is also a control plate that contains media without the growth of any organism.
Plates III to VI show the growth of the four organisms in the presence of penicillin G. 2.5, 5, 7.5, 10 and 12.5 are the micrograms of penicillin G present in the respective discs.

Q. 1.B.1. (4 points) Observe these plates and infer which organism is growing in each plate. Write your answers **in Table 1.B.1. in the Answer Sheet**.

Table 1.B.1.

Plate	Organism
III	
IV	
V	
VI	

PART C (4 points)

Correlating K_i values of pesticides to bacterial growth

Four pesticides P1 to P4 are reversible inhibitors of an enzyme E that is essential for the growth of a bacterium B. Their K_i values are given in the table below. Each of these four pesticides is used in four geographically different
regions R1 to R4. The residual concentrations of these four pesticides in the respective regions are also shown in the table below:

Region	R1	R2	R3	R4
Pesticide	P1	P2	P3	P4
K_i for the enzyme E	1 nM	5 nM	0.45 μM	0.55 μM
Residual concentration	60 nM	100 pM	30 nM	5.5 μM

Q. 1.C.1. (4 points) Indicate whether the bacterium B would grow or not in each of the four regions by putting tick marks (√) in the appropriate boxes **in the Table 1.C.1. in the Answer Sheet**.

Table 1.C.1.

Region	R1	R2	R3	R4
Bacterium B grows				
Bacterium B does not grow				

********** END OF PRACTICAL TEST 3 **********

PRACTICAL TEST 4: ANIMAL BEHAVIOR

(49 points, 60 minutes)

Task 1 – Part A (6 points)

Study of the olfactory response of *Drosophila melanogaster* larvae

Experimental design

You have been given Part A of this task. You have to answer this part in 10 minutes after which the buzzer will ring and the Answer Sheet for this part will be collected from you. Only then will the rest of the paper be given to you.

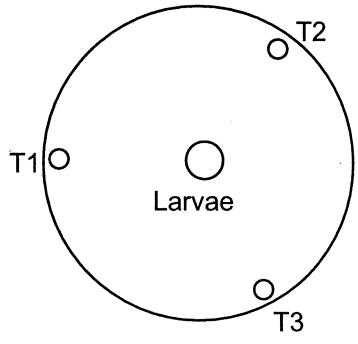
Introduction

Insects have a strong sense of smell. Adult moths, for example, can find their mates by smelling pheromone molecules at very low concentrations. The sense of smell is associated with a discriminatory behavior as well. This is evident from the fact that insects are able to choose their food by odor. The nature of an odor stimulus can be categorized into three types: (1) attractive, (2) repulsive, and (3) neutral.

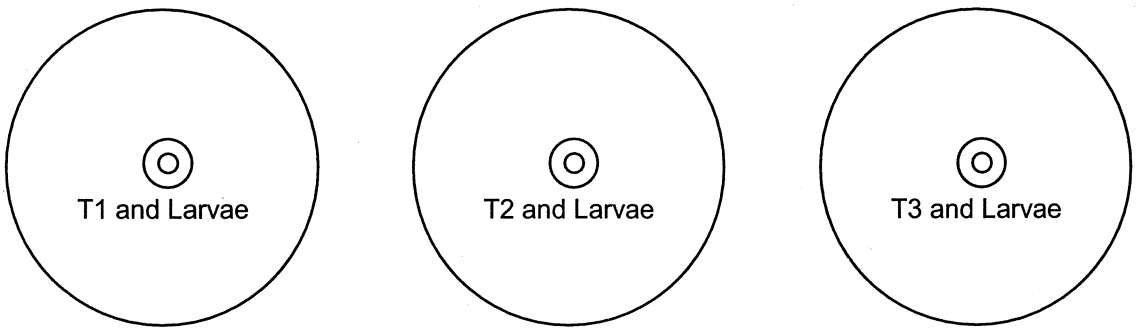
The odor discriminatory behavior of insects such as *Drosophila melanogaster*, the common fruit fly, can be assessed using either the adults or the larvae. *Drosophila* larvae respond to odor stimuli by crawling either towards or away from them. It is, therefore, possible to design an experiment to test the larval response towards different chemicals on a Petri plate.

Q. 1.A.1. (3 points) Suppose you want to determine the response of *Drosophila melanogaster* larvae to three chemical odorants T1, T2, and T3. Five possible experimental designs for this purpose are given below:

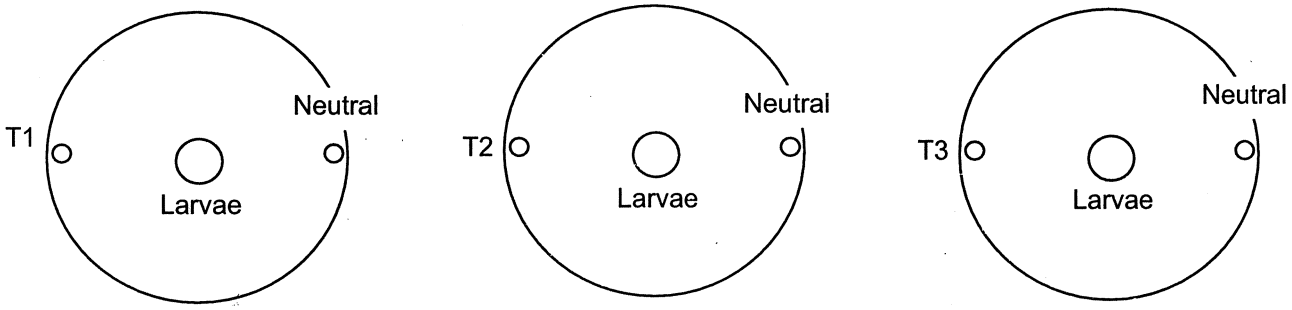
Design I: All the three chemicals are placed at equidistant positions on the periphery of a Petri plate and the larvae are introduced at the centre.



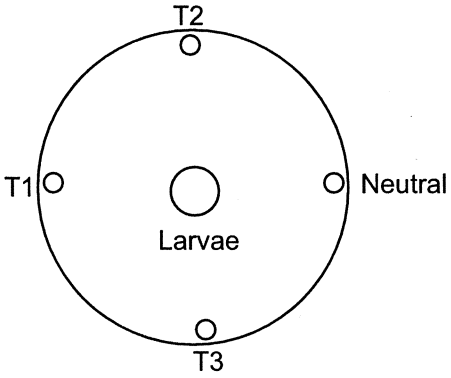
Design II: One of the chemicals and the larvae are placed together at the centre of a plate. Three such plates are set up for the three chemicals.



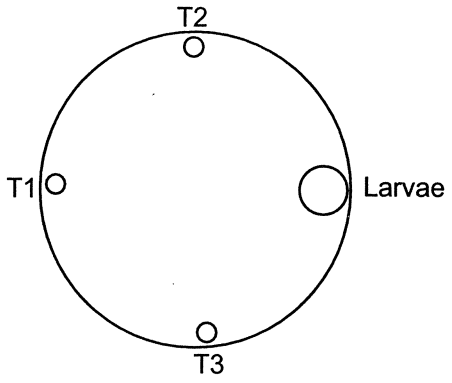
Design III: One of the chemicals and an odor-free (neutral) chemical are placed at two ends of a plate. Larvae are introduced in the centre. The test is repeated for the remaining chemicals.



Design IV: The three test chemicals and a neutral chemical are placed at equidistant positions on the periphery of a plate and the larvae are introduced at the centre.



Design V: The three test chemicals and the larvae are placed at equidistant positions on the periphery of a plate.



Choose the most appropriate experimental design and put a tick mark (√) against it **in Q. 1.A.1. in the Answer Sheet.**

Design I	
Design II	
Design III	
Design IV	
Design V	

Please note that the next question (Q. 1.A.2.) will be evaluated only if your answer to this question (Q. 1.A.1.) is correct.

Q. 1.A.2. (4 points) Mark the following statements as TRUE or FALSE in accordance with your choice of the experimental design.

STATEMENT	TRUE	FALSE
I. It allows the larvae to choose between two or more different chemicals presented simultaneously and thus acts as a discriminatory test.		
II. It can clearly distinguish between attractants and repellants by testing them one at a time against the neutral chemical.		
III. The entire experiment (i.e., testing all the chemicals) can be completed using a single test and thus inter-experimental variation can be avoided.		
IV. It can clearly distinguish the repulsive and attractive nature of the stimuli as each can enhance the response of the larvae to the other(s).		

V. There will not be any mixing of the odors and hence more reliable results will be obtained.		
VI. All the chemicals can be tested against the same control in a single plate.		
VII. Amongst the designs presented, it is the one in which the effect of the weakest odorants can be tested.		
VIII. Larvae can disperse in any direction without any hindrance.		

**********END OF PART A**********

PRACTICAL TEST 4

ANIMAL BEHAVIOR

Task 1 – Parts B and C

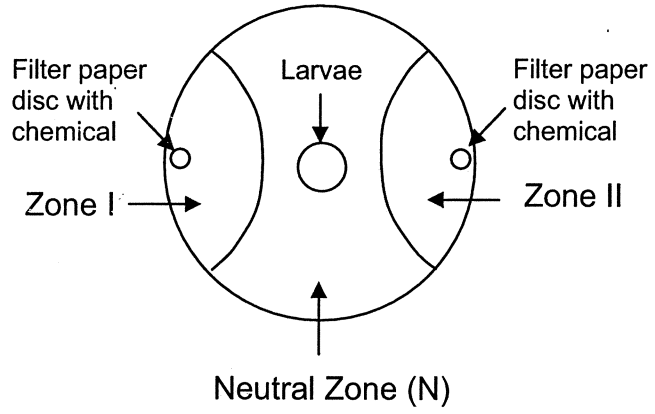
Study of the olfactory and phototactic responses of *Drosophila melanogaster* larvae

You should try and complete Parts B and C of this task in 35 minutes.

Part B (18 points)
Larval plate test

Design

Five experiments were conducted to test the response of *Drosophila melanogaster* larvae to chemical and light stimuli. Four chemical odorants, A, B, C, and D were used in the tests. Of these, D was known to be a neutral chemical while A, B, and C could be an attractant, repellent or a neutral chemical. The design for the experiment is as shown in the figure:



Method

Third instar larvae were used in these experiments. These larvae were obtained by washing the 6-day-old *Drosophila* culture with 15% sucrose solution. The larvae that float in this solution were washed free of sucrose and immediately used in the tests. The tests were performed in Petri plates containing a layer of 1% agarose.

In each experiment, two chemicals were spotted on separate filter paper discs that were placed in two Zones, Z I and Z II (marked as semicircular areas) at two diametrically opposite ends of a Petri plate. Approximately 30-40 larvae were placed at the centre of each plate and their movement over the next five minutes was recorded. Five such experiments were conducted. The recordings of these experiments have been provided to you as video films. Experiments No. 1, 2, and 4 were conducted under uniform light conditions. In Experiments No. 3 and 5, half the plate was covered with black paper and the remaining half was left exposed to light.

Q. 1.B.1. (10 points): Observation of video films

1. Double click on the video file labelled **1** on the computer monitor to observe the movement of larvae.

2. The duration of the video film is 5 minutes, compressed to 2.5 minutes. You may forward or rewind the video film, if required.
3. At the end of the experiment, count the number of larvae in Zone I (N_{ZI}) and Zone II (N_{ZII}).
4. Record your readings **in Table 1.B.1. in the Answer Sheet**.
5. Repeat steps 1 to 4 for the video files labelled **2** to **5**.

Table 1.B.1.

Experiment	Chemical in ZI	Number of larvae in ZI (N_{ZI})	Chemical in ZII	Number of larvae in ZII (N_{ZII})	$\frac{N_{ZI}}{N_{ZI}+N_{ZII}}$	$\frac{N_{ZII}}{N_{ZI}+N_{ZII}}$
1	B		C			
2	A		B			
3	A (in dark)		B			
4	B		D			
5	B (in dark)		C			

Q. 1.B.2. (3 points) What is the likely nature of the three chemicals A, B and C? Put a tick mark (√) in the appropriate box **in the Answer Sheet**.

Chemical	Attractant	Repellant	Neutral chemical	Nature cannot be determined
A				
B				
C				

Q. 1.B.3. (5 points) Based on your observations, mark whether the following statements are true or false by putting a tick mark (√) in the appropriate box **in the Answer Sheet**.

a. Larvae exhibit a stronger positive movement towards the attractant odorant tested than towards darkness.
b. Light is a stronger repelling stimulus for the larvae than the repellant odorant tested.

c. The positive phototaxis shown by the larvae is stronger than the movement towards the attractant odorant.
d. In the presence of light, the larvae do not exhibit chemotaxis.
e. The repellant odorant has a stronger influence on the larvae than does darkness.

	True	False
a.		
b.		
c.		
d.		
e.		

Part C (11 points)

Study of olfactory adaptation in *Drosophila melanogaster* larvae

Continuous stimulation of the olfactory system with a given odor tends to result in adaptation, also known as desensitization. As a result, the larvae fail to respond to the odor to which they have been adapted. A researcher working on olfaction in *Drosophila melanogaster* larvae wanted to study adaptation in these larvae. She selected the following odorants for her study:

1. Ethyl acetate
2. Pentyl acetate
3. Hexyl acetate
4. Heptyl acetate

Pre-stimulation experiment: In each experiment (except in Experiment 1), the larvae were pre-stimulated by placing them in a Petri plate containing 40 microlitres of one of the above odorants for 25 min. The same larvae were then picked up from this plate and tested for their response to the same or different odorants using the protocol described earlier in Part B of Task 1.
The data obtained from these tests are tabulated below.

Data from the pre-stimulation experiment

Experiment	Pre-stimulation	Test odorant							
		Experiment A		Experiment B		Experiment C		Experiment D	
		Ethyl acetate	*	Pentyl acetate	*	Hexyl acetate	*	Heptyl acetate	*
		N_{ZI}	N_{ZII}	N_{ZI}	N_{ZII}	N_{ZI}	N_{ZII}	N_{ZI}	N_{ZII}
1	None	21	3	18	5	14	12	8	13
2	Ethyl acetate	14	11	15	11	13	10	9	15
3	Pentyl acetate	16	15	12	11	9	19	9	14
4	Hexyl acetate	17	9	17	14	16	13	8	13
5	Heptyl acetate	15	10	13	5	8	13	10	13

N_{ZI} and N_{ZII} are the number of larvae in Zone I and Zone II, respectively.

*** Zone II in all the experiments contained a neutral chemical.**

The data given in the table are a set of average responses. The actual numbers varied up to 10% on either side of the average.

Q. 1.C.1. (5 points) Calculate the Response Index (RI) for each experiment according to the formula:

$$RI = \frac{N_{ZI} - N_{ZII}}{N_{ZI} + N_{ZII}} \times 100$$

Fill in the RI values **in Table 1.C.1. in the Answer Sheet.**

Table 1.C.1.

Experiment	Pre-stimulation	Test odorant			
		Experiment A	Experiment B	Experiment C	Experiment D
		Ethyl acetate	Pentyl acetate	Hexyl acetate	Heptyl acetate
		RI	RI	RI	RI
1	None				
2	Ethyl acetate				
3	Pentyl acetate				
4	Hexyl acetate				
5	Heptyl acetate				

Q. 1.C.2. (2 points) To which odorant have the larvae adapted the most?
Put a tick mark (√) in the appropriate box **in the Answer Sheet.**

Ethyl acetate	
Pentyl acetate	
Hexyl acetate	
Heptyl acetate	

Q. 1.C.3. (2 points) To which odorant have the larvae adapted the least?
Put a tick mark (√) in the appropriate box **in the Answer Sheet.**

Ethyl acetate	
Pentyl acetate	
Hexyl acetate	
Heptyl acetate	

Q.1.C.4. (2 points) In which one of the experiments do you find that larval sensitivity to the odorant has been reversed?
Put a tick mark (√) the appropriate box **in the Answer Sheet.**

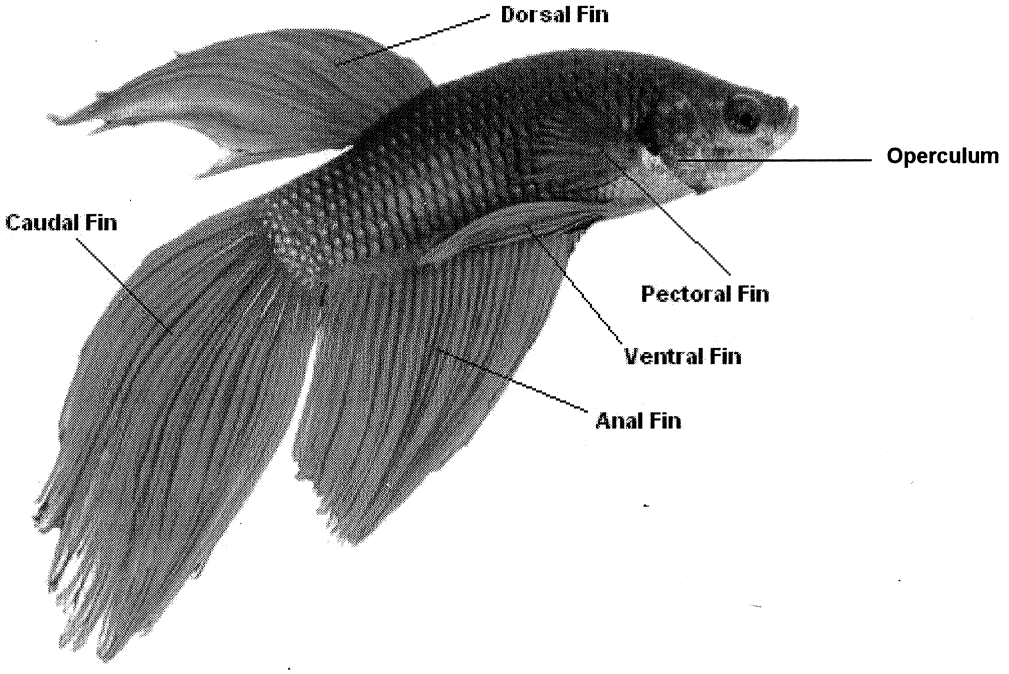
Experiment	Experiment			
	A	B	C	D
1				
2				
3				
4				
5				

Task 2 (13 points)
Study of fish behavior

You should try and complete this task in 15 minutes.

Introduction

The Siamese fighting fish, *Betta splendens,* is one of the most popular species of freshwater aquarium fish. This fish shows varied responses when exposed to different stimuli.



You have been provided with a video recording of an experiment using a male Siamese fighting fish.

Q. 2.1. (11 points) Double click on the video file **6** on the computer monitor and observe the behavior of the fish before and after introduction of a mirror.
After observing the film, write a '+' for the particular behaviors that were displayed by the fish and '-' for those that were not displayed. Record your observations **in Table 2.1. in the Answer Sheet.**

Table 2.1.

Number	Behavior	Before the introduction of the mirror	After the introduction of the mirror
1.	Pectoral fin beating		
2.	Rapid zigzag movement of the body and the caudal fin		
3.	Appearance of horizontal stripes on body		

4.	Pecking at the base of the aquarium		
5.	Brightening of body coloration		
6.	Erection of dorsal, anal and caudal fin		
7.	Appearance of vertical stripes on body		
8.	Operculum display (opening of the operculum)		
9.	Bleaching of body color		
10.	Lateral display*		
11.	Gasping for air		

*The lateral display is a behavior where the fish exhibits the lateral surface of its body, expands its dorsal and caudal fins and vibrates/quivers its body.

Q. 2.2. (1 point) The differences in behavior of the fish that you observed before and after the mirror was introduced into the aquarium could be due to:

a. an apparent increase in the size of the territory that the fish now has to defend.
b. an urge to display courtship behavior towards a conspecific individual that the fish now perceives in its territory.
c. an urge to establish dominance over a conspecific individual that the fish now perceives in its territory.
d. a startle response displayed by the fish when confronted with a mirror.

Put a tick mark (√) in the appropriate box **in Q. 2.2. in the Answer Sheet.**

a.	b.	c.	d.

Q. 2.3. (1 point) Different behaviors in animals have certain benefits and costs associated with them. For example, prolonged extension of the gill cover or operculum display may indicate its physical strength but may also severely limit the ability of the fish to ventilate its gills. In the light of your observation, what could be the rationale for the experimental fish displaying or not displaying this particular behavior?

a. Fish always prefer to maintain regular opercular movement without any display, independent of the presence or absence of another conspecific individual, to maintain the oxygen supply for the body at its optimum.

b. Fish will exhibit the operculum display advertising its ability to tolerate oxygen stress in presence of another conspecific individual to establish its dominance.
c. Operculum display, being an energetically costly behavior, is usually not exhibited by a fish under most circumstances. Males of this species, however, may display this behavior in the presence of a conspecific female because the potential reproductive success that it will acquire will more than compensate for the energetic cost of the display.
d. Operculum display is likely to be determined only by abiotic environmental factors such as level of dissolved oxygen in the water. Thus, fish in sufficiently aerated water will always show this response so as to declare its territory and maintain its dominance.

Put a tick mark (√) in the appropriate box **in Q. 2.3. in the Answer Sheet.**

a.	b.	c.	d.

********** END OF PRACTICAL TEST 4 **********

ANSWER KEY TO EXPERIMENTAL TESTS

PRACTICAL TEST 1

PLANT ANATOMY AND PHYSIOLOGY

Task 1 (33 points)

Study of factors affecting the activity of stomata

Q. 1.1. (0.5 x 6 = 3 points)

	True	False
a.	√	
b.	√	
c.		√
d.		√
e.		√
f.		√

Q. 1. 2. (0.5 points)

a.	b.	c.	d.
√			

Q. 1.3. (2 points)

a.	b.	c.	
	√		X = 0.373 g
			Y = 0.5 ml

Q. 1. 4. (1 x 8 rows = 8 points):

Table 1.4.

Treatment	Total number of stomata counted	Number of open stomata	Number of closed stomata
1	20	20 **(3: 1 in the correct direction; less than 20 stomata counted – no marks)**	0 **(±5)**
2	20	0	20
3	20	0	20
4	20	0	20
5	20	20	0
6	20	20	0
7	20	20	0
8	20	0	20

Q. 1. 5. (2 x 5 = 10 points)

A. 4, 10

B. 5

C. 3, 9

D. 1, 2, 6, 7, 8

Q. 1. 6. (2.5 points)

a.	b.	c.	d.
	√		

Q. 1. 7. (2.5 points)

a.	b.	c.	d.	e.
			√	

Q. 1. 8. (2.5 points)

a.	b.	c.	d.	e.
		√		

Q. 1. 9. (0.5 x 4 = 2 points)

Step I: 1

Step II: 2

Step III: **8**

Step IV: 6

Step V: **4**

Step VI: **9**

Step VII: **11**

Task 2 (14 points)

Study of plant anatomy and its correlation with the habitat

Q. 2.1. (2 x 2 = 4 points)

I. Trichomes — E

II. Stomata — P

Q. 2.2. (0.5 x 8 = 4 points)

	Present	Absent
7. Cuticle	√	
8. Sclerenchyma	√	
9. Collenchyma	√	
10. Air spaces		√
11. Water storage tissue	√	
12. Glands:		
a. Oil gland		√
b. Salt gland	√	
c. Digestive gland		√

Q. 2.3. (0.5 x 7 = 3.5 points)

	Present	Absent
7. Cuticle	√	
8. Sclerenchyma	√	
9. Collenchyma	√	
10. Air spaces	√	
11. Water storage tissue		√
12. Vascular bundle:	Open	Closed
		√
	Collateral	Bicollateral
	√	

Q. 2.4. (2.5 points)

a.	b.	c.	d.	e.	f.	g.	h.
						√	

********** END OF PRACTICAL TEST 1 **********

PRACTICAL TEST 2

ANIMAL ANATOMY AND PHYSIOLOGY

Task 1 (54 points)

Study of animal skeletal systems

Q. 1.A.1. (2 points)

a.	
b.	√
c.	
d.	

Q. 1.A.2. (1 x 6 = 6 points)

Table 1.A.2.

Character		1	2	3
Type of skull	Anapsid		√	
	Diapsid	√		
	Synapsid			√
	Euryapsid			
Type of dentition	Homodont	√	√	
	Heterodont			√

Q. 1.A.3. (1 x 6 = 6 points)

Table 1.A.3.

Features		1	2	3
Vision	Predominantly stereoscopic vision			
	Predominantly non-stereoscopic vision	√	√	√
Feeding habit	Predominantly carnivorous	√	√	
	Predominantly herbivorous			√

Q. 1.B.1. (1 x 8 = 8 points)

Table 1.B.1.

Characters		4	5	6
Ribs	Present	√	√	
	Absent			√
Major type of ribs	True	√		
	False			
	Floating		√	
Tail	Present	√	√	
	Reduced /Absent			√

Q. 1.B.2. (1 x 3 = 3 points)

Table 1.B.2.

Feature		4	5	6
Neck movement	Restricted			√
	Free	√	√	

Q. 1.C.1. (1 x 12 = 12 points)

Table 1.C.1.

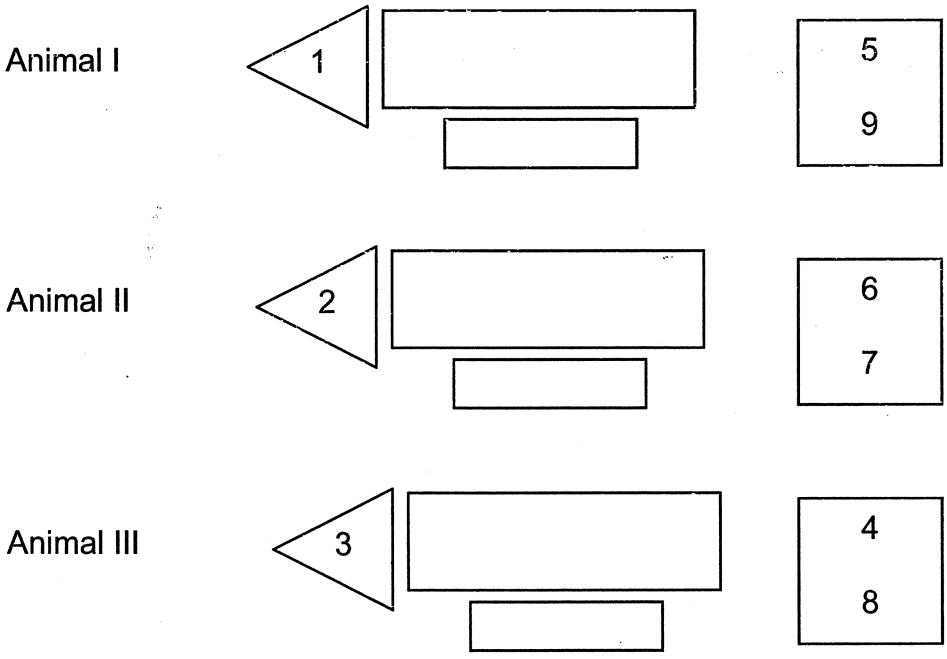
Characters		7	8	9
Position of limb with respect to body	Sprawled	√		√
	Underneath		√	
Length of fore- and hindlimbs	Similar			
	Fore limbs longer			
	Hind limbs longer	√	√	√
Claws	Present		√	√
	Absent	√		
Modifications	Tibia and fibula completely fused	√		
	Tibia and fibula partially separate		√	√

Q. 1.C.2. (1 x 8 = 8 points)

Table 1.C.2.

Features		7	8	9
Limb movement during locomotion	Swinging (rotational movement)	√		√
	Pendulum-like		√	
Habit of the animal	Saltatorial (jumping)	√		
	Cursorial (walking)		√	√
	Fossorial (digging)		√	√

Q. 1.D.1 (1 x 6 = 6 points)



Q. 1.D.2 (1 x 3 = 3 points):

Animal I: Class: B

Animal II: Class: D

Animal III: Class: A

Task 2 (12 points)

Semi-quantitative estimation of nitrogenous waste products

Q. 2.1.1. to 2.1.3. (1 x 9 = 9 points)

Table 2.1.

All three rows must be filled completely and the maximum weightage must be for the correct chemical

Samples	Uric acid test	Urea test	Ammonia test
S1	++/+	+++	+
S2	+	++/+	++++
S3	+++	++	+
Positive control	+++	+++	+++
Negative control	-	-	-

Q. 2. 2. (3 points):

Answer: ____d____

********** END OF PRACTICAL TEST 2 **********

PRACTICAL TEST 3

BIOCHEMISTRY AND CELL BIOLOGY

Task 1

Study of β-lactamase activity and its inhibition

PART A (35 points)

Q. 1.A.1. (3 x 6 = 18 points)

Table A.1.

Test tube	Absorbance
1	0.84 (0.756 – 0.924: 3 points) (0.672-0.755 – 0.925-1.008: 1.5 points)
2	0.84 (0.756 – 0.924: 3 points) (0.672-0.755 – 0.925-1.008: 1.5 points)
3	0.75 (0.675 – 0.825: 3 points) (0.600-0.674 – 0.826-0.900: 1.5 points)
4	0.57 (0.513 – 0.627: 3 points) (0.456-0.512 – 0.628-0.684: 1.5 points)
5	0.16 (0.144 – 0.176: 3 points) (0.128-0.143 – 0.177-0.190: 1.5 points)
6	0.00

Q. 1.A.2. (1 x 6 = 6 points)

Table 1.A.2.

Test tube	[I] (mM)	v_i/v_0
1	0	
2	0.8	
3	1.6	
4	2.4	
5	3.2	
6	4.0	

Q. 1.A.3. (5 points): Points will be transferred from the Graph Paper.

1 point each for the correct axes.

0.5 point for the correct plotting of each data point.

Q. 1.A.4. (3 points)

IC_{50} = 2.7 mM

2.0 – 3.4 (3 points)

1.4-1.9 – 3.5-4.1 (1.5 points)

Q. 1.A.5. (3 points)

K_i = 0.508 mM 0.375 – 0.625 (3 points) 0.250-0.374 – 0.626-0.750 (1.5 points)

PART B (4 points)

Q. 1.B.1. (1 x 4 = 4 points)

Table 1.B.1.

Plate	Organism
III	P or R or both
IV	P or R or both
V	S
VI	Q

PART C (4 points)

Q. 1.C.1. (1 x 4 = 4 points)

Table 1.C.1.

Region	R1	R2	R3	R4
Bacterium B grows		√	√	
Bacterium B does not grow	√			√

********** END OF PRACTICAL TEST 3 **********

PRACTICAL TEST 4

ANIMAL BEHAVIOR

Task 1 – Part A (7 points)

Study of the olfactory response of *Drosophila melanogaster* larvae

Experimental Design

Q. 1.A.1. (3 points)

Design I	
Design II	
Design III	√
Design IV	
Design V	

Q. 1.A.2. (4 points)

I.	II.	III.	IV.	V.	VI.	VII.	VIII.
F	T	F	F	T	F	T	T

**********END OF PART A**********

Task 1 – Parts B and C

Study of the olfactory response of *Drosophila melanogaster* larvae

Part B (18 points)

Larval Plate Test

Q.1.B.1 (0.5 x 20 = 10 points)

Table 1.B.1.

Experiment	Chemical in ZI	Number of larvae in ZI (N_{ZI})	Chemical in ZII	Number of larvae in ZII (N_{ZII})	$\frac{N_{ZI}}{N_{ZI}+N_{ZII}}$	$\frac{N_{ZII}}{N_{ZI}+N_{ZII}}$
1	B	2 / 3	C	20 / 21	0.08 / 0.09 / 0.1	0.8 / 0.9
2	A	4 / 5 / 6	B	11 / 12 / 13 / 14	0.2 / 0.3 / 0.4	0.6 / 0.7 / 0.8
3	A (in dark)	9 / 10 / 11 / 12	B	2 / 3	0.8	0.1 / 0.2
4	B	7	D	6	0.5	0.5
5	B (in dark)	2 / 3	C	16 – 29	0.1	0.9

Q.1.B.2. (1 x 3 = 3 points)

Chemical	Attractant	Repellant	Neutral chemical	Nature cannot be determined
A		√		
B			√	
C	√			

Q.1.B.3. (1 x 5 = 5 points)

	True	False
a.	√	
b.	√	
c.		√
d.		√
e.		√

Part C (11 points)

Study of olfactory adaptation in *Drosophila melanogaster* larvae

Q.1.C.1. (0.25 x 20 = 5 points)

Table 1.C.1.

Experiment	Pre-stimulation	Test odorant			
		Experiment A	Experiment B	Experiment C	Experiment D
		Ethyl acetate	Pentyl acetate	Hexyl acetate	Heptyl acetate
		RI	RI	RI	RI
1	None	75.0	56.5	7.6	- 23.8
2	Ethyl acetate	12.0	15.4	13.0	- 25.0
3	Pentyl acetate	3.2	4.34	35.7	- 21.7
4	Hexyl acetate	30.7	9.6	10.3	- 23.8
5	Heptyl acetate	20.0	44.4	- 23.8	- 13.0

Q. 1.C.2. (2 points)

Ethyl acetate	
Pentyl acetate	√
Hexyl acetate	
Heptyl acetate	

Q. 1.C.3. (2 points)

Ethyl acetate	
Pentyl acetate	
Hexyl acetate	√
Heptyl acetate	

Q. 1.C.4. (2 points)

Experiment	Experiment			
	A	B	C	D
1				
2				
3				
4				
5			√	

Task 2

Study of fish behavior

Q. 2.1. (1 x 11 = 11 points)

Table 2.1.

Number	Before the introduction of the mirror	After the introduction of the mirror
1.	+	+
2.	–	+
3.	–	–
4.	–	–
5.	–	–
6.	–	+
7.	–	–
8.	–	+
9.	–	–
10.	–	+
11.	+	+

Q. 2.2. (1 point)

a.	b.	c.	d.
		√	

Q. 2.3. (1 point)

a.	b.	c.	d.
	√		

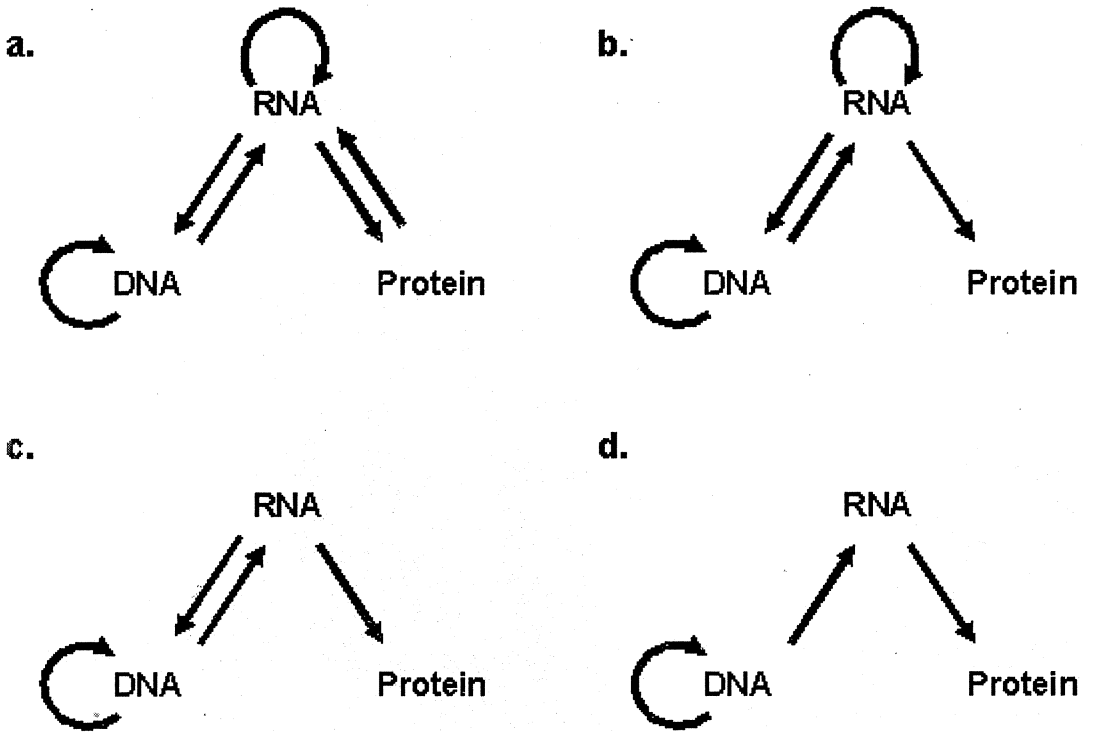
**********END OF PRACTICAL TEST 4**********

THE THEORETICAL TEST

THEORETICAL TEST – PART A

CELL BIOLOGY (13 points)

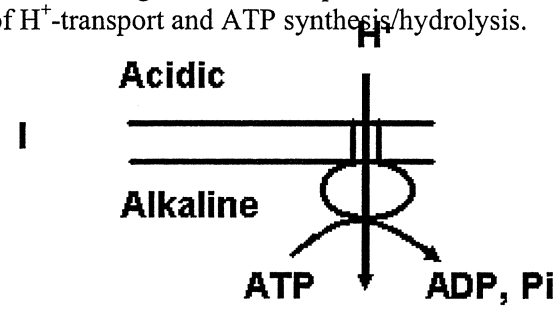
1. (1 point) The central dogma originally proposed by Francis Crick has seen changes reflecting new insights obtained from time to time. Which one of the following schematics correctly depicts our current understanding of the replication of genetic material and the "flow of information" in biological systems?

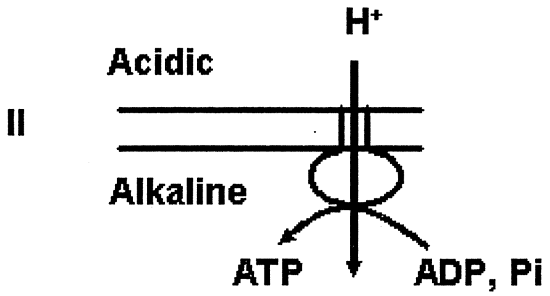


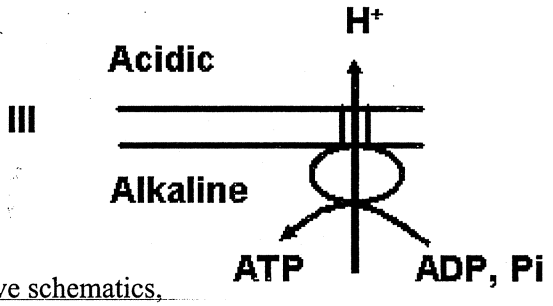
2. (1 point) In an experiment, mice were injected intravenously with uniformly labeled [^{14}C] – glucose. The molecules in the body where the ^{14}C would be found are:

a. essential amino acids and proteins.
b. lipids and all vitamins.
c. proteins and lipids.
d. proteins and all vitamins.

3. (1 point) The following schematics depict the orientation of F_1F_O-ATPase along with the direction of H^+-transport and ATP synthesis/hydrolysis.





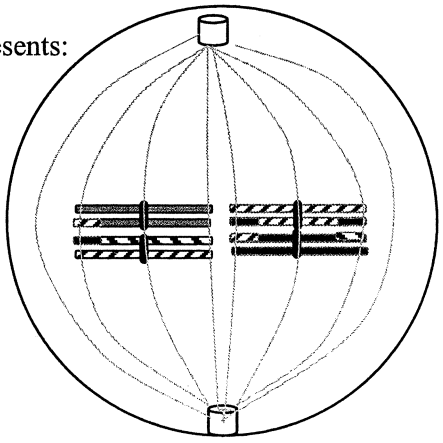


Of the above schematics,

a. Only I is correct.
b. Only II is correct.
c. Only III is correct.
d. Both I and III are correct.

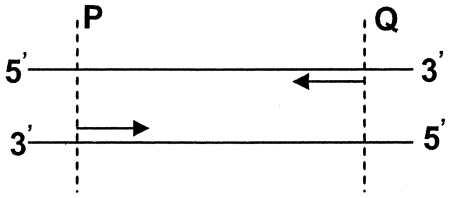
4. (1 point) A given DNA sample has 60% purines. The source of this DNA is most likely to be:
   a. a eukaryotic cell.
   b. a bacterial cell.
   c. a bacteriophage with double-stranded DNA.
   d. a bacteriophage with single-stranded DNA.

5. (1 point) The stage of cell division shown in the figure below represents:



a. Meiotic metaphase I with n = 4
b. Meiotic metaphase II with n = 4
c. Meiotic metaphase II with n = 8
d. Meiotic metaphase I with n = 2

6. (1 point) Polymerase Chain Reaction (PCR) is a technique for rapid amplification of DNA segments. If you are given double-stranded DNA with appropriate forward and reverse primers as shown in the figure below, the minimum number of cycles you will require to obtain at least one copy of the desired fragment PQ, as dsDNA without overhangs, will be:



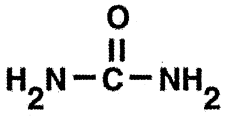
a. 1
b. 3
c. 4
d. 40

7. (1 point) Which of the primer pairs is the correct one to amplify the gene sequence below with PCR?

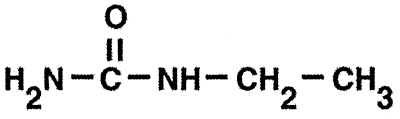
5'-GCGTTGACGGTATCAAAACGTTAT... ...TTTACCTGGTGGGCTGTTCTAATC-3'

a. 5'-GCGTTGACGGTATCA-3' and 5'-TGGGCTGTTCTAATC-3'
b. 5'-CGCAACTGCCATAGT-3' and 5'-TGGGCTGTTCTAATC-3'
c. 5'-GCGTTGACGGTATCA-3' and 5'-GATTAGAACAGCCCA-3'
d. 5'-TGATACCGTCAACGC-3' and 5'-GATTAGAACAGCCCA-3'

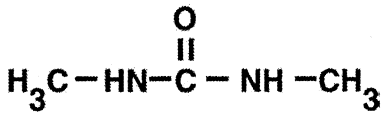
8. (1 point) Equimolar concentrations of urea, ethyl urea, and dimethyl urea were separately added to a suspension of red blood cells (RBC). The relative rates of diffusion of these molecules into RBCs will be:



1. Urea



2. Ethyl urea



3. Dimethyl urea

a. 1 > 2 > 3
b. 1 > 2 = 3
c. 3 > 2 > 1
d. 3 = 2 > 1

9. (1 point) A region of a double-stranded DNA is represented in the following schematic and the hyphens denote sequences of unspecified lengths:

```
5′ ----GACTAG GACTA------GTACA TGCTA----3′
3′ ----CTGATC CTGAT------CATGT ACGAT----5′
```

The region of DNA enclosed within the box undergoes inversion. Which one of the following correctly depicts the above DNA after inversion?

a.
```
5′ ----GACTAG ACATG------ATCAG TGCTA----3′
3′ ----CTGATC TGTAC------TAGTC ACGAT----5′
```

b.
```
5′ ----GACTAG ATCAG------ACATG TGCTA----3′
3′ ----CTGATC TAGTC------TGTAC ACGAT----5′
```

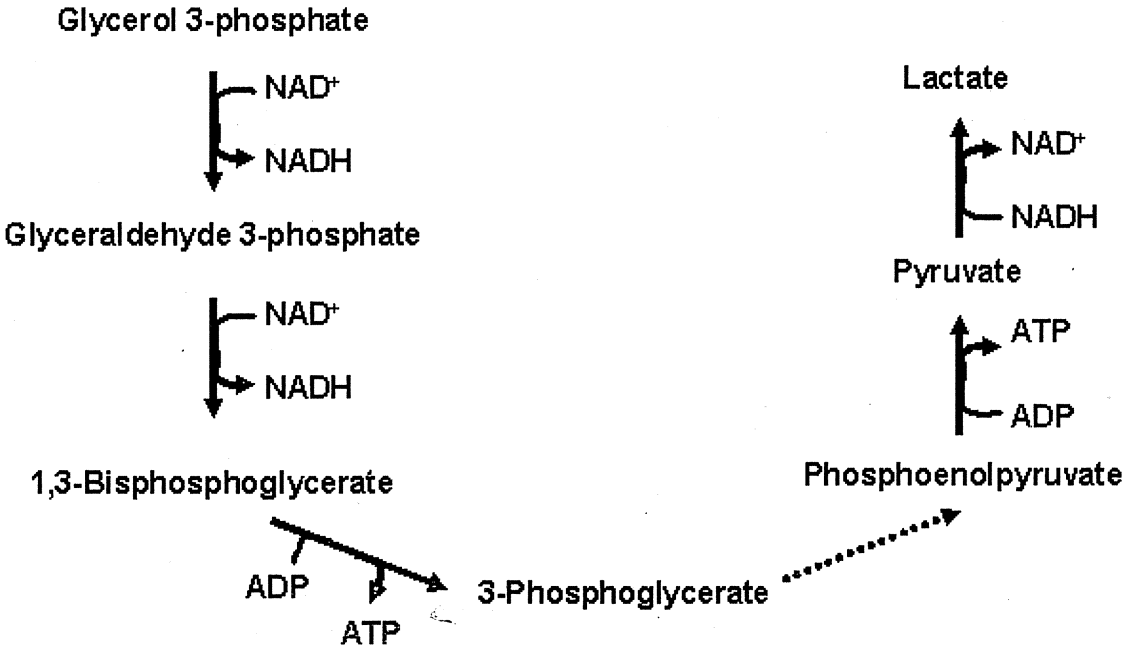
c.
```
5′ ----GACTAG TGTAC------TAGTC TGCTA----3′
3′ ----CTGATC ACATG------ATCAG ACGAT----5′
```

d.
```
5′ ----GACTAG CTGAT------CATGT TGCTA----3′
3′ ----CTGATC GACTA------GTACA ACGAT----5′
```

10. (1 point) A rare genetic disease is characterized by immuno-deficiency, developmental and growth delay, and microcephaly. Suppose you extract DNA from a patient with this syndrome and find almost equal quantities of long and very short DNA strands, which enzyme is likely to be defective in this patient?

a. DNA ligase
b. Topoisomerase
c. DNA polymerase
d. Helicase

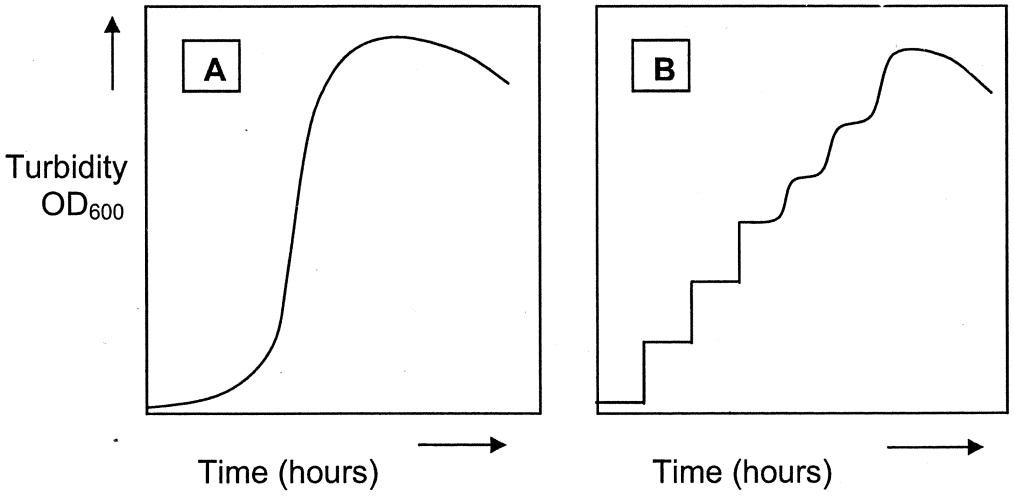
11. (1 point) A scientist has suggested that a homolactic fermenting organism grows anaerobically on glycerol 3-phosphate as the sole source of carbon, exclusively using the following pathway:



However, the scientific community rejected this suggestion because:

a. the number of ATP molecules produced is insufficient to support growth.
b. the number of NAD^+ that are reduced is not same as the number of NADH that are oxidized in the pathway.
c. the carbon source is not as reduced as glucose and hence, cannot support growth.
d. the number of negative charges on lactic acid (which is being produced) is not the same as that on glycerol 3-phosphate (which is being consumed).

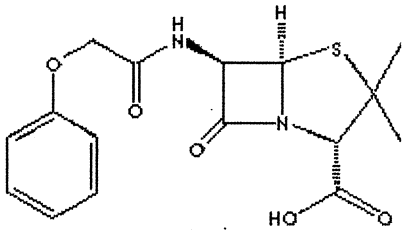
12. (1 point) The growth curve of a bacterial culture grown in a rich medium at 37°C is shown in Figure A. The same organism when exposed to 45°C for 30 min and then inoculated into a rich medium at 37°C, exhibited a growth curve shown in Figure B.



Which of the following statements is most likely to explain the growth pattern in Figure B?

a. Heat kills the original bacterial population and the growth pattern observed is due to a contaminating bacterial strain.
b. Heat causes growth arrest at a particular stage, thereby synchronizing cells and resulting in all cells dividing at the same time.
c. Heat exposure alters surface properties of cells causing errors in turbidity measurements.
d. The increase in turbidity is not due to growth but caused by increasing lysis of heat-treated cells with time.

13. (1 point) Absorption of a drug in the gastro-intestinal tract depends on a number of factors. Penicillin V, whose structure is shown below, is a weak acid (pKa = 2.7). The pH in stomach is about 2.0 and that in the intestine is 7.5. Most of the drug is absorbed in the intestine.



Choose the most likely reason for this from the following statements:

a. The drug being hydrophobic in nature, passes through gastric and intestinal membranes to a very small extent. However, because of the much greater surface area in the intestine, the major quantity of the drug is absorbed here.
b. The un-ionized form of the drug prevails in stomach, which slows down its absorption. Hence, the drug gets preferentially absorbed in the intestine.
c. The ionized form of the drug prevails in the intestine which hinders/slows down its absorption. However, owing to the large surface area available in the intestine, the drug is absorbed mainly here.
d. Due to rapid churning movement and the low pH in the stomach, the drug is completely broken down into smaller fragments, which are subsequently absorbed in the intestine.

PLANT SCIENCES (9 points)

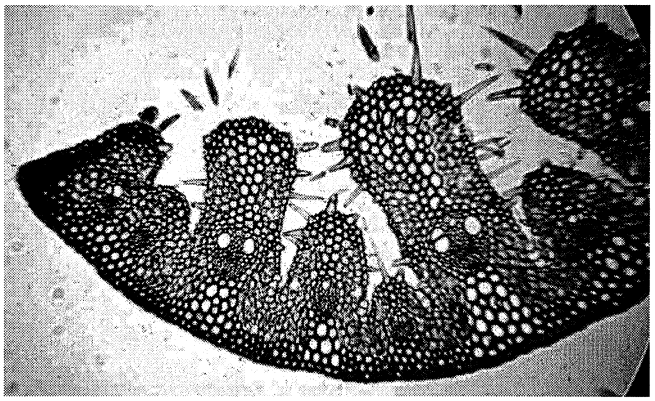
14. (1 point) Which of the following will harm a dicotyledonous plant the most?

a. Removal of the central pith
b. Removal of the cork
c. Removal of the bark
d. Removal of the cork cambium

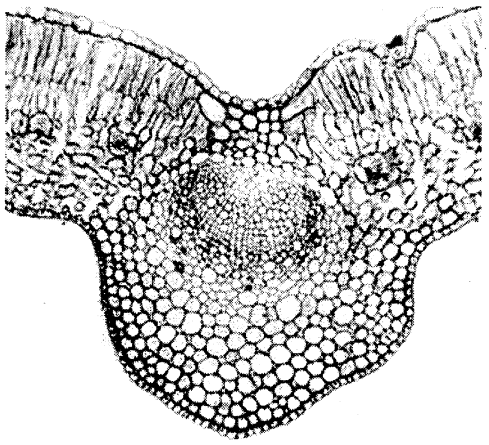
15. (1 point) The transverse sections of the leaves A and B given below represent, respectively:

a. a xerophyte and a mesophyte.

A



B



b. a xerophyte and a floating hydrophyte.
c. a floating hydrophyte and a submerged hydrophyte.
d. a submerged hydrophyte and a xerophyte.

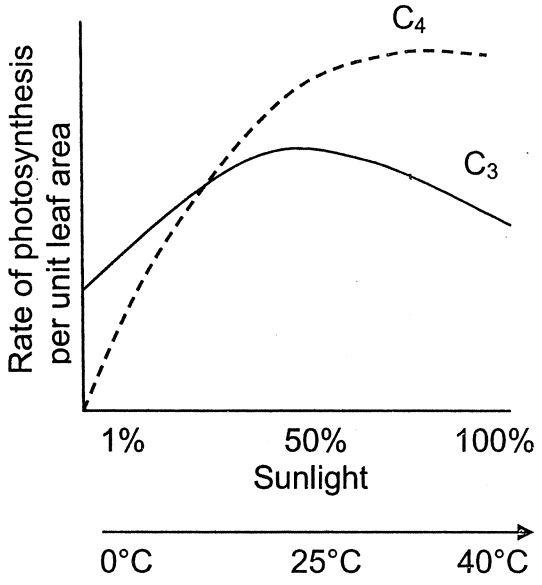
16. (1 point) Certain plant species such as Red Oak (*Quercus rubra*) can tolerate severe drought over a long period of time without affecting its photosynthesis. Which of the following adaptations is likely to contribute to this ability?
    a. Stomatal closure
    b. Large negative leaf water potential
    c. Bundle sheath cells with chloroplasts (Kranz leaf anatomy)
    d. Fibrous root system that increases root surface area

17. (1 point) The net assimilation of CO_2 of a plant is 0.5 moles when illuminated during the day. The net consumption of O_2 is 0.12 moles during the night. Assuming that all the gas exchange is due to photosynthesis and respiration of the biomass (equivalent molecular mass of 30), what is the net production or consumption of biomass in grams during a complete 12 h day:12 h night diurnal cycle?

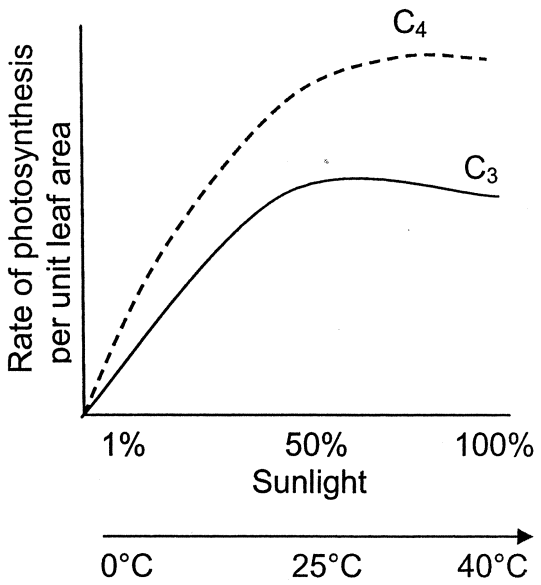
a. 3.6 g
b. 7.8 g
c. 11.4 g
d. 15.0 g

18. (1 point) Choose the figure that correctly represents the photosynthetic efficiencies of C_3 and C_4 plants.

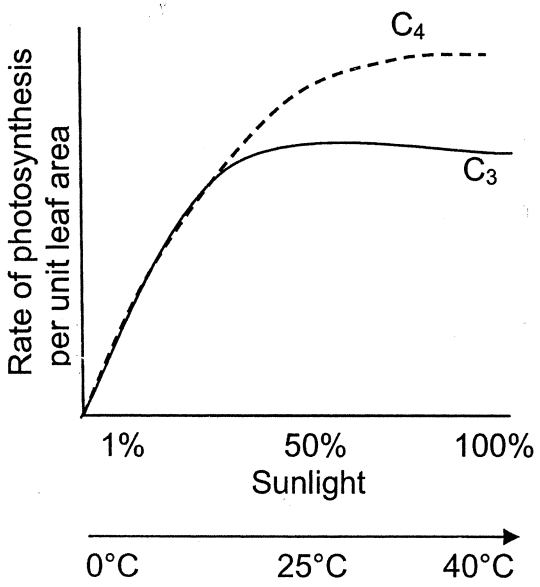
a.



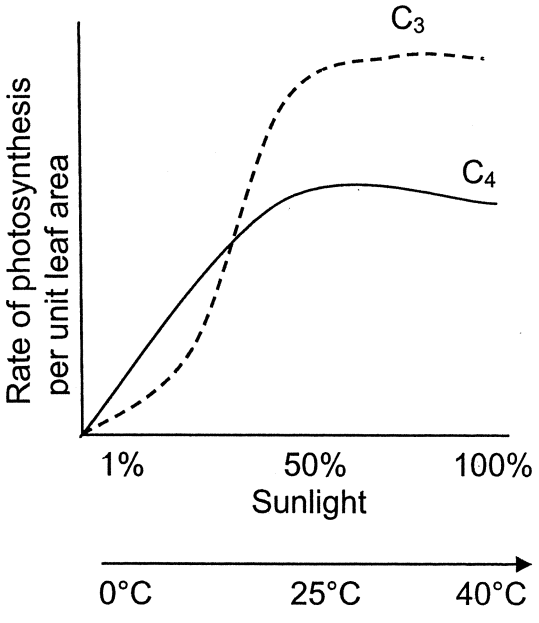
b.



c.



d.

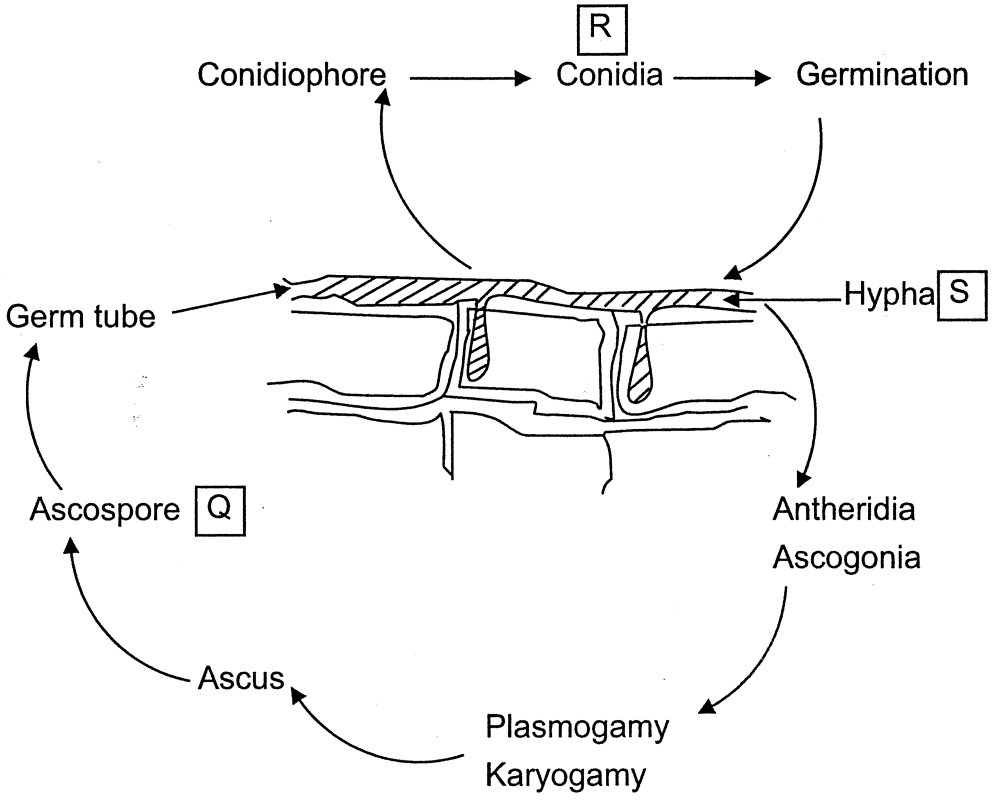


19. (1 point) Plant chloroplasts are believed to have evolved from cyanobacteria-like progenitors through endosymbiosis. Which of the following statements support this hypothesis?

I. Chloroplasts and cyanobacteria share similar photosynthetic pigments and thylakoid membranes.
II. Cyanobacteria exhibit an oxygenic photosynthesis.
III. Chloroplasts are maternally inherited.
IV. Chloroplasts have their own DNA and ribosomes.
V. Viable chloroplasts can be isolated from cells but cannot be cultured in vitro.
VI. Prokaryotic genes express well in chloroplasts.

a. I, III, IV and V
b. I, II, IV and VI
c. I, II, III and V
d. II, IV, V and VI

20. (1 point) Powdery mildew is a plant disease caused by an ectoparasitic fungus. The fungal infection can spread to neighboring host cells in the following ways:



The ploidy levels of the structures Q, R and S are, respectively:

a. 2n, n, n
b. n, n, n
c. 2n, n, 2n
d. n, n, 2n

21. (1 point) A few characteristics of photoautotrophs are tabulated below.

Group	Light compensation point (klux units)	Light saturation point (klux units)	CO_2 compensation point (ppm)
I	1 – 3	> 80	0
II	1 – 2	50 – 80	> 40
III	0.2 – 0.5	5 – 10	> 40
IV	Data not available	1 – 2	Data not available

The four groups (I –IV) represent, respectively:

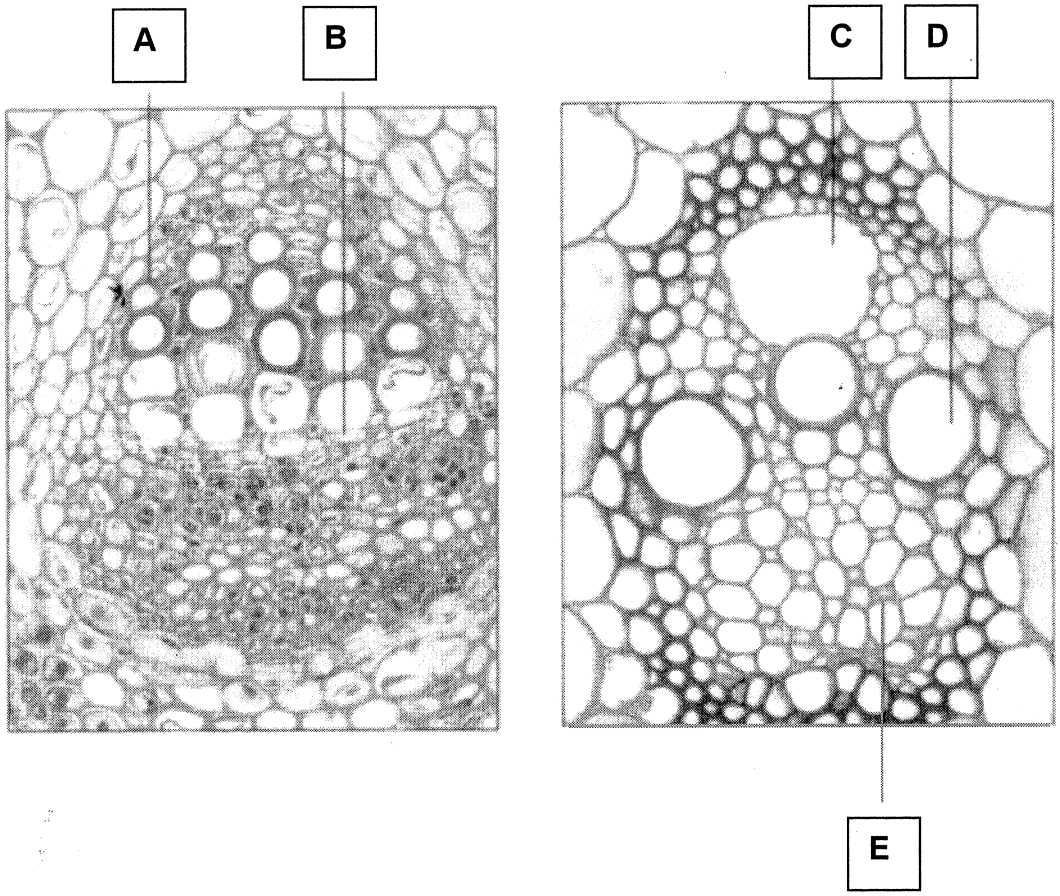
a. I: C_4 plants
III: Shade-loving C_3 plants
II: Sun-loving C_3 plants
IV: Deep-sea algae

b. I: Sun-loving C_3 plants
III: C_4 plants
II: Shade-loving C_3 plants
IV: Bryophytes

c. I: C_4 plants
III: Sun-loving C_3 plants
II: Bryophytes
IV: Shade-loving C_3 plants

d. I: C_4 plants
III: Deep-sea algae
II: Sun-loving C_3 plants
IV: Bryophytes

22. (1 point) The stem of a lily plant was placed in water tinted with red ink to monitor the movement of water through it. Two transverse sections of stems are given below. In which of the labeled structures would you expect the red color?



a. A
b. B
c. C
d. D
e. E

ANIMAL SCIENCES (11 points)

23. (1 point) A few intact skeletons of birds were found during a field trip to the Pampas in Argentina. In all the skeletons examined, the sternum lacked a keel bone. These skeletons most likely belonged to:

a. terrestrial birds capable of short and powerful flight.
b. flightless aquatic birds.
c. insectivorous flying birds.
d. flightless terrestrial birds.

24. (1 point) Which one of the following is a feature of a heterothermic endotherm?

a. Its body temperature can vary, but it produces heat from its own tissues.
b. Its body temperature varies because it gains most of the heat from sources outside its body.
c. Its body temperature does not vary because it produces heat from its own tissues.
d. Its body temperature does not vary even though it gains heat from sources outside its body.

25. (1 point) Which of the following will be an advantage of breathing in air over breathing in water?

I. As air is less dense than water, less energy is required to move air over respiratory surfaces.
II. Oxygen diffuses faster through air than it does through water.
III. The oxygen content of air is greater than that of an equal volume of water.

a. Only I and II
b. Only I and III
c. Only II and III
d. I, II and III

26. (1 point) Which characteristics would allow you to declare an organism found on a beach as an echinoderm?

a. Radially symmetric adults with presence of spines and tube feet.
b. Radially symmetric adults with dorsal hollow notochord.
c. Exoskeleton with pharyngeal gill-slits and tube feet.
d. Radially symmetric adults with mantle cavity.

27. (1 point) In an individual X, the pituitary gland was found to function normally while the adrenal glands were atrophied. In another individual Y, both the pituitary and adrenal glands were found to be underdeveloped. If adrenocorticotropic hormone (ACTH) is administered to these individuals as a remedial measure, it will be effective in:

a. individual X alone.
b. individual Y alone.
c. both X and Y.
d. neither X nor Y.

28. (1 point) Which of the following are associated with stereoscopic vision?

I. Effect of the blind spot of one eye is cancelled by the other eye.
II. Total visual field of 360° and frontal visual field of 30°.
III. Likely to be observed in predatory birds.
IV. Centrally situated fovea that gives good visual acuity.

a. I, II and IV
b. I, II and III
c. II, III and IV
d. I, III and IV

29. (1 point) The glycoside "Phloridzin" present in apple peel can block the normal reabsorption of glucose from kidney tubules. As a result, sugar is almost completely excreted through the urine. A mouse fed with Phloridzin along with sodium succinate will develop:
a. hypoglycemia and no sugar will be detected in the urine sample.
b. hyperglycemia and urine test for sugar will be positive.
c. hyperglycemia and no sugar will be detected in the urine sample.
d. hypoglycemia and urine test for sugar will be positive.

30. (1 point) Cardiac output is defined as the amount of blood pumped by each ventricle. It is determined by multiplying the heart rate and the stroke volume. The stroke volume is the amount of blood ejected by each ventricle with each beat. If the heart of a woman beats 56 times in a minute, the volume of blood in her heart is 120 ml at the end of diastole and 76 ml at the end of systole, what would be her cardiac output?
a. 10.976 L/min
b. 2.464 L/min
c. 6.720 L/min
d. 4.256 L/min

31. (1 point) The drinking water consumed by a population is contaminated with a modified bisphenol-A, which is not degraded in the body. As a result, there are measurable levels of this compound in the blood. Which of the following would result if the modified bisphenol-A were an oestrogen-mimicking compound?
a. Males would have decreased sperm production.
b. Males would have elevated levels of follicle-stimulating hormone.
c. Females would have elevated levels of gonadotropin-releasing hormone.
d. Males would have elevated levels of blood testosterone.
e. Follicle stimulation would increase in females.

32. (1 point) If a molecule of carbon dioxide released into the blood in your left foot travels out of your nose, it must pass through all of the following structures except the:
a. right atrium
b. pulmonary vein
c. alveolus
d. bronchus
e. pulmonary artery

33. (1 point) The process of artificial kidney dialysis is shown schematically using the following symbols:

O : erythrocyte

○ : salts

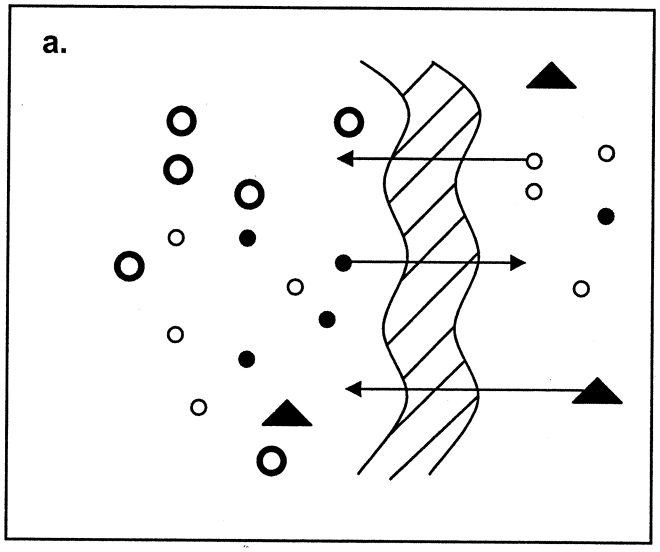
 : semi-permeable membrane

● : urea

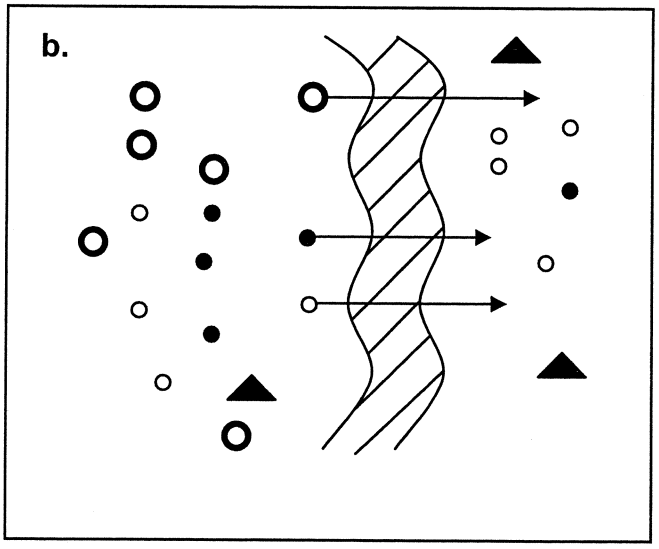
▲ : proteins

Which of the following correctly depicts the process?

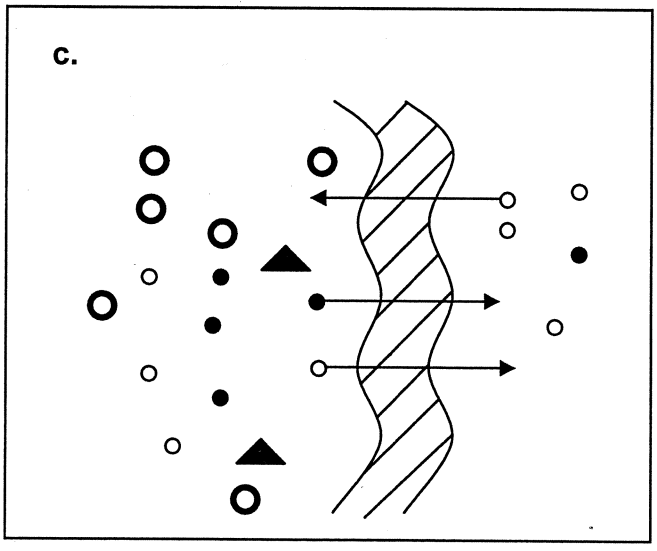
a.



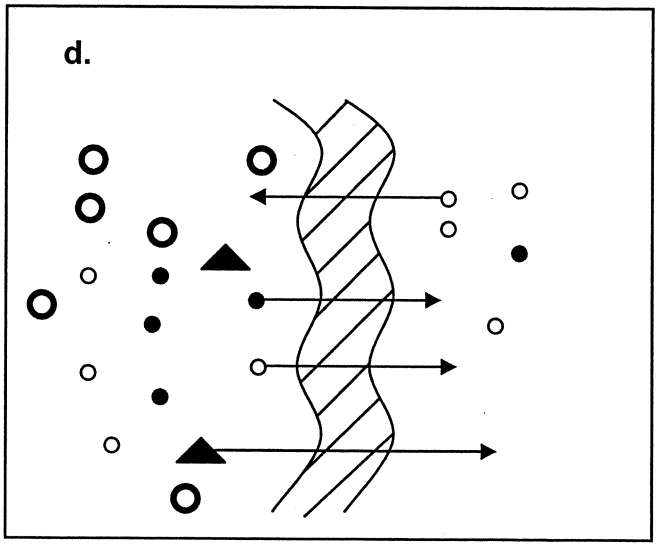
b.



c.



d.



GENETICS AND EVOLUTION (17 points)

34. (1 point) A mutation results in the absence of sweat glands, a disease called anhidrotic ectodermal dysplasia. A woman suffering from this disease has a mosaic of skin patches lacking sweat glands. The woman is likely to be:

a. homozygous for an autosomal recessive mutation.
b. heterozygous for an autosomal dominant mutation.
c. homozygous for a X-linked recessive mutation.
d. heterozygous for a X-linked recessive mutation.

35. (1 point) A mink breeder allows random mating among his minks. He discovers that, on an average, 9% of his minks have rough fur that fetches less money when sold. So he decides to focus upon smooth fur and does not allow minks with rough fur to mate. Rough fur is linked to an autosomal recessive allele. What is the theoretical percentage of minks with rough fur that he will obtain in the next generation?

a. 7.3
b. 5.3
c. 2.5
d. 1.2

36. (1 point) In a breed of rabbits, multiple alleles with the following dominance relationships control coat coloration:
C (agouti) > c^{ch} (chinchilla) > c^{h} (Himalayan) > c (albino).
An experimental cross between agouti and Himalayan produced 50% agouti and 50% Himalayan progeny. Which of the following crosses could produce this result?

I. Cc^{h} X $c^{h}c^{h}$
II. Cc X $c^{h}c$
III. Cc^{h} X $c^{h}c$
IV. Cc X $c^{h}c^{h}$

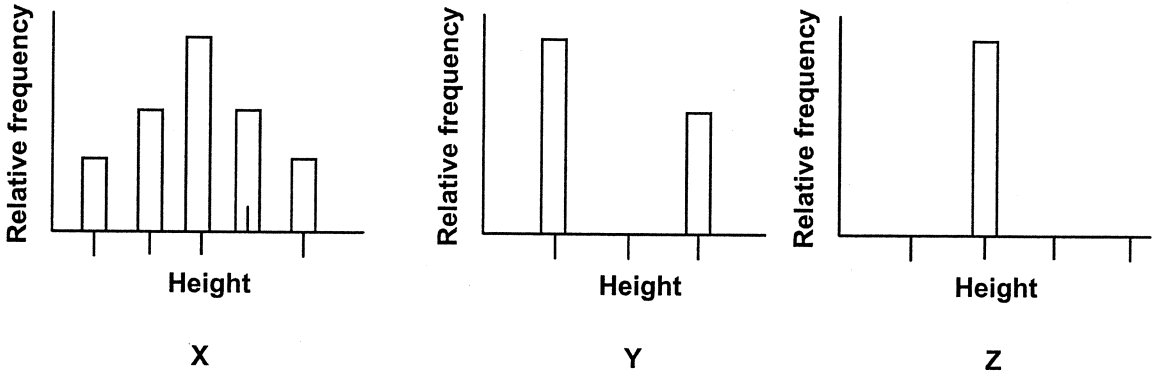
a. I, II and III
b. II, III and IV
c. I, III and IV
d. I, II and IV

37. (1 point) Alleles I^{A} and I^{B} present on chromosome 9 are responsible for blood groups A and B, respectively. Blood group O results when these alleles are either absent or not expressed. The alleles I^{A} and I^{B} are expressed only if the H allele is present on chromosome 19, either in the homozygous or heterozygous condition, where h stands for the recessive allele.
Gilbert belongs to the AB blood group. His sister Helen belongs to the A group while their father belongs to the O group. Identify the maternal and paternal genotypes.

	Mother	**Father**
a.	H/H, I^{A}/I^{B}	H/h, I^{O}/I^{O}
b.	H/h, I^{B}/I^{O}	h/h, I^{A}/I^{O}
c.	h/h, I^{O}/I^{O}	h/h, I^{A}/I^{O}
d.	H/H, I^{A}/I^{O}	H/h, I^{B}/I^{O}

e. h/h, I^B/I^O H/h, I^O/I^O

38. (1 point) The phenotypes of three experimental populations of plants are shown in the following graphs.



The three populations X, Y and Z represent, respectively:

a. F_1, F_2 and F_3 generations
b. P, F_1 and F_2 generations
c. F_2, P and F_1 generations
d. F_3, F_1 and F_2 generations

39. (1 point) In a population of mice, 40% of males showed a dominant X-linked trait. Assuming random mating, the most frequent mating is expected between the genotypes:

a. X^BX^b and X^bY
b. X^BX^B and X^bY
c. X^BX^b and X^BY
d. X^bX^b and X^bY

40. (1 point) Hunting of Northern elephant seals reduced their population size to as few as 20 individuals at the end of the 19th century. Their population has since rebounded to over 30,000. But their genomes still carry the marks of this bottleneck when compared to the population of Southern elephant seals that was not so intensely hunted. Such bottlenecks are manifested in the form of:

I. abundance of unique mutations.
II. increased frequency of lethal recessive alleles.
III. reduced genetic variation.
IV. increased population size.

a. Only I and II
b. Only III
c. I, II and IV
d. II and III

41. (1 point) What is true for both genetic drift and natural selection?

I. They are mechanisms of evolution.
II. They are entirely random processes.
III. They usually result in adaptations.
IV. They affect the genetic make-up of the population.

a. I and II
b. I and III
c. II and III
d. I and IV

42. (1 point) The frequencies of two codominant alleles with similar fitness values in a laboratory population of mice were 0.55 and 0.45. After 5 generations, the values changed to 0.35 and 0.65, respectively. Which two of the following mechanisms are most likely to be responsible for this observation?

I. Point mutation
II. Nonrandom mating
III. Genetic drift
IV. Selection pressure

a. I and IV
b. II and IV
c. I and III
d. II and III

43. (1 point) In pea plants, the allele for yellow color of seeds (*Y*) is dominant over that for green color (*y*) while the allele for round seeds (*R*) is dominant over that for wrinkled seed (*r*). The results of an experimental cross with such garden pea plants are tabulated below:

Seed phenotype	Number
Yellow and round	32
Yellow and wrinkled	28
Green and round	12
Green and wrinkled	9

The parental genotypes are likely to be:

a. *YyRr* and *Yyrr*
b. *Yyrr* and *YyRR*
c. *YyRr* and *YyRr*
d. *YyRR* and *yyRr*

44. (1 point) A population has 6 times as many heterozygous as homozygous recessive individuals. The frequency of the recessive allele will be:

a. 1/3
b. 1/4
c. 1/2
d. 1/6

45. (1 point) If you have data on genotypic frequencies for several generations of a population and if you apply the Hardy-Weinberg equation to it, which of the following can be deduced?

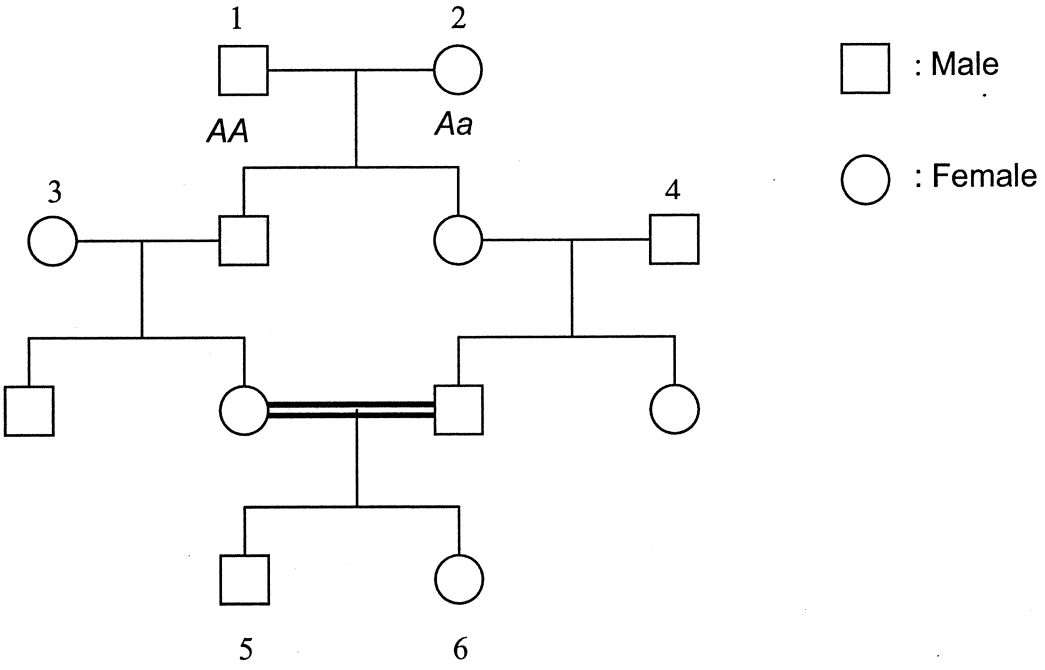
I. Whether evolution has occurred in the population.
II. The direction of evolution, if it has occurred.
III. The cause of evolution, if it has occurred.

a. Only I and II
b. Only I and III
c. Only II and III
d. I, II and III

46. (1 point) The residues of mines often contain such high concentrations of toxic metals (e.g., copper, lead) that most plants are unable to grow on them. However, in a particular study, certain grasses were found to spread from the surrounding uncontaminated soil onto such waste heaps. These plants developed resistance to the toxic metals while their ability to grow on uncontaminated soil decreased. As grasses are wind-pollinated, breeding between the resistant and non-resistant populations went on. Despite this, the less resistant plants growing on contaminated soil and the more resistant plants growing on uncontaminated soil died out. This process is indicative of:

a. directional selection.
b. bottleneck effect.
c. sympatric speciation.
d. disruptive selection (diversifying selection).

47. (1 point) A genetic disease is caused by an autosomal recessive allele. Individual 2 in the following pedigree is a carrier for this trait. Assuming that individuals 3 and 4 are normal homozygous, what is the probability that individual 6 will have the disease?



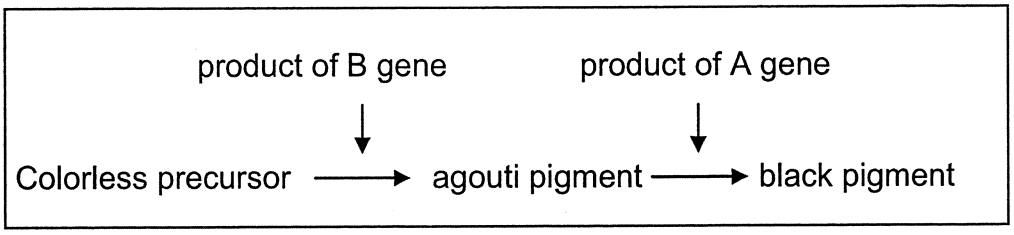
a. 1/16
b. 1/32
c. 1/64
d. 1/128

48. (1 point) Note the following genotypes and corresponding phenotypes:

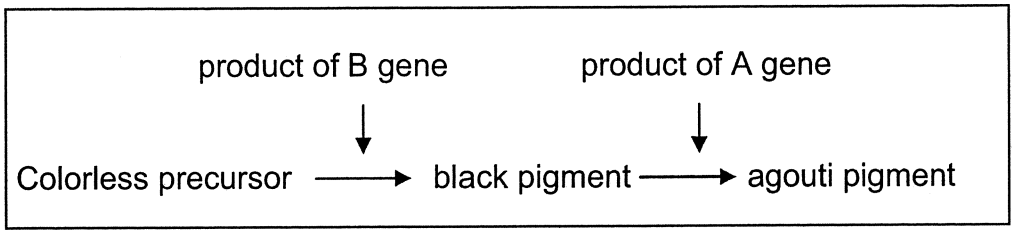
A–B–	Agouti
A–bb	Albino
aaB –	Black
aabb	Albino

The biochemical process that can explain the above pattern is:

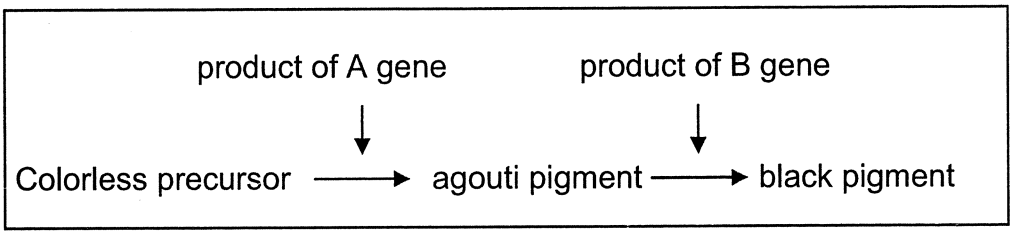
a.


product of B gene
product of A gene
Colorless precursor
agouti pigment
black pigment

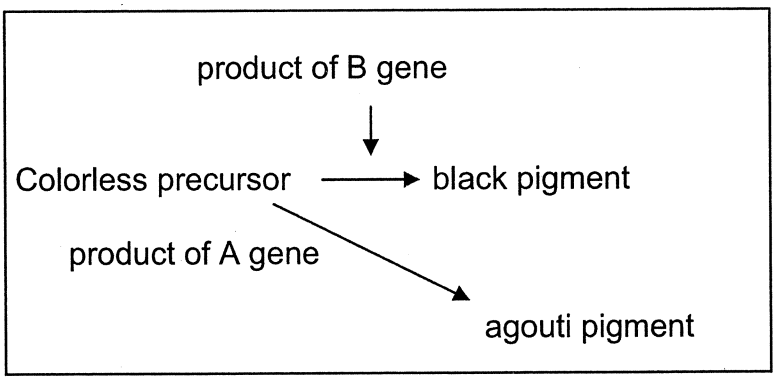
b.


product of B gene
product of A gene
Colorless precursor
black pigment
agouti pigment

c.


product of A gene
product of B gene
Colorless precursor
agouti pigment
black pigment

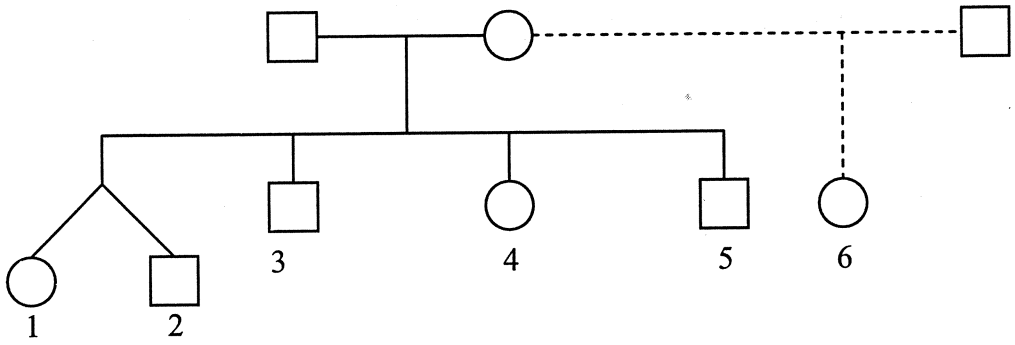
d.

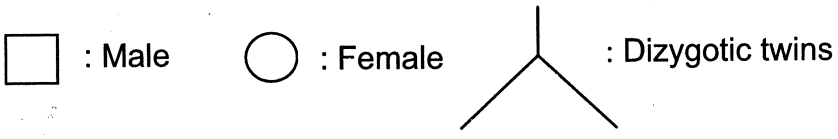

product of B gene
Colorless precursor
black pigment
product of A gene
agouti pigment

49. (1 point) In a population, 90% of the alleles at the Rh locus are 'R'. Another alternative form of this allele is 'r'. Forty children from this population go to a particular play school. The probability that all are Rh positive is:

a. $40^{0.81}$
b. 0.99^{40}
c. $40^{0.75}$
d. $1\text{-}0.81^{40}$

50. (1 point) Study the pedigree and answer the following question.



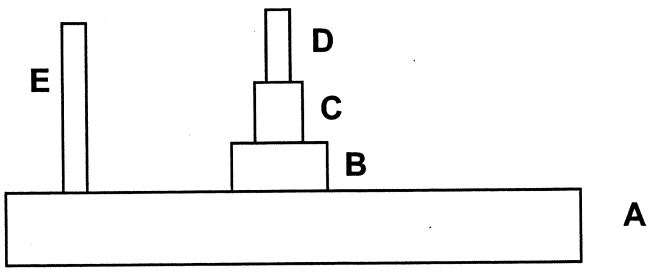


The genetic relatedness between individuals 1 and 2 and between individuals 5 and 6, respectively, is:

a. 0.5 and 0.25
b. 0.25 and 0.5
c. 1.0 and 0.5
d. 1.0 and 0.25

ECOLOGY (7 points)

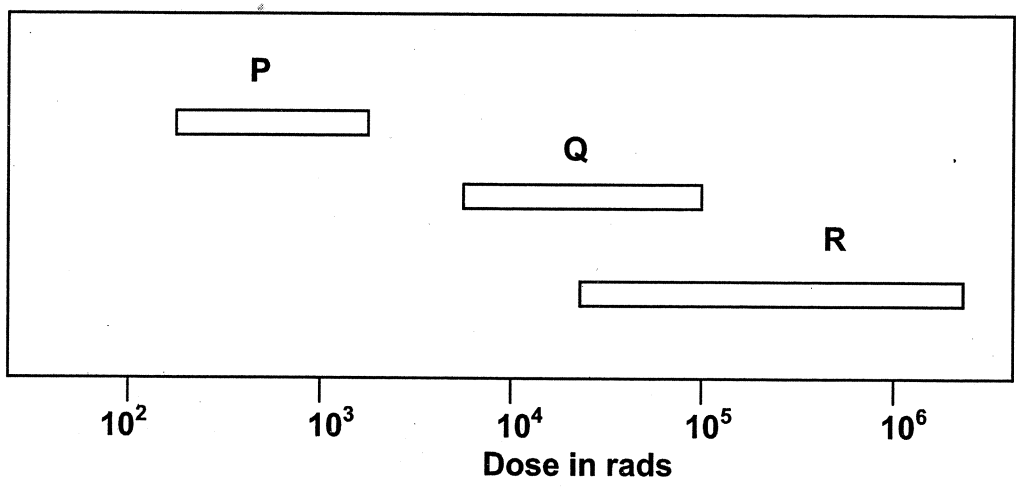
51. (1 point) A typical biomass pyramid is represented in the figure below.



If A represents a primary producer, then E is likely to be a:

a. photo-litho-heterotroph.
b. chemo-organo-heterotroph.
c. chemo-litho-autotroph.
d. photo-organo-heterotroph.

52. (1 point) Comparative sensitivity of three groups of organisms to single large doses of x or □ rays delivered at short intervals is shown in the figure below.



The three groups P, Q, R respectively are:

a. insects, mammals and bacteria
b. mammals, bacteria and insects
c. bacteria, mammals and insects
d. mammals, insects and bacteria

53. (1 point) Hay is boiled in water and cooled. Some pond water, containing only heterotrophic protozoa, is added to it and kept in the dark for a long time. Which of the following are true?

I. Heterotrophic succession of protozoa will occur with increase in total biomass.
II. The energy of the system is maximum at the beginning.
III. Succession will occur, eventually reaching a steady state in which energy flow is maintained.
IV. The ecosystem may undergo succession but finally all organisms will die or go into resting stages.

a. I and III
b. II and IV
c. II and III
d. I and IV

54. (1 point) An ecologist is comparing the growth of a herbaceous plant species growing in two different sites A and B. To compare the populations from the two sites, she has harvested 30 individuals from each site, then measured the root length, root biomass, and shoot biomass of each individual. A summary of those measurements are as follows:

Location	Mean root length (cm)	Mean root biomass (g)	Mean shoot biomass (g)
Site A	27.2 ± 0.2	348.7 ± 0.5	680.7 ± 0.1
Site B	13.4 ± 0.3	322.4 ± 0.6	708.9 ± 0.2

Based on the data presented, which of the following statements is likely to be true?

a. Soil water availability is lower in Site B than in Site A.
b. Plant productivity is higher in Site A than in Site B.
c. Soil water availability is lower in Site A than in Site B.
d. Soil nutrient availability is lower in Site B than in Site A.

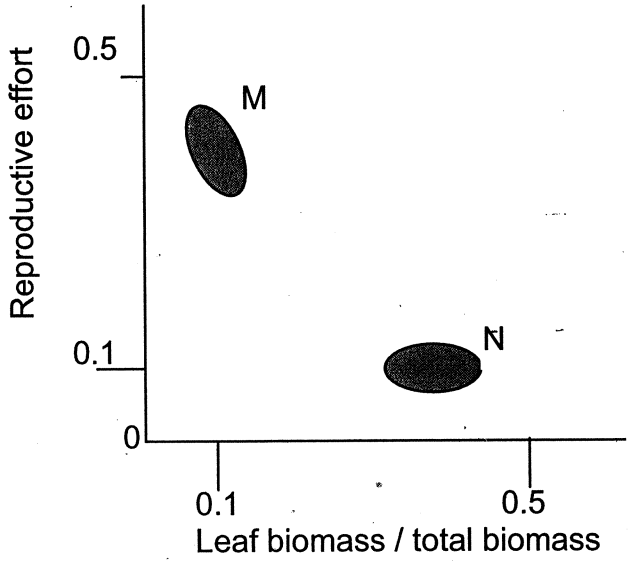
55. (1 point) In an aquatic ecosystem, the total dry biomass of each of three groups of organisms is as follows:

I. Ciliates: 1.1062 g
II. Midge larvae: 0.9623 g
III. Oligochaetes: 1.005 g

The most likely food chain that they represent is:

a. I → II → III
b. II → I → III
c. I → III → II
d. III → II → I
e. II → III → I

56. (1 point) The reproductive effort of a plant is defined as the ratio of the dry weight of its reproductive organs to that of its above-ground tissues. The reproductive effort of two purely sexually reproducing plant species M and N, as compared to their relative leaf biomass is plotted in the graph below.



Choose the correct interpretation.

a. M is a r-strategist adapted to a highly disturbed habitat.
b. N is a k-strategist adapted to a highly disturbed habitat.
c. N is a r-strategist growing under favorable environmental conditions.
d. M is a k-strategist growing under favorable environmental conditions.

~~57. (1 point) Prey-predator relationships are often considered analogous to a 'life-dinner' relationship in behavioral ecology. Which of the following statements best describe this analogy and the relative evolutionary rates of the prey and predator species in a population?~~

~~I. This analogy indicates the fact that the prey species serves as the 'dinner' for the predator species, the 'life' of which depends on the former.~~

~~II. This analogy indicates that a prey species caught by a predator loses its 'life' while a predator that fails to catch a prey only loses a 'dinner'.~~

~~III. The prey species is usually under greater selection pressure from its predators and tends to evolve faster than does a predator species.~~

~~IV. The predator species is usually under greater selection pressure because of its dependence on a prey species for food and tends to evolve faster than does a prey species.~~

~~a. I and III~~
~~b. I and IV~~
~~c. II and III~~
~~d. II and IV~~

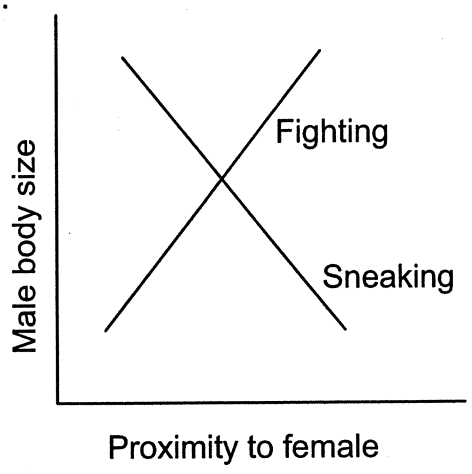
ETHOLOGY (4 points)

58. (1 point) Animals can use their circadian clocks to determine direction from the position of the sun. In a particular experiment conducted in Iceland, a bird, kept in a cage open to the sky, was trained to seek food on the western side. Its circadian rhythm was then phase-delayed by 6 hours and after phase shifting, the bird was returned to its open cage at 12.00 noon real time. It was observed to seek food in the:

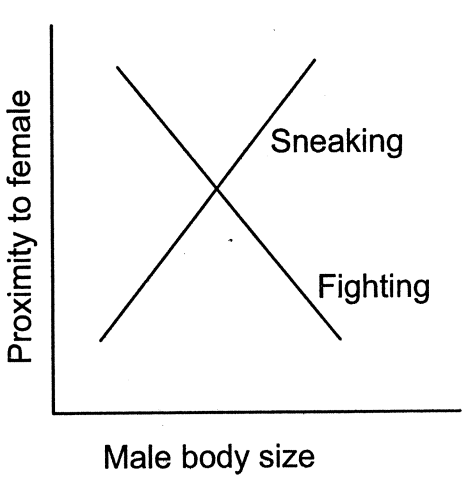
a. north.
b. south.
c. east.
d. west.

59. (1 point) Coho Salmon is a fish found in the freshwater streams of North America. The males of this species have two reproductive strategies to fertilize the eggs laid by females. Larger males are able to fight with each other successfully but smaller males are unable to do so. The latter adopt another strategy, that of sneaking, in which they hide behind rocks and quickly approach females to fertilize the eggs before the larger males are able to do so. Which of the following graphs depicts the correct strategies?

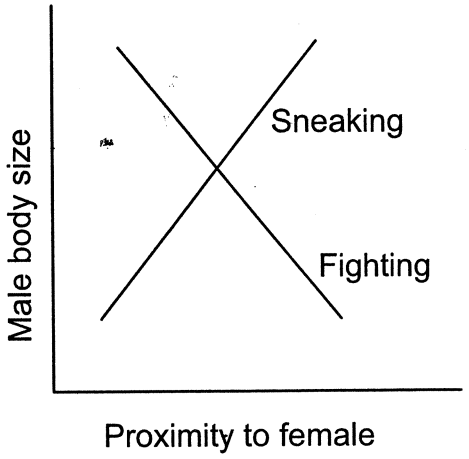
a.



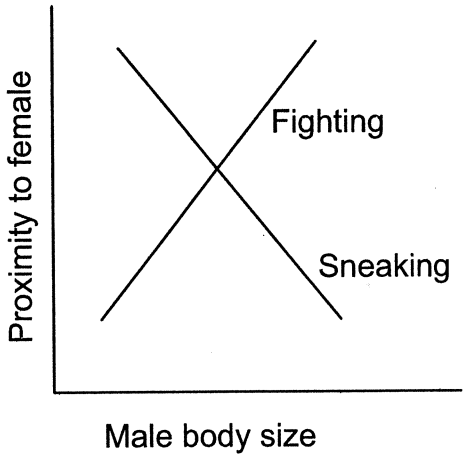
b.



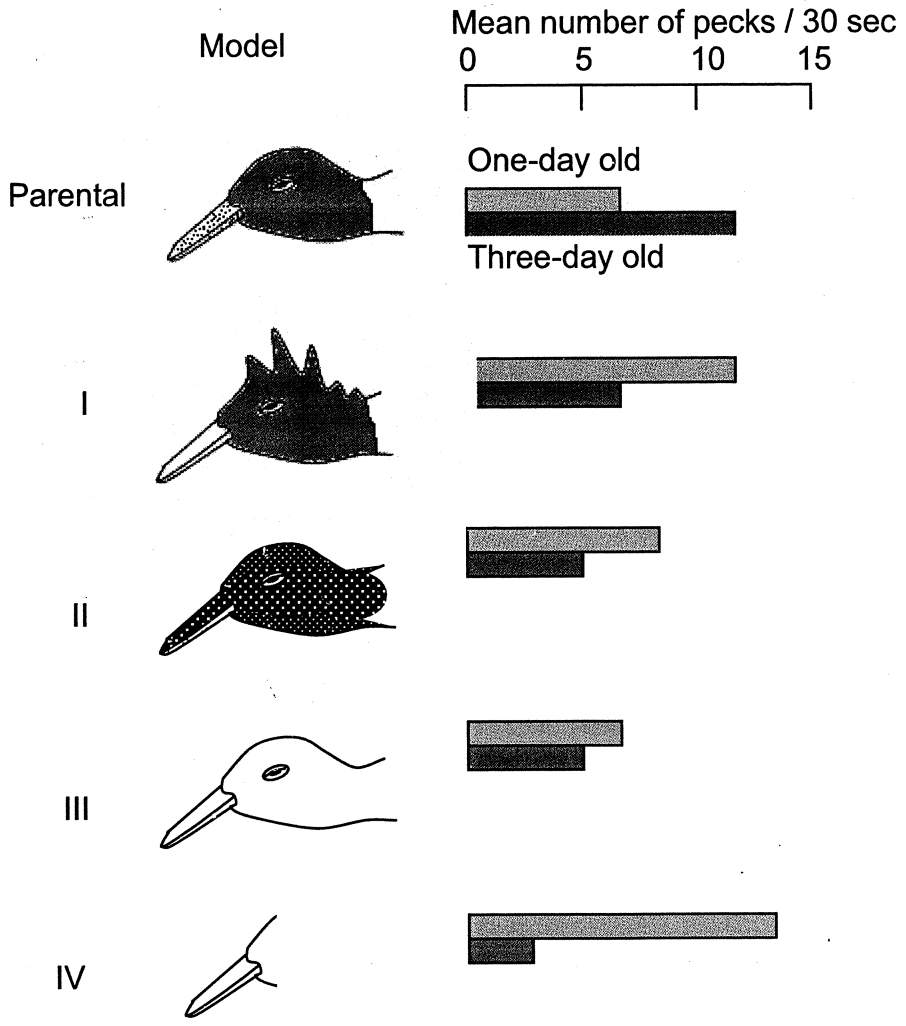
c.



d.



60. (1 point) Young laughing gull chicks peck at the tip of the parent's beak which, in turn, induces the adult gull to regurgitate food. Experiments were conducted with one-day old and three-day old chicks, the latter being reared with their parents. These chicks were presented with the following models of the parent head and the following responses were obtained:



Choose the correct interpretation of the experiment.

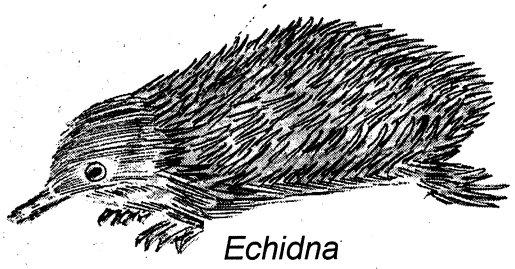
a. Pecking behavior is a fixed action pattern where any long pointed object acts as an equally effective stimulus.
b. The pecking rate of laughing gull chicks increases with age.
c. The response of one-day old chicks is more pronounced when the model is closer to that of the parent.
d. Act of pecking is an innate behavior while the discriminatory capacity of the chicks is a result of learning.

61. (1 point) While studying the frogs of a certain species in their natural habitat in the night time during the mating season, you observe a chorus of male frogs in which some individuals are calling while others remain silent. On further observation, you see the silent frogs are sitting closer to those that are calling.
Which of the following is most likely to explain the behavior of this chorus of frogs?

a. The individuals who are not calling are alternating their calls with those of the others and are likely to call later in the season after the latter have finished mating.
b. The silent frogs are close genetic relatives of the calling individuals and do not expend valuable energy in calling as the offspring from the matings that the latter will receive would provide adequate indirect fitness to them.
c. The silent frogs have evaluated that their calls are inadequate in attracting females, as compared to those of the calling individuals, and lie in wait to sneak matings with the females that approach the calling males.
d. The silent frogs do not expend energy in themselves calling as the female frogs that are attracted to the calls of the others are anyway likely to visually inspect the closely-spaced males and then choose their mating partners.

BIOSYSTEMATICS (2 points)

62. (1 point) Although *Echidna* lays eggs, it has been classified as a mammal due to the presence of mammary glands. Which of the following additional features of *Echidna* are also unique to the class Mammalia?

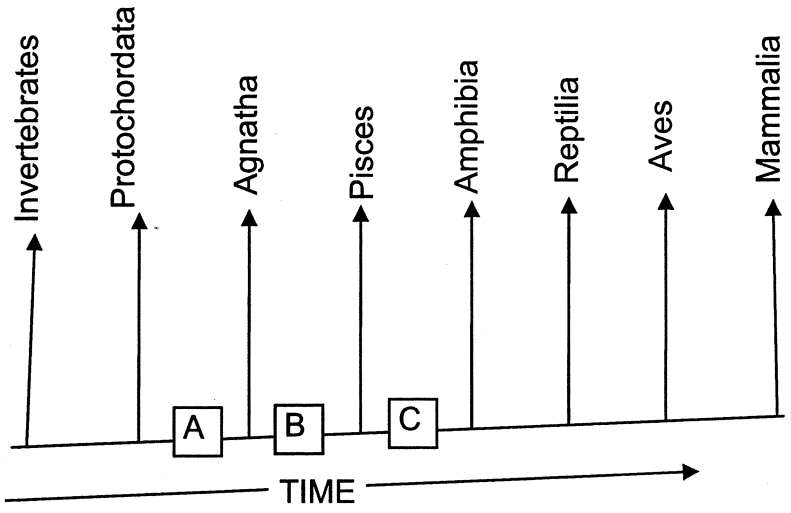


Echidna

I. Hair over parts of the body.
II. Presence of pituitary and thyroid gland.
III. Complete separation of pulmonary and systemic circulation in a 4 -chambered heart.
IV. A diaphragm separating thoracic and abdominal cavities.
V. Regulation of body temperature irrespective of ambient temperature.
VI. Enucleated red blood cells.

a. III and VI
b. I, IV and V
c. Only I and IV
d. I and II
e. I, IV and VI

63. (1 point) Study the adjoining schematically drawn evolutionary lineage. The derived characters A, B and C represent, respectively:



a. vertebral column and cranium, jaw, pentadactyl limbs.
b. tail, heart, teeth.
c. heart, gill, cranium.
d. cranium, cloaca, hepatic portal system.

********** END OF PART A **********

THEORETICAL TEST – PART B

CELL BIOLOGY (26 points)

1. (5 points) A bacterium has a single copy of a 4 x10^6 bp circular genomic DNA. Use a value of 3 for π, 6 x 10^{23} for the Avogadro's number and 660 for the molecular weight of 1 bp of DNA. Note that 10 bp of linear DNA has a length of 3.4 nm. The volume of a sphere of radius r is $\frac{4}{3}\pi r^3$.

I. If the diameter of this spherical cell is 1 μm, what would be the molar concentration of DNA in this cell?

Answer: _____Molar

II. If the DNA assumed a conformation as proposed by Watson and Crick, what would be the linear length of the bacterial DNA.

Answer: _____metre

III. How many bacterial cells one should take to get 1 mg of DNA?

Answer: _____

2. (3 points) Smooth endoplasmic reticulum (SER) is mainly concerned with the following functions:
   I. Lipid synthesis
   II. Drug detoxification
   III. Ca^{++} storage
   IV. Gluconeogenesis

   Fill in the following table with a tick mark (√) wherever appropriate and indicate the function/s of SER wherever it is extensively present, by choosing from options I – IV above.

	Organ/Cell	SER extensively present	SER not extensively present	Function/s (if extensively present)
a.	Adrenal gland			
b.	Sebaceous glands			

c.	Intestinal villi			
d.	Muscles			
e.	Liver			
f.	Pancreas			

3. (2 points) There are various mechanisms by which a cell can commit suicide – a phenomenon known as "apoptosis". One of the mechanisms is triggered by reactive oxygen species. The outer membrane of mitochondria normally expresses a protein Bcl-2 on its surface. Another protein Apaf-1 binds Bcl-2. Reactive oxygen species cause Bcl-2 to release Apaf-1 and a third protein Bax to penetrate the mitochondrial membrane, releasing cytochrome c. The released cytochrome c forms a complex with Apaf-1 and caspase 9. This complex sequentially activates many proteases that digest cellular proteins. Finally, the cell is phagocytosed.

   What will be the fate of a cell exposed to reactive oxygen species in the following situations? Choose from the options given on the next page.

   Situation I: The cell receives a signal for inhibition of expression of Apaf-1 protein. _____

   Situation II: The cell expresses low-affinity Bcl-2 proteins. _____

   Situation III: A competitive inhibitor of Apaf-1 for Bcl-2 binding is added to the cell in excess quantity. _____

   Situation IV: A chemical which significantly lowers the ratio of Bax to Bcl-2 is added to the cell. _____

   Choose from the following options:

A. The cell resists apoptosis.
B. The cell is forced towards apoptosis.
C. The fate of the cell cannot be predicted.

4. (3 points) The stoichiometry of aerobic and anaerobic degradation of glucose by yeast are as follows:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

In an experiment, the complete utilization of 0.5 mol of glucose, partly under aerobic and partly under anaerobic conditions, yielded 1.8 mol of CO_2.

I. Calculate the fraction of glucose that is utilized aerobically.

Answer: _____%

II. Calculate the Respiratory Quotient, which is defined as the molar ratio of the CO_2 produced to the O_2 utilized.

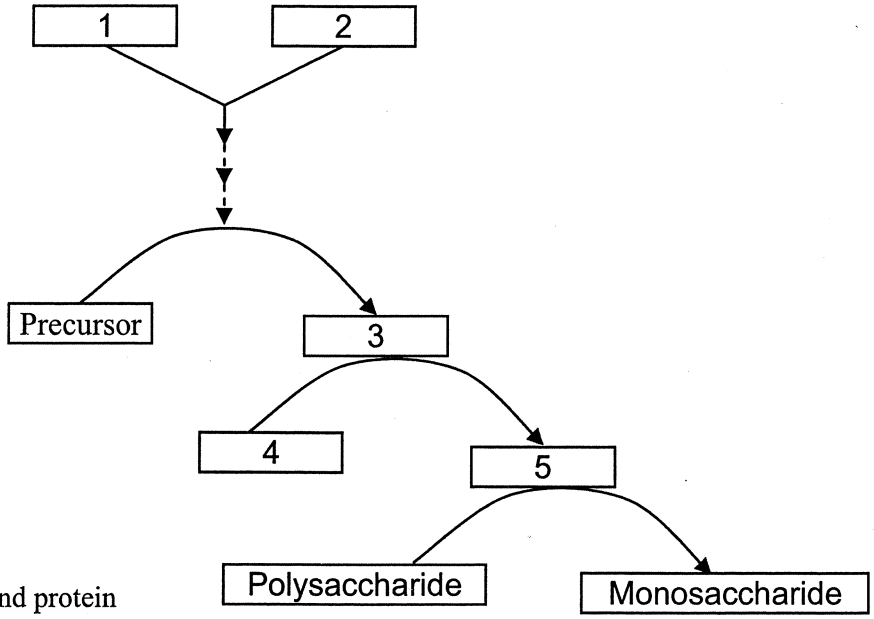
Answer: _____

5. (2.5 points) In order to study the effect of a hormone on the breakdown of a polysaccharide in liver tissue, fresh liver was homogenized in an isotonic buffer system. Part of this homogenate was centrifuged to obtain a clear supernatant and a pellet.

The following experiments were then conducted.

Experiment	Reaction mixture	Result	
		Quantity of enzyme	Activity of enzyme
I	Liver homogenate	++++	±
II	Liver homogenate + hormone	++++	++++
III	Supernatant + hormone	++++	±
IV	Pellet + hormone	±	±
V	Supernatant + small quantity of reaction mixture from Experiment IV	++++	++++
VI	Supernatant + small quantity of heated reaction mixture from Experiment IV	++++	++++
VII	Supernatant + small quantity of heated pellet + hormone	++++	±

Complete the signal transduction pathway for the breakdown of the polysaccharide in the following schematic.



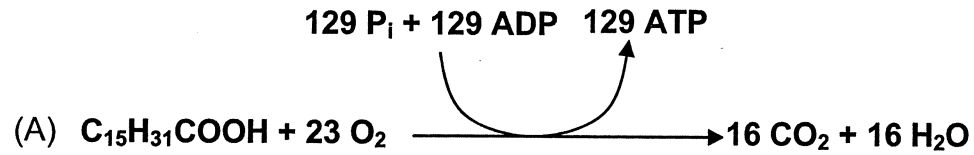
Options:

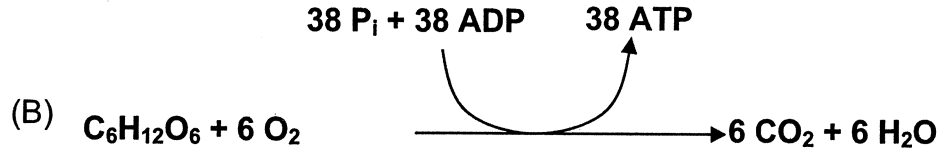
A. Membrane-bound protein
B. Heat-stable molecule
C. Inactive enzyme
D. Active cytosolic enzyme
E. Hormone
F. Organic inhibitor
G. Heat shock protein

Fill in the appropriate letters in the table from the options given.

1	2	3	4	5

6. (4 points) Sugars and fatty acids are important biomolecules that provide energy to the majority of living systems. The estimated utilization of palmitic acid and glucose in the human body is shown in the equation below:





Answer the following questions:
(Atomic weights of H: 1, C: 12 and O: 16)

I. ATP yield (in moles) per mole of oxygen in Reaction A :_____

II. ATP yield (in moles) per mole of oxygen in Reaction B:_____

III. ATP yield (in moles) per gram of fuel in Reaction A: _____

IV. ATP yield (in moles) per gram of fuel in Reaction B:_____

V. Based on the above reactions, state whether the following statements are true or false by putting tick marks (√) in the appropriate boxes.

Statements:

a. Under conditions of mild-intensity exercise and abundance of oxygen, the Respiratory Quotient tends to be < 1.
b. High-intensity exercise is primarily fuelled by fat when oxygen concentration is limiting.
c. Reaction A represents the energy-acquiring process of nervous tissue while Reaction B is more common in skeletal muscles involved in rapid movement.
d. Under conditions of hypoxia, the shift of tissue metabolism from fatty acid oxidation to glucose oxidation will yield more ATP.

	True	False
a.		
b.		
c.		
d.		

7. (4 points) Leena is a molecular biology student. She purifies two fragments of DNA, 800 and 300 base pairs long. These were obtained from a plasmid after digesting it with *Hin*dIII. Each of these fragments has a single *Eco*RI recognition site.
Leena wants to join these two fragments to get a 1.1kb gene as shown in Figure 7.1. She suspects that this gene has a unique protein-coding sequence.

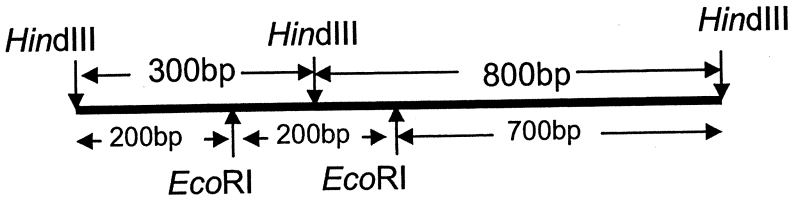


Figure 7.1

She, therefore, mixes the two fragments in the presence of excess DNA ligase in an appropriate buffer and incubates the mixture. She removes an aliquot (a small part of the reaction mixture) after 30 minutes and loads it on an agarose gel to check the results. She is surprised to find many bands along with the expected 1.1kb band (as shown in the figure 7.2) in the gel!

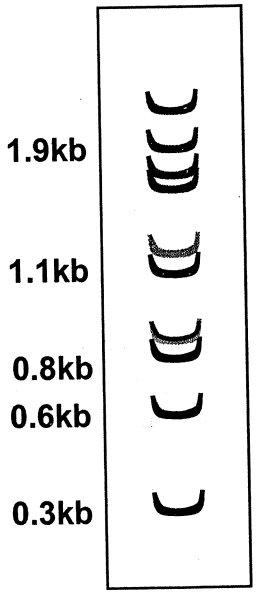


Figure 7.2

I. Which one of the following statements can explain this result?
a. The two fragments used for ligation were not sufficiently purified.
b. The multiple bands on the gel are due to the degradation of DNA in the reaction mixture.
c. The observed band pattern is a result of ligation of randomly-selected fragments.

d. DNA ligase did not function, and hence, it led to the random catenation of the DNA molecules.
Put a tick mark (√) in the appropriate box.

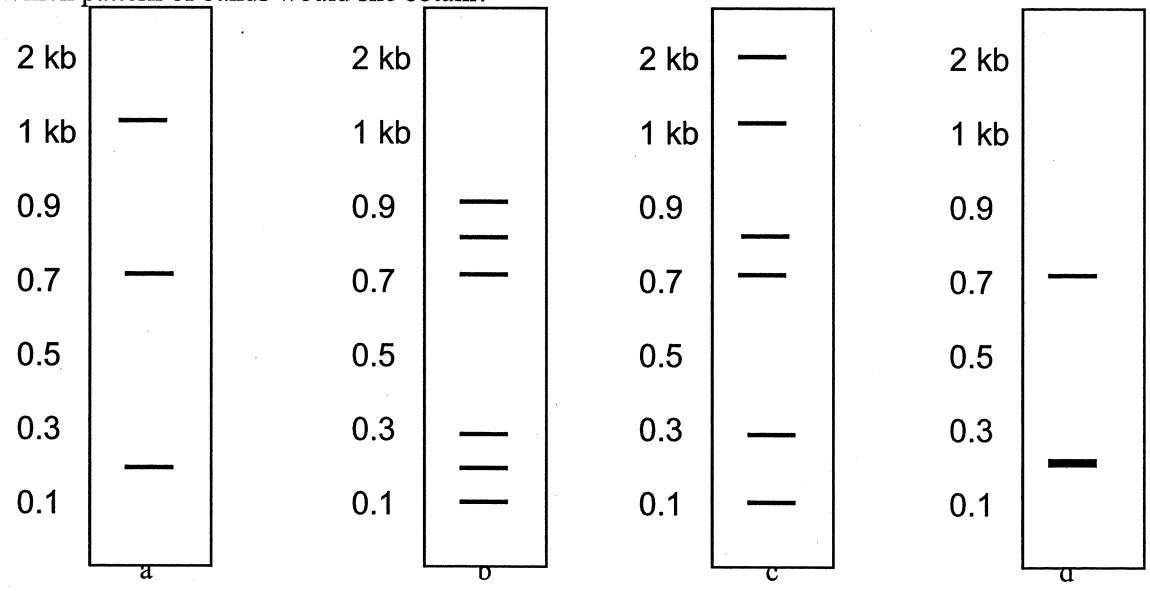
a.	b.	c.	d.

II. If another aliquot of the reaction mixture is removed after 8 hours, which one of the following would be expected?
a. Prominent bands of high molecular weight.
b. Prominent bands of low molecular weight.
c. Large number of molecules of varying lengths leading to a smearing on the gel.
d. The gel pattern would remain the same. Only the intensity of bands would increase.

Put a tick mark (√) in the appropriate box.

a.	b.	c.	d.

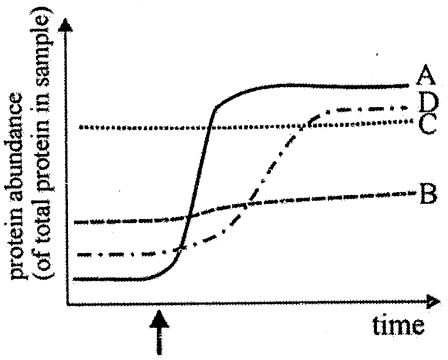
III. Leena is interested in the 1.1kb fragment shown in Figure 7.1. Hence, she elutes the 1.1kb fragment from the gel shown in Figure 7.2 and subjects part of this sample to *Hin*dIII digestion. She obtains the expected pattern with two bands, 800 and 300 base pairs long. To confirm its restriction map, she subjects the remaining sample to complete *Eco*RI digestion. Which pattern of bands would she obtain?

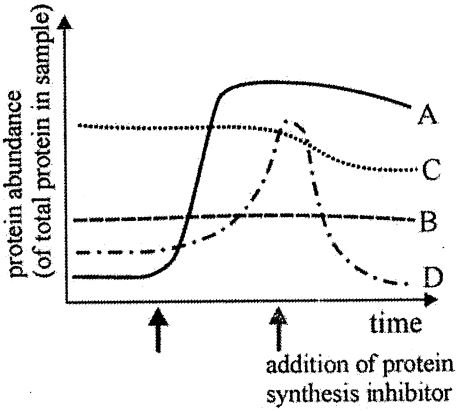


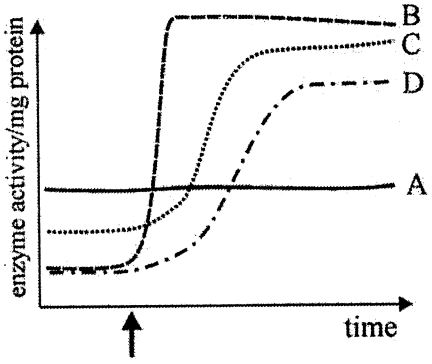
Put a tick mark (√) in the appropriate box.

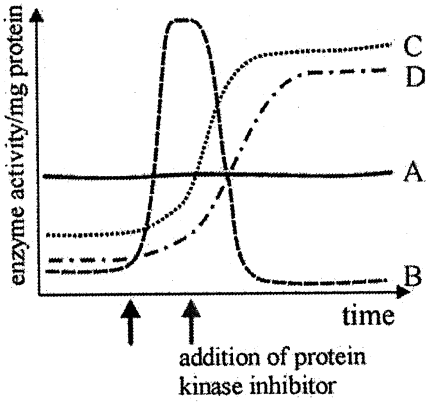
a.	b.	c.	d.

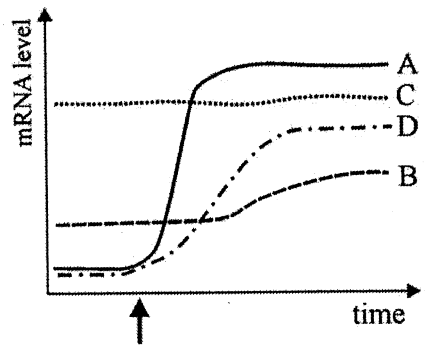
8. (2.5 points) Protein function can be regulated at many levels. By interpreting the graphs below, find out how each of these proteins (A to D) is regulated. They are all enzymes involved in the same physiological process, their activity is induced by the same treatment and their respective activities in a sample can be measured with specific assays. The arrows indicate the beginning of the activating treatment.











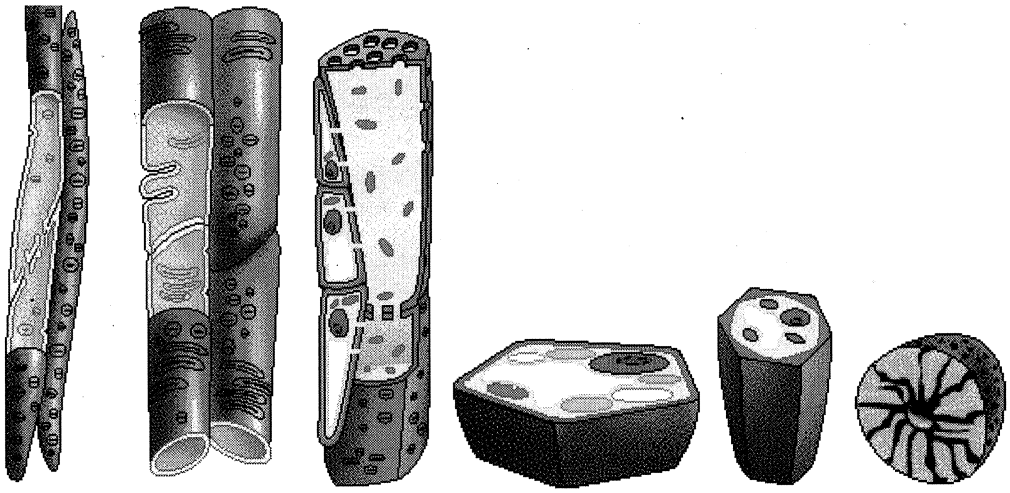
Match the proteins A to D with their mode(s) of regulation (I to IV) by putting tick marks (√) in the appropriate boxes.

I. Post-translational modification, but not phosphorylation
II. Transcriptional regulation
III. Proteasomal degradation and rapid turnover
IV. Phosphorylation

Protein	Mode of regulation			
	I	II	III	IV
A				
B				
C				
D				

PLANT SCIENCES (15 points)

9. (4 points) Study the schematics of the plant tissues/cells shown below and fill in the blank column with appropriate letter/s.



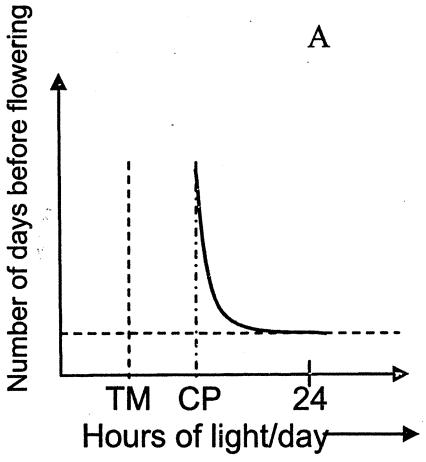
A B C D E F

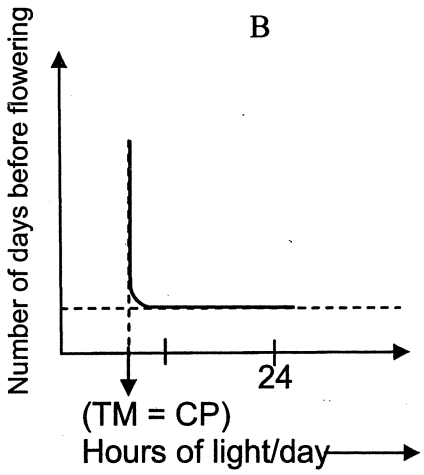
No.		Answer
I	Cell/s that is/are not alive when functional.	

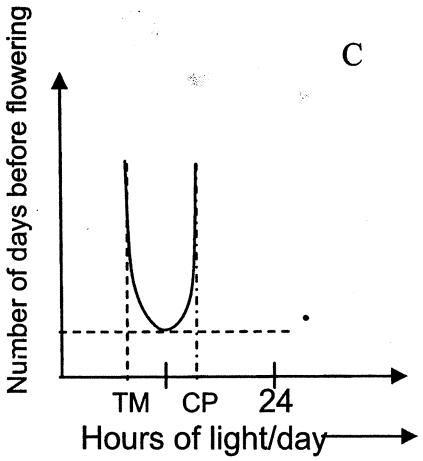
II	Plasmodesmata can be found associated with this/these cell/s.	
III	When you eat potato, you eat the tissue formed of this/these cell/s.	
IV	Cell/s that harden/s the nut skin.	

10. (1.5 points) On the basis of the photoperiod required for flowering, plants can be described as:
    I. Short-day plants
    II. Long-day plants
    III. Day-length indifferent plants

    The effect of varying light periods on flowering in these three types of plants is depicted in the graphs below, where TM, trophic minimum, is the minimum light that is required to produce the organic matter indispensable to its metabolism and CP is the critical period for flowering.



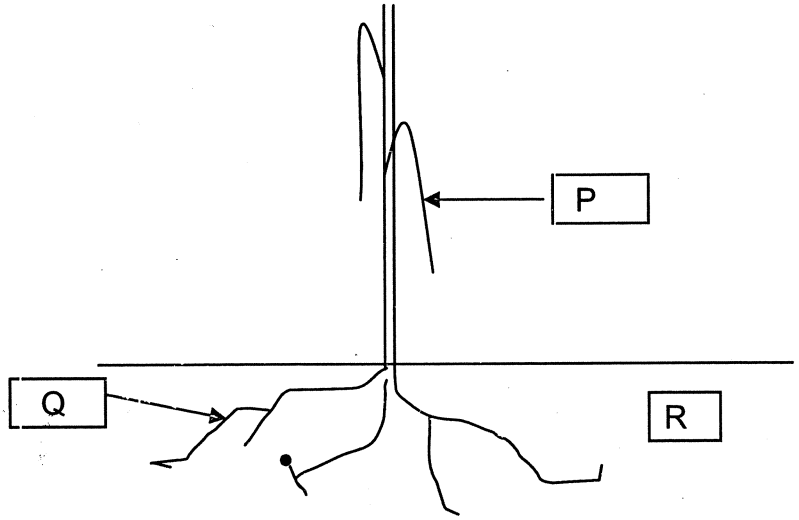




Choose a plant type (I, II or III) for each of the three graphs and fill in the table.

Graph	Plant type
A	
B	
C	

11. (2 points) (A) A mesophyte was planted in soil with high salt concentration and watered. It showed wilting. Assign the appropriate values of water potentials to the regions marked P, Q, and R in the schematic representation of this plant.



Choose from the options given below and fill in the table:

- -1 atm
- -5 atm
- -8 atm

Region	Water potential
P	_____ atm
Q	_____ atm
R	_____ atm

(B) Which of the following remedial measures will completely reverse wilting in this plant? Put a tick mark (√) in the appropriate box.

a. Increasing environmental humidity.
b. Irrigation to flush out the excess salts.
c. Applying wax on the surface of leaves.
d. Placing the plant in shade.

a.	b.	c.	d.

12. (4 points) A few characteristics of some organisms are listed in the table. Put a tick mark (√) against the appropriate organisms.

	Chlamydomonas	Cyano-bacteria	Green-sulphur bacteria	Purple-sulphur bacteria
Phototrophic autotrophs				
Photosystem II absent				
Respiratory enzymes located on plasma membrane				
Chlorophyll *a* as the major photosynthetic pigment				

13. (3.5 points) The total respiration (R) of a young growing plant is described by the following expression:

$$R = 0.27\ P + 0.015\ W,$$

where P is the total amount of glucose produced per day and W is the average mass of the plant.

Of the processes listed below, some influence the factor 0.27 of the above equation whereas the others do not.

1. Movement of water within the cells
2. Reduction of nitrate (NO_3^-) ions to ammonium (NH_4^+) ions
3. Uptake of K^+ ions through the plasma membrane of endodermal cells
4. Uptake of 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*

Indicate with a tick mark (√) in the appropriate column in the table below, which of these processes do or do not affect the factor 0.27.

Process	Does affect	Does not affect
1		
2		
3		
4		
5		
6		
7		

ANIMAL SCIENCES (18.5 points)

14. (2 points) The tidal volume is defined as the volume of air entering the lungs in a single inspiration (inhalation), which is approximately equal to the volume exhaled during subsequent expiration (exhalation) on normal quiet breathing. Exchange of gases with the blood occurs in the alveoli of lungs. In the conducting airways (e.g. trachea), which also contain a volume of air, no exchange takes place. The space within these airways is called the anatomic dead space. Thus the volume of fresh air entering the alveoli during each inspiration equals the tidal volume minus the volume of air in the anatomic dead space. The total volume of fresh air entering the alveoli per minute is called the alveolar ventilation and is expressed in ml/min; it varies directly with the respiration rate.

Consider the hypothetical breathing patterns of three individuals A, B and C:

Individual	Tidal volume (ml/breath)	Frequency (breaths/min)	Anatomic dead space (ml/breath)
A	800	12	600
B	500	16	350
C	600	12	200

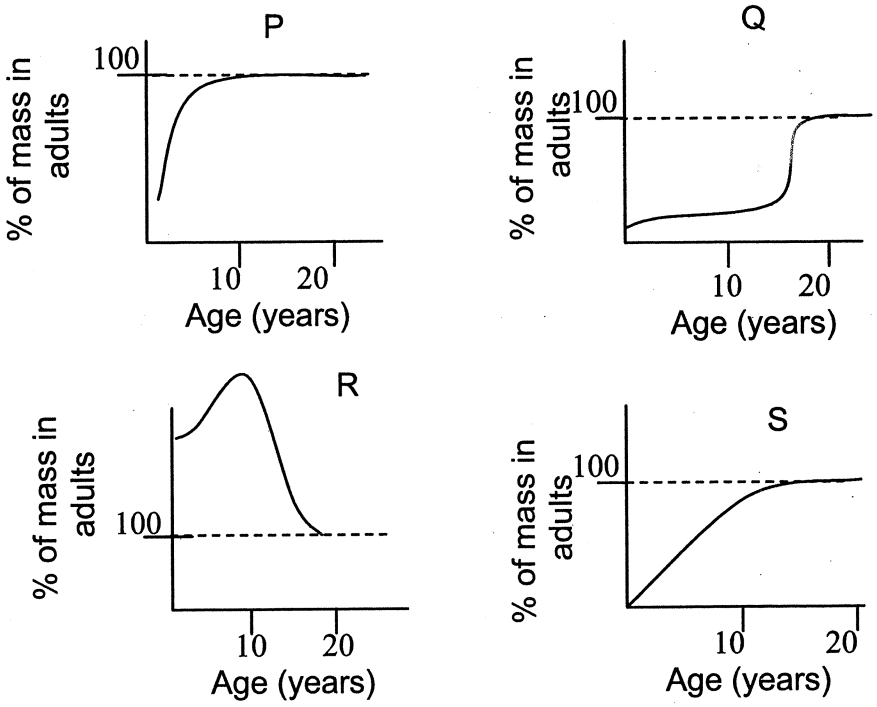
Which of the following holds true about the alveolar ventilation of these three individuals?

a. B has considerably greater alveolar ventilation than C.
b. A has considerably greater alveolar ventilation than C.
c. C has considerably greater alveolar ventilation than B.
d. A has considerably greater alveolar ventilation than B.

Put a tick mark (√) for the correct statement(s) in the appropriate box of the table.

a.	b.	c.	d.

15. (2 points) The relative growth rates of four organs of the human body are shown in the following graphs.



Match the graphs with the organs by putting a tick mark (√) in the appropriate box of the table.

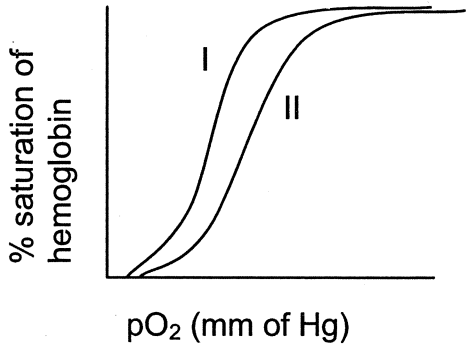
	P	Q	R	S
Liver				
Brain				
Thymus				
Gonads				

16. (2 points) A few statements regarding the respiratory processes in vertebrates are given below:
    a. Amphibians use negative pressure to force air into the lungs.
    b. Reptiles, birds, and mammals use positive pressure to force air into the lungs.
    c. Lungs of amphibians and mammals are incompletely ventilated during each breathing cycle.
    d. Lungs of birds are completely ventilated during each breathing cycle.

Mark whether each statement is true or false by putting a tick mark (√) in the appropriate box of the table.

	True	False
a.		
b.		
c.		
d.		

17. (2 points) The oxygen saturation of hemoglobin when plotted versus pO_2 is sigmoid and this is conventionally referred to as the oxygen dissociation curve. Many parameters such as pH, pCO_2, temperature, and metabolic activity of the cell affect the oxygen dissociation curve. Two such curves, I and II, are depicted in the following graph



Determine whether the curves could represent the sets of conditions given below. Put a tick mark (√) in the appropriate boxes in the table.

Set	Condition	True	False
A	Curve I. Normal blood pH and Curve II. Acidosis		
B	Curve I. 40°C and Curve II. 30°C		
C	Curve I. Elephant hemoglobin and Curve II. Cat hemoglobin		
D	Curve I. Fetal hemoglobin and Curve II. Maternal hemoglobin		

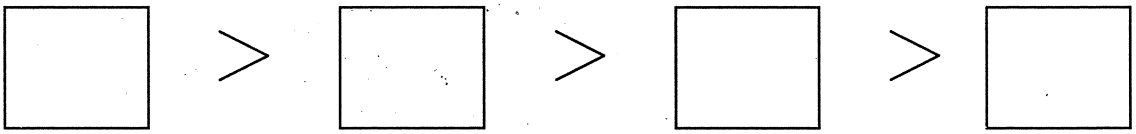
18. (2 points) Given below are the data on breathing rate, heart rate and body temperature of four different mammals A, B, C, and D.

Animals	Breathing rate (inhalations/min)	Heart rate (beats/min)	Body temperature (°C)
A	160	500	36.5
B	15	40	37.2
C	28	190	38.2
D	8	28	35.9

Study the data and rank these animals in descending order of surface area per unit volume as well as the total volume of blood by filling in the boxes with appropriate letters (A to D).

Surface area per unit volume of the body

Total volume of blood in the body



19. (5 points) In order to find out the nature of factors involved in humoral immunity, three groups of mice were immunized according to the scheme below:

Immunization scheme

1. Mice → Isolate serum **(S1)** after 2 weeks
2. Mice → Immunized with pathogen P → Isolate serum **(S2)** after 2 weeks
3. Mice → Immunized with pathogen Q → Isolate serum **(S3)** after 2 weeks

Using sera from the above immunization schemes, the following experiments were conducted to test the response of these sera towards pathogens P or Q:

Number	Experiment
I	Serum S1 → Add pathogen P or Q → No lysis of pathogen P or Q
II	Serum S2 → Add pathogen P → Lysis of pathogen P
III	Serum S3 → Add pathogen Q → Lysis of pathogen Q
IV	Serum S2 → Add pathogen Q → No lysis of pathogen Q
V	Serum S3 → Add pathogen P → No lysis of pathogen P
VI	Serum S2 → Heat at 55°C for 30 min → Add pathogen P → No lysis of pathogen P
VII	Serum S3 → Heat at 55°C for 30 min → Add pathogen Q → No lysis of pathogen Q
VIII	Serum S2 → Heat at 55°C for 30 min → Add serum S1 → Add pathogen P → Lysis of pathogen P
IX	Serum S2 → Heat at 55°C for 30 min → Add serum S1 heated at 55°C for 30 min → Add pathogen P → No lysis of pathogen P
X	Serum S2 → Heat at 55°C for 30 min → Add serum S3 → Add pathogen P → Lysis of pathogen P

Answer the following questions:

(A) If serum S3 is heated at 55°C for 30 min, and mixed with serum S1, which of the following pathogen would it lyse?

a. Only P
b. Only Q
c. P and Q both

d. Neither P nor Q
Put a tick mark (√) in the appropriate box.

a.	b.	c.	d.

(B) If serum S2 is heated at 55°C for 30 min, and mixed with serum S3, which of the following pathogen would it lyse?
a. Only P
b. Only Q
c. P and Q both
d. Neither P nor Q
Put a tick mark (√) in the appropriate box.

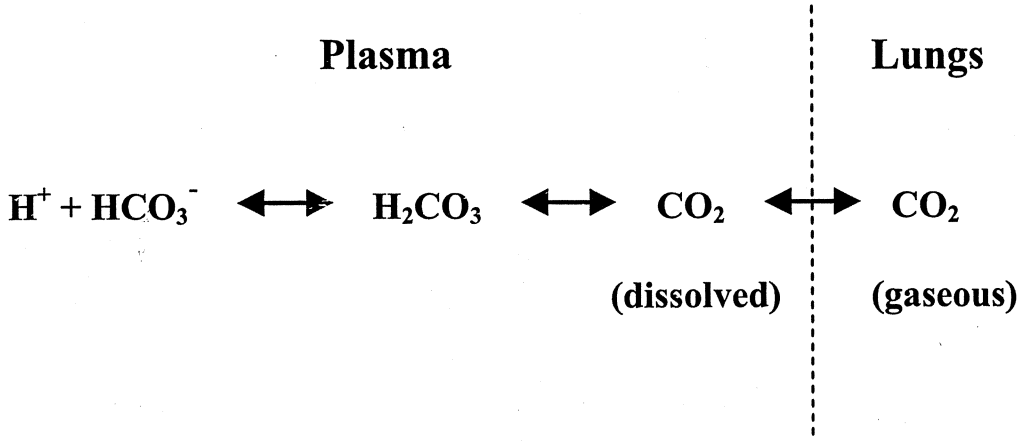
a.	b.	c.	d.

(C) Which of the following statements are TRUE or FALSE for the above experiment?
a. The lysis of pathogen requires only one component, which is heat-labile.
b. The lysis of pathogens requires at least two components. One component is induced by the pathogen, while the other is non-inducible and is pathogen non-specific.
c. The pathogen-induced component is heat-labile whereas the non-specific component is heat-stable.
d. The pathogen-induced component is heat-stable whereas the non-specific component is heat-labile.
e. The pathogen-specific components cannot function if present together.
f. The non-specific component has to be derived from the same mice in which the pathogen-specific component would be induced.

Put a tick mark (√) in the appropriate boxes.

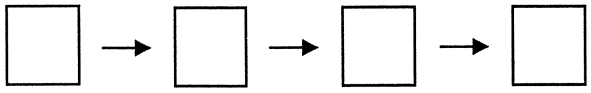
Options	True	False
a.		
b.		
c.		
d.		
e.		
f.		

20. (3.5 points) In air-breathing animals, bicarbonate ions present in the blood play an important role of buffering. Various equilibria that occur in lungs and plasma are shown below.

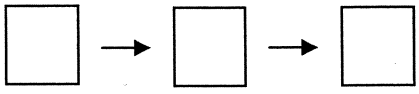


Indicate the events that will occur in sequence as a result of following activities by filling in the boxes with the appropriate numbers I to VI of the given options:

1. A person is hyperventilated as a result of rapid breathing.



2. A person continues vigorous exercise:



Options:

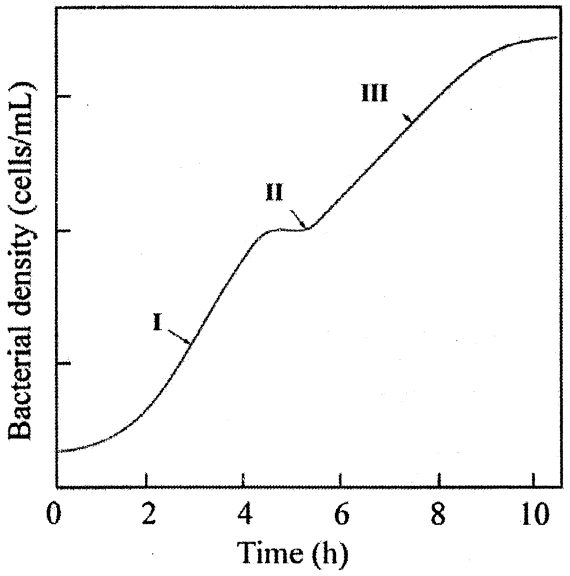
I. Decrease in plasma carbon dioxide concentration
II. Decrease in blood bicarbonates
III. Acidosis
IV. Increase in blood bicarbonates
V. Increase in exhalation of carbon dioxide
VI. Alkalosis

GENETICS AND EVOLUTION (20.5 points)

21. (2 points) Cystic fibrosis is an autosomal recessive trait. If parents who are both carriers for this gene have 3 children, what is the probability that exactly two will be phenotypically normal?

Answer: _____

22. (2 points) *E. coli* cells were grown in a medium containing glucose and lactose, and a growth curve was obtained which is shown below.



Fill in the table using tick marks (√) to indicate which of the listed events would predominate during the three phases of growth (I to III).

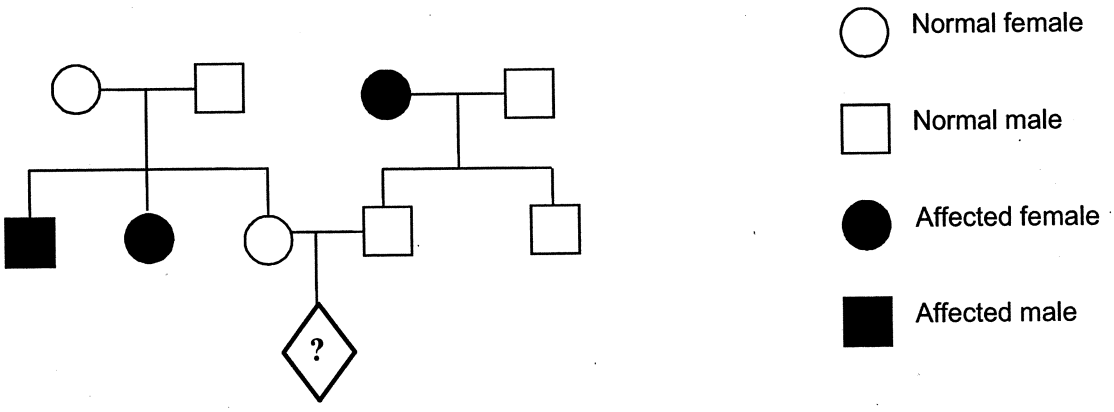
	I	II	III
Lactose hydrolysis by β-galactosidase			
Reduction of *lac* repressor's affinity for the *lac* operator			
Binding of the CAP-cAMP complex to the *lac* promoter			
Utilization of glucose			

23. (2 points) In a small tribal population, the frequencies of two alleles *A* and *a* at a particular locus were 0.3 and 0.7, respectively. However, not all the individuals with genotype *aa* could live up to the reproductive age and the relative fitness of this genotype was found to be 0.5. The remaining genotypes had a relative fitness of 1.

What is the expected percentage of heterozygotes among newborns in the next generation?

Answer: _____%

24. (2 points) In the following pedigree, the probability that the individual marked as ◊ will be affected is:

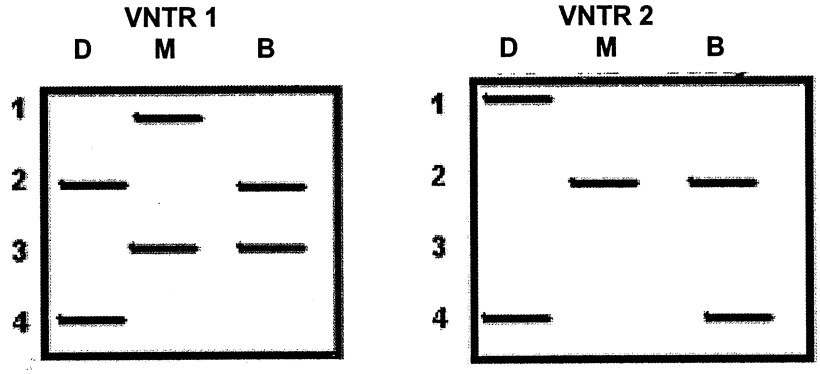


Answer: _____

25. (2 points) If two heterozygotes (*Aa*) mate, what is the minimum number of offspring they should have such that the probability of at least one offspring having genotype *aa* is greater than 90%?

Answer: _____

26. (2 points) A celebrity has been named in a paternity suit. The defendant (labeled D in the autoradiogram), the mother (labeled M), and the baby (labeled B) have each been typed for two loci VNTR1 and VNTR2, as shown in the autoradiograms below. Each of these VNTR loci has four alleles. For VNTR1, the frequencies of the alleles 1, 2, 3, and 4 in the general population are 0.2, 0.4, 0.3, and 0.1, respectively. For VNTR2, the frequencies of alleles 1, 2, 3, and 4 are 0.1, 0.1, 0.2, and 0.6, respectively.



a. Do the autoradiograms indicate that D could be the father of the baby B?
Put a tick mark (√) in the appropriate box.

Yes	No

b. What is the probability that another male in the general population could be the father of the baby B?

Answer: _____

27. (2 points) In some populations, inbreeding takes place amongst first cousins. Inbreeding leads to a reduction in the frequency of heterozygotes and is measured as the inbreeding co-efficient, F, where

$$f_{\text{observed}}^{\text{heterozygotes}} = f_{\text{expected}}^{\text{heterozygotes}} \times (1 - \text{F})$$

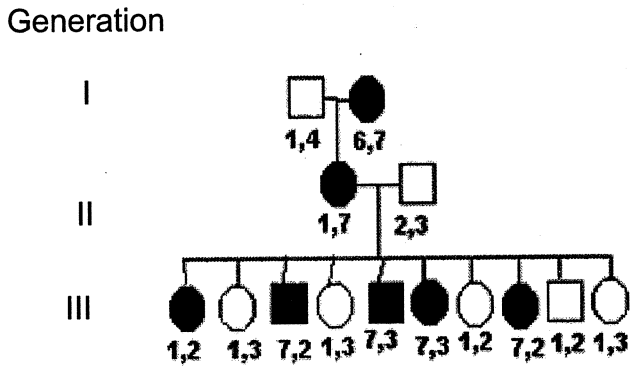
The symbol *f* denotes frequency.
If F = 1 (complete inbreeding), the population consists entirely of homozygotes.

In a population of 150 individuals, the observed numbers of MN blood group genotypes are: 60 *MM*, 36 *MN*, 54 *NN*.

a. Calculate F.
Answer: _____

b. If, for another population of the same species, the allelic frequencies remain the same but the value of F is half of that calculated in a, what will be the frequency of the heterozygotes (*MN*) observed in this group?
Answer: _____

28. (2 points) The transmission pattern of a disease caused by an autosomal dominant gene is shown in the following pedigree:

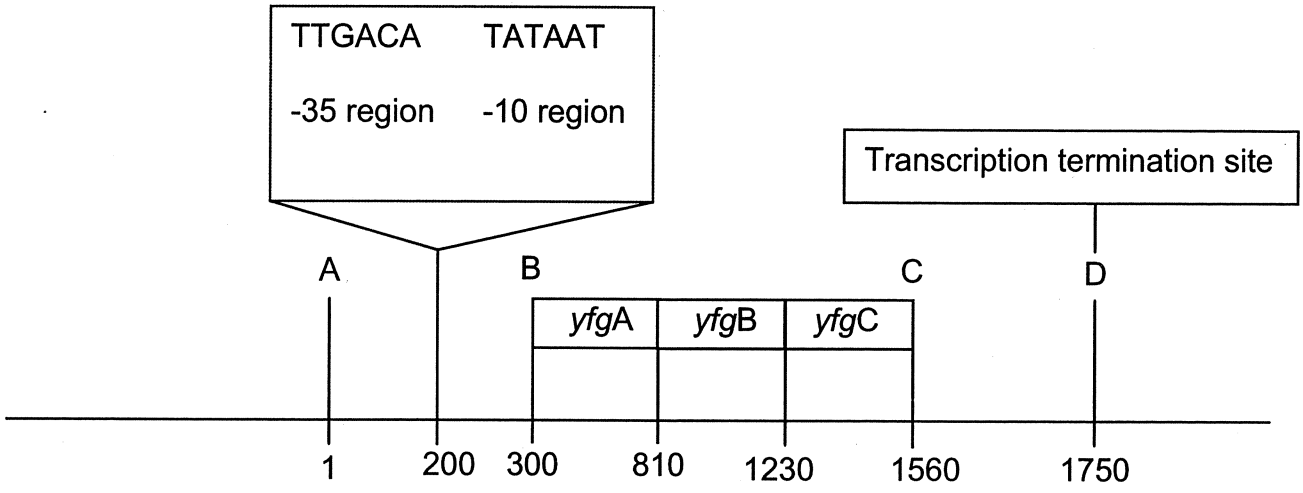


Each family member has been typed for a seven-allele microsatellite polymorphism. Based on the genotypes in Generation III, calculate the recombination frequency between the disease and microsatellite loci.

Answer: _____

29. (2 points) The figure given below depicts a region of double stranded DNA, in a bacterium, containing a polycistronic operon with three of your favorite genes *yfgA*, *yfgB* and *yfgC*, as shown. The positions of certain bases in the nucleotide sequence around *yfg* operon, with respect to position A are marked in the figure.

The *yfg* operon



Length of DNA in base pairs

Answer the following questions:

I. What is the expected minimum number and length of the transcript(s) from this operon?

a. A single transcript of 1260b
b. A single transcript of 1450b
c. A single transcript greater than 1451b but less than 1550b
d. Three transcripts of 330b, 420b and 510b

Put a tick mark (√) in the appropriate box.

a.	b.	c.	d.

II. From the above figure, calculate the maximal expected mass of the YfgA protein.
_____ kDa
(Assume the mass of an amino acid to be 110 Da)

30. (2.5 points) The map distance between two genes on a chromosome can be calculated using the frequency of crossing over between them. In case of a genetic cross involving three genes, the crossover (CO) classes of progeny can be categorized as
(i) Single crossover I (SCO I),
(ii) Single crossover II (SCO II), and
(iii) Double crossover (DCO).
DCO requires the simultaneous occurrence of the two SCOs.

Among the progeny of a test cross, the number of non-crossovers (NCO) is the highest followed by SCO I and II. The DCO is the least frequent.

A *Drosophila* fly, heterozygous for alleles *p*, *q* and *r*, when crossed with a homozygous recessive fly, had the following progeny:
(p^+, q^+, and r^+ indicate wild-type alleles whereas *p*, *q*, and r indicate the mutant alleles.)

Genotype	Number of progeny
$p\,q^+\,r$	375
$p^+\,q\,r^+$	355
$p\,q\,r$	50
$p^+\,q^+\,r^+$	45
$p^+\,q^+\,r$	75
$p\,q\,r^+$	85
$p\,q^+\,r^+$	8
$p^+\,q\,r$	7
	Total = 1000

The middle gene is the one that has altered position in the DCO classes compared to that in the NCO classes.

(A) Which is the middle gene in the given cross? Put a tick mark (√) in the appropriate box.

p	
q	
r	

(B) Assuming 1% crossover as one map unit (mu), calculate the distance between *p*, *q*, and *r*.

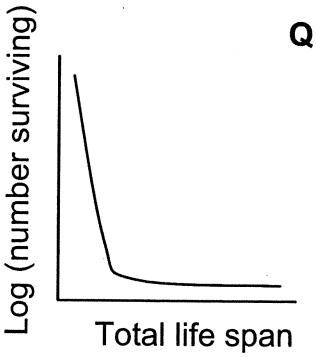
Distance between *p* and *q*	_____ mu
Distance between *p* and *r*	_____ mu

Distance between *q* and *r*	_____ mu

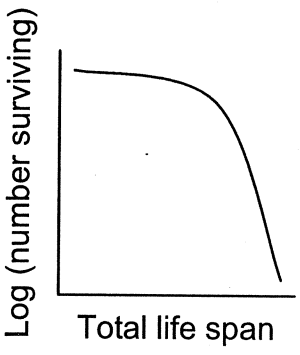
ECOLOGY (16.5 points)

31. (1.5 points) Consider a population of r-selected insects in the early part of its growth season. Choose the appropriate growth curve at this stage, survivorship curve and current age structure (from each pair of graphs) that represent this population and put the corresponding letter in the boxes below.

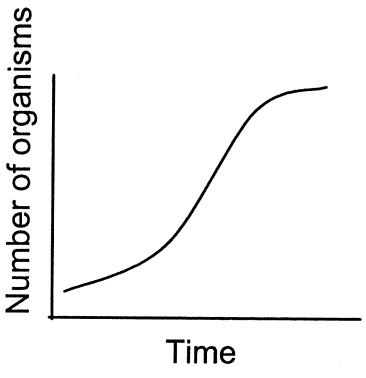
P



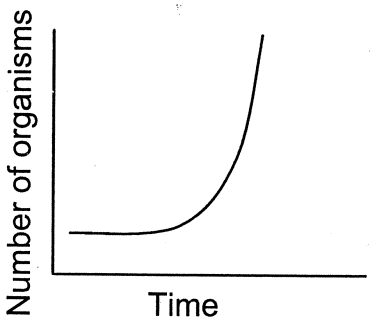
Q



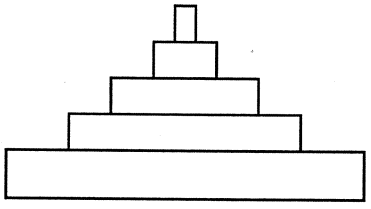
R



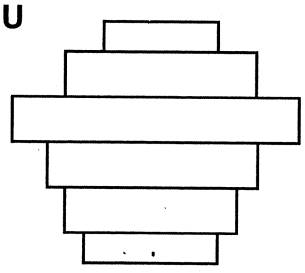
S



T



U



Growth curve	Survivorship curve	Age structure

32. (3 points) Nitrogen, as a mineral nutrient, has the greatest effect on plant growth. Atmosphere contains nearly 80% nitrogen gas (N_2), yet plants have to be provided ammonium salts or nitrates as fertilizers for optimum growth and yield. Certain nitrogen-fixing bacteria (rhizobia, cyanobacteria, etc.) can convert atmospheric N_2 into ammonia using nitrogenase by the following reaction:

$$N_2 + 8\ e^- + 8\ H^+ + 16\ ATP \longrightarrow 2\ NH_3 + H_2 + 16\ ADP + 16\ P_i$$

Such bacteria can be used as biofertilizers in agriculture. In soil, ammonia is protonated to ammonium (NH_4^+). This, in turn, is converted to nitrate (NO_3^-) and then to N_2 gas by the action of nitrifying and denitrifying bacteria, respectively. Plants require nitrogen mainly in the form of nitrate, which is exported from roots to shoots, reconverted to ammonium and assimilated as amino acids.

(A) Plants do not themselves fix N_2, because:

I. it is easily available from the soil.
II. they lack the nitrogenase enzyme complex.
III. the process has a very high requirement of ATP per mole of N_2 fixed.
IV. hydrogen evolved in the process is deleterious to plants.

Put a tick mark (√) in the appropriate box.

a.	b.	c.	d.

(B) Processes related to nitrogen conversion to different chemical forms in the soil, carried out by the nitrogen-fixing bacteria, nitrifying bacteria and denitrifying bacteria can be, respectively, described as:

a. reduction, oxidation and oxidation.
b. reduction, oxidation and reduction.
c. reduction, reduction and oxidation.
d. oxidation, oxidation and reduction.

Put a tick mark (√) in the appropriate box.

a.	b.	c.	d.

(C) Based on the given information, which type of soil bacteria will NOT be beneficial for plants?

a. Nitrogen-fixing bacteria
b. Nitrifying bacteria
c. Denitrifying bacteria

Put a tick mark (√) in the appropriate box.

a.	b.	c.

33. (2 points) The relationship between members of different species is termed as interspecific relationships. Some such relationships are listed below. -

1. Mosses (A) grow on the trunks and branches of trees (B).

2. A female moth (A), the only pollinator, arrives at a *Yucca* flower (B) with a ball of *Yucca* pollen. She places her pollen ball on the stigma and then lays eggs in some, but not all, of the ovules. Offspring development kills the seeds on which they feed. If too many seeds are killed, the fruit is aborted by the plant, killing the developing moth larva.

3. *Wolbachia*, a rickettsia-like bacterium (A) infects some insects (B). The infected males are either killed or develop as females, leading to distorted sex ratios (female bias) in the population.

4. Certain plants (A) attract ants (B) through extra-floral nectaries to deter herbivores.

Indicate in the table given below whether the species (A and B) involved in each of these are benefited (indicate by +), harmed (indicate by –) or not affected (indicate by 0). Identify also the type of interaction by choosing from the options I to VII given below.

Options:

i. Amensalism
ii. Commensalism
iii. Competition
iv. Mutualism
v. Parasitism
vi. Predation

Number	A	B	Type of interaction
1.			
2.			
3.			
4.			

34. (4 points) Mathematical models can be applied to many aspects of predator behavior. In a simple mathematical model, it is assumed that a predator can feed on two prey species, Prey1 and Prey2 and that it captures and consumes every prey it encounters. For this predator, the variables T_s, N_1, N_2, E_1, E_2, T_{H1}, and T_{H2} are defined as follows:
T_s: Total time spent searching for the prey species
N_1: Number of Prey1 encountered per unit time
N_2: Number of Prey2 encountered per unit time
E_1: Energy gained from a single Prey1
E_2: Energy gained from a single Prey2
T_{H1}: Handling time needed for each Prey1. This includes time required for capturing and consuming the prey.
T_{H2}: Handling time needed for each Prey2

(A) Once a prey has been captured, the profitability (calories gained per unit time) of each prey species for the predator is, respectively:

a. $\frac{E_1}{T_{H1}}$ and $\frac{E_2}{T_{H2}}$

b. $\frac{E_1}{T_{H1}+T_{H2}}$ and $\frac{E_2}{T_{H1}+T_{H2}}$

c. $\frac{E_1}{N_1 T_{H1}}$ and $\frac{E_2}{N_2 T_{H2}}$

d. $\frac{E_1}{T_{H1}+T_{H2}+T_S}$ and $\frac{E_2}{T_{H1}+T_{H2}+T_S}$

Put a tick mark (√) in the appropriate box

a.	b.	c.	d.

(B) The total energy gain E for the predator will be:

a. $E = (E_1 + E_2)T_S$

b. $E = E_1N_1 + E_2N_2$

c. $E = (E_1N_1 + E_2N_2)T_S$

d. $E = \frac{E_1N_1 \times E_2N_2}{T_S}$

Put a tick mark (√) in the appropriate box.

a.	b.	c.	d.

(C) The total time (T) spent to gain the total energy E will be:

a. $T = T_S + T_S(N_1T_{H1} + N_2T_{H2})$

b. $T = T_S + T_{H1} + T_{H2}$

c. $T = 1 + N_1T_{H1} + N_2T_{H2}$

d. $T = T_S + N_1T_{H1} + N_2T_{H2}$

Put a tick mark (√) in the appropriate box.

a.	b.	c.	d.

(D) In one situation, the following data were obtained:

T_s = 60 minutes

Prey1	Prey2
N_1 = 2/min	N_2 = 5/min
T_{H1} = 10 min	T_{H2} = 20 min
E_1 = 1000 cal	E_2 = 700 cal

Which of the following hypothesis does the above mathematical model support?

a. The predator should specialize on Prey1 as it leads to a better rate of energy gain.
b. The predator should specialize on Prey2 as it leads to a better rate of energy gain.
c. The predator should not specialize on one particular prey as a combination of both prey species is more beneficial
d. The predator should specialize on both prey species as any one of them may be likely to be unavailable in future.

Put a tick mark (√) in the appropriate box.

a.	b.	c.	d.

35. (6 points) A female gall fly (*Eurosta solidaginis*) typically lays a single egg in the bud of some plants. After the egg hatches, the larva burrows its way through the bud and produces a tumor-like structure called a gall. Larvae inside these galls present a very nutritious food source for many birds.

(A) After observing some galls, a student proposed a hypothesis that birds choose larger galls in preference to smaller ones. In order to gather the data to test this hypothesis, she conducted a survey of one such site and measured the widths of disturbed (fed on by the birds) as well as undisturbed galls. The results are as follows:

Disturbed galls		Undisturbed galls	
Gall number	Width (mm)	Gall number	Width (mm)
1.	12	1.	18
2.	15	2.	15

3.	30	3.	22
4.	20	4.	12
5.	23	5.	20

You need to put this hypothesis to test. (Some of the required statistical formulae as well as the Student-t and Chi-square probabilities are provided in the **Annexure** at the end of Part B-Question Paper.)

I. Which of the following is the correct null hypothesis?

a. The birds do not choose galls of smaller size.
b. The birds do not choose galls of larger size.
c. The birds do not choose galls based on size.
d. The birds do not choose galls of smaller size in preference to larger size.

Put a tick mark (√) in the appropriate box.

a.	b.	c.	d.

II. The test that you will require to do is:

a. Student's t test
b. Chi-square test
c. Both Student's t test and chi-square test
d. Either Student's t test or chi-square test

Put a tick mark (√) in the appropriate box

a.	b.	c.	d.

III. The degree/s of freedom is/are: Answer:_____

IV. The value/s of the statistic/s (up to two decimal points):
Answer: _____

V. Mark the correct interpretation:

a. At $p < 0.05$, the null hypothesis can not be rejected.
b. At $p < 0.05$, the null hypothesis is rejected.

Put a tick mark (√) in the appropriate box

a.	
b.	

(B) After observing more sites, another student came up with a hypothesis that patches with high density of galls are foraged more than those with low density. To test this hypothesis, he surveyed six patches. The results are as follows:

Gall description	Site I	Site II	Site III	Site IV	Site V	Site VI	Total
Density	High	Low	High	High	Low	Low	
Foraged	15	6	10	14	7	8	60
Undisturbed	5	3	7	8	7	9	39
Total	20	9	17	22	14	17	99

I. The null hypothesis will be:

a. The birds do not choose galls in less dense areas.
b. Density of galls is not more important than the size of the gall.
c. Choosing of galls by birds is independent of the gall density in the patch.
d. Choosing of galls by birds is not dependent on the size of galls but on the density of the patch.

Put a tick mark (√) in the appropriate box.

a.	b.	c.	d.

II. To test the hypothesis, the test that will be required is:

a. Student's t test
b. Chi-square test
c. Both Student's t test and chi-square test
d. Either Student's t test or chi-square test

Put a tick mark (√) in the appropriate box.

a.	b.	c.	d.

III. The degree/s of freedom is/are: _____

IV. The value/s of the statistic/s (up to two decimal points): _____

V. Based on the value you obtain, the correct interpretation is:
a. At $p < 0.05$, the null hypothesis can not be rejected.
b. At $p < 0.05$, the null hypothesis is rejected.

Put a tick mark (√) in the appropriate box.

a.	
b.	

ETHOLOGY (11 points)

36. (2 points) In a population of prey animals, most individuals are solitary and stay well apart from others. But some mutant types arise that search out others, use them as shields against predators and take away fitness from the solitary types by making them more conspicuous to their predators. Let the fitness payoff for a solitary individual living in a population consisting of only solitary types be P. But when a solitary individual is found and used by a social type, the solitary animal loses some fitness (B) to the social type. There is also an additional cost C to being social in terms of the time required to find a solitary individual to hide behind and that arising from the resulting increased conspicuousness to predators. When two social types interact, assume that they each have an equal chance of hiding behind the other when the predator attacks. A game theory diagram summarizes these interactions as follows:

Payoff for	In presence of	
	Solitary	Social
Solitary	P	P – B
Social	P + B – C	P + B/2 – B/2 – C = P – C

(A) If B is greater than C, what behavioral type will predominate in the population over time?
a. Solitary
b. Social

Put a tick mark (√) in the appropriate box.

a.	
b.	

(B) The average fitness payoff of a prey
(i) when it enters a population composed entirely of solitary types and
(ii) when it enters a population composed entirely of social types
would, respectively, be:

a. $P - B/2 - C/2$, $P + B/2 - C/2$
b. $P - B/2$, $P + B/2 - C$
c. $P + B/2 - C/2$, $P - B/2 - C/2$
d. $P + B/2$, $P - B/2 - C$

Put a tick mark (√) in the appropriate box.

a.	b.	c.	d.

37. (3 points) Game theory models have been borrowed from economics and often applied to behavioral ecology in order to understand the strategies that animals use against each other while competing for resources. In a Hawk-Dove game, for example, in which there were two kinds of competing individuals, Hawks and Doves, with different behavioral strategies, John Maynard Smith suggested the following pay-offs:

Winner	+50
Injury	-100
Loser	0
Display	-10

(A) Assuming that (a) Hawks always win against Doves, (b) Hawks win on half the occasions when they meet other Hawks but suffer injury during the other half, (c) Doves always display when they meet other Doves, but win on only half of these occasions, and (d) Doves never display to Hawks, what would be the average pay-off to the attacker in different fights as listed in the following matrix?

		Opponent	
		Hawk	Dove
Attacker	Hawk		
	Dove		

(B) An Evolutionary Stable Strategy (ESS) is one that will always win against any other strategy and no other strategy can be successful within the population. Evaluate whether the following statements are true or false given the pay-offs for the Hawk and Dove strategies listed above.

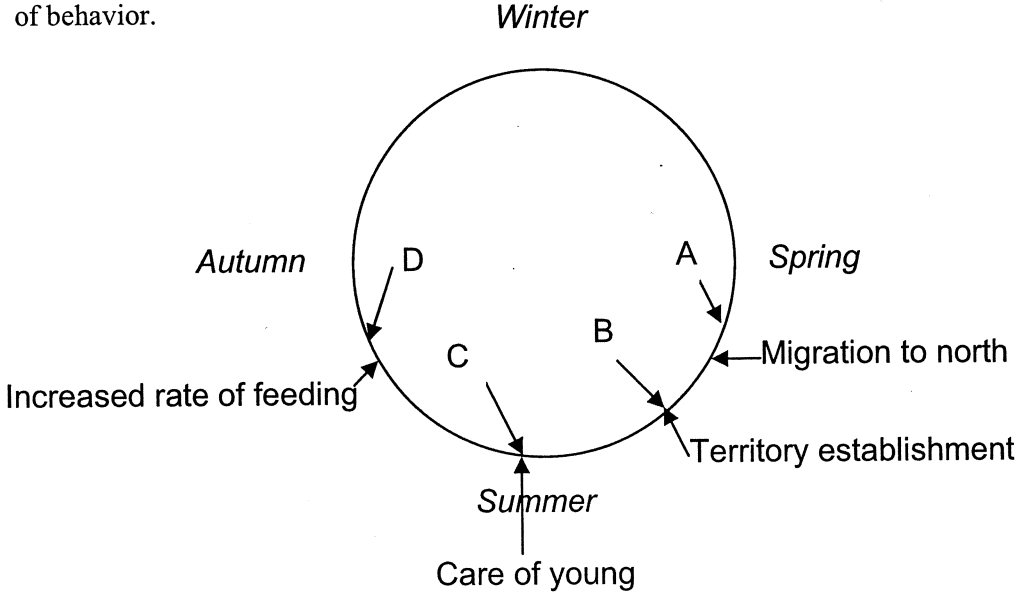
a. Hawk is an ESS and when all individuals in a population play this strategy, a mutation to Dove can never be successful.

b. Dove is an ESS and when all individuals in a population play this strategy, a mutation to Hawk can never be successful.

Put a tick mark (√) in the appropriate box.

Statement	True	False
a.		
b.		

38. (2 points) White crown sparrows that live in temperate regions show a complex annual cycle of behavior.



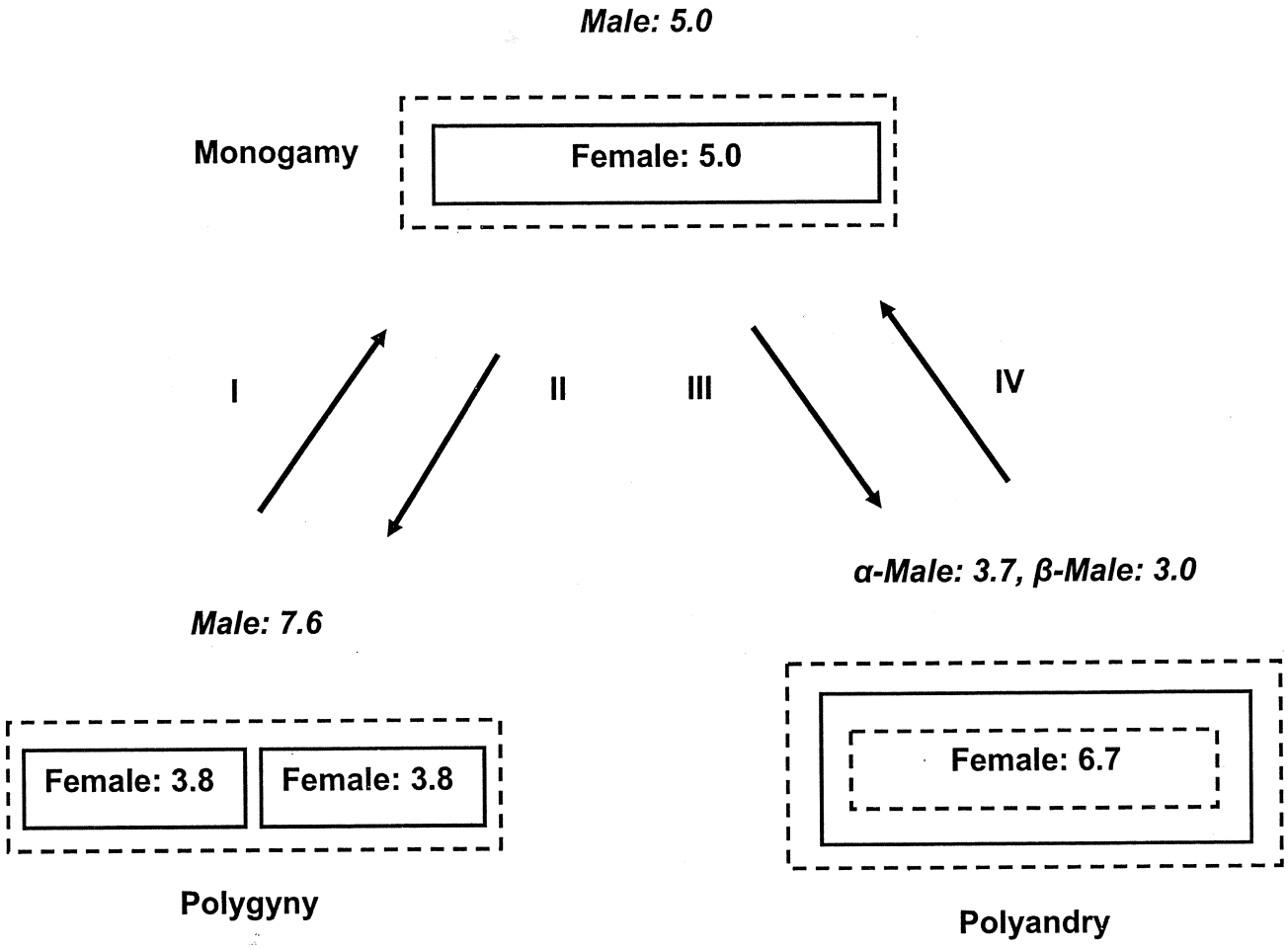
Match the physiological changes (I to V) in these birds with the appropriate points in the behavioral cycle (A to D). Choose from the following options and fill in the table given below with the appropriate numbers:

Options:

I. Molting / moulting
II. Gonadal regression (shrinking of reproductive tissue)
III. Gonadal development (development of the reproductive tissue)
IV. Fat deposition
V. Hibernation

Points in the behavioral cycle	Physiological changes
A	
B	
C	
D	

39. (4 points) The dunnock is a common bird of the British Islands. The females of this species establish territories represented by solid lines in the figure below, which may be defended by one or two (α and β) unrelated males (dashed lines). The numbers in the figure refer to the average number of young raised per season by males and females in the different mating combinations. The arrows indicate the directions in which the behaviour of the males and females encourage changes in the mating system.



(A) Identify the specific individuals, which would attempt to change the mating system in the directions shown by the arrows.

a. I: Male, II: Female, III: Female, IV: β-Male
b. I: Female, II: Male, III: β-Male, IV: α-Male
c. I: Female, II: Male, III: Female, IV: α-Male
d. I: Male, II: Female, III: α-Male, IV: β-Male

Put a tick mark (√) in the appropriate box.

a.	b.	c.	d.

(B) Which of the following statements are true?

I. The benefit of polygyny to males is the increased amount of food brought for the chicks by two females instead of one.
II. The cost of polygyny to females is shared male care because the contribution of the male's feeding efforts is essential for the survival of the chicks.

III. The cost of polyandry to females is the aggression that often results between the two males who have mated with her.
IV. The cost of polyandry to males is shared paternity.

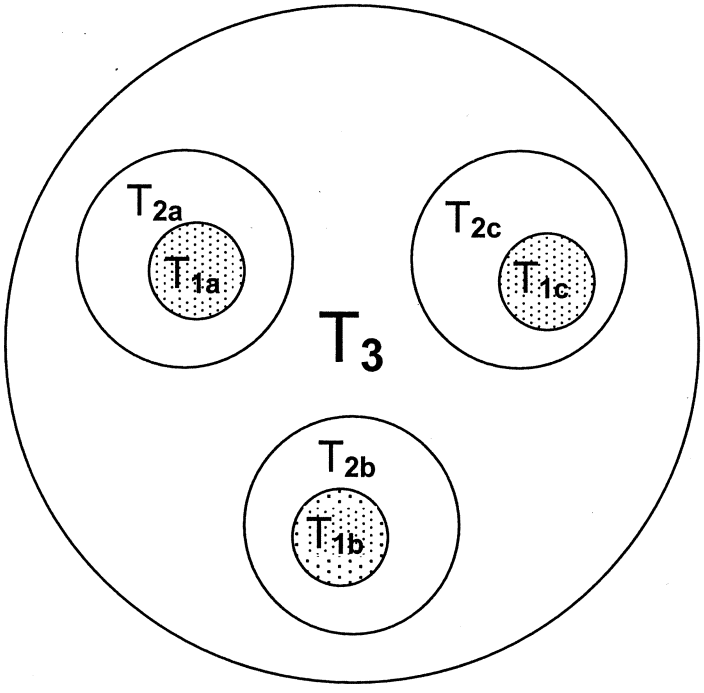
a. I and II
b. II and III
c. I and IV
d. II and IV

Put a tick mark (√) in the appropriate box.

a.	b.	c.	d.

BIOSYSTEMATICS (13)

40. (2 points) The schematic diagram below represents group-in-group relationships. The **T_3 taxon**, represented by the largest circle, includes three **T_2 taxa**. Each of these three **T_2 taxa** has one **T_1 taxon**, represented by circles filled with dots; the dots represent individuals.



According to above scheme, assign the correct taxa from the options given below to each of the circles. Fill in your answers by writing the appropriate number in the table. **Points will be awarded only if the entire table is correctly filled.**

Options:

I. Annelida
II. Lepidoptera
III. Polychaeta
IV. Mollusca

V. Orthoptera
VI. Insecta
VII. Arthropoda
VIII. Crustacea
IX. Gastropoda
X. Arachnida
XI. *Lumbricus* (earthworm)
XII. *Hirudo* (leech)
XIII. *Gryllus* (cricket)
XIV. *Unio* (freshwater mussel)
XV. *Euscorpias* (scorpion)
XVI. *Daphnia* (water flea)

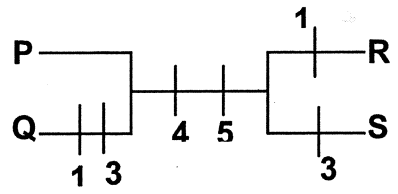
Taxon	Option
T3	
T2a	
T1a	
T2b	
T1b	
T2c	
T1c	

41. (2 points) The sequence of a pentanucleotide DNA segment of four species P, Q, R and S are given.

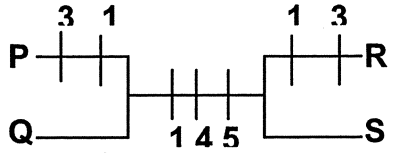
Species	Sequence site				
	1	2	3	4	5
P	A	G	T	T	C
Q	C	G	A	T	C
R	C	G	T	A	T
S	A	G	A	A	T

The most parsimonious phylogenetic classification of these species would be:

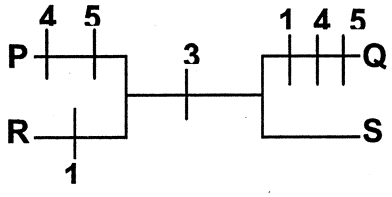
a.



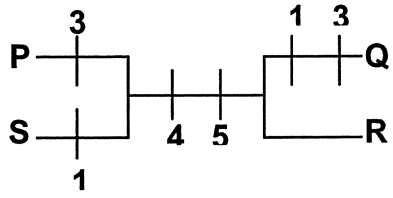
b.



c.



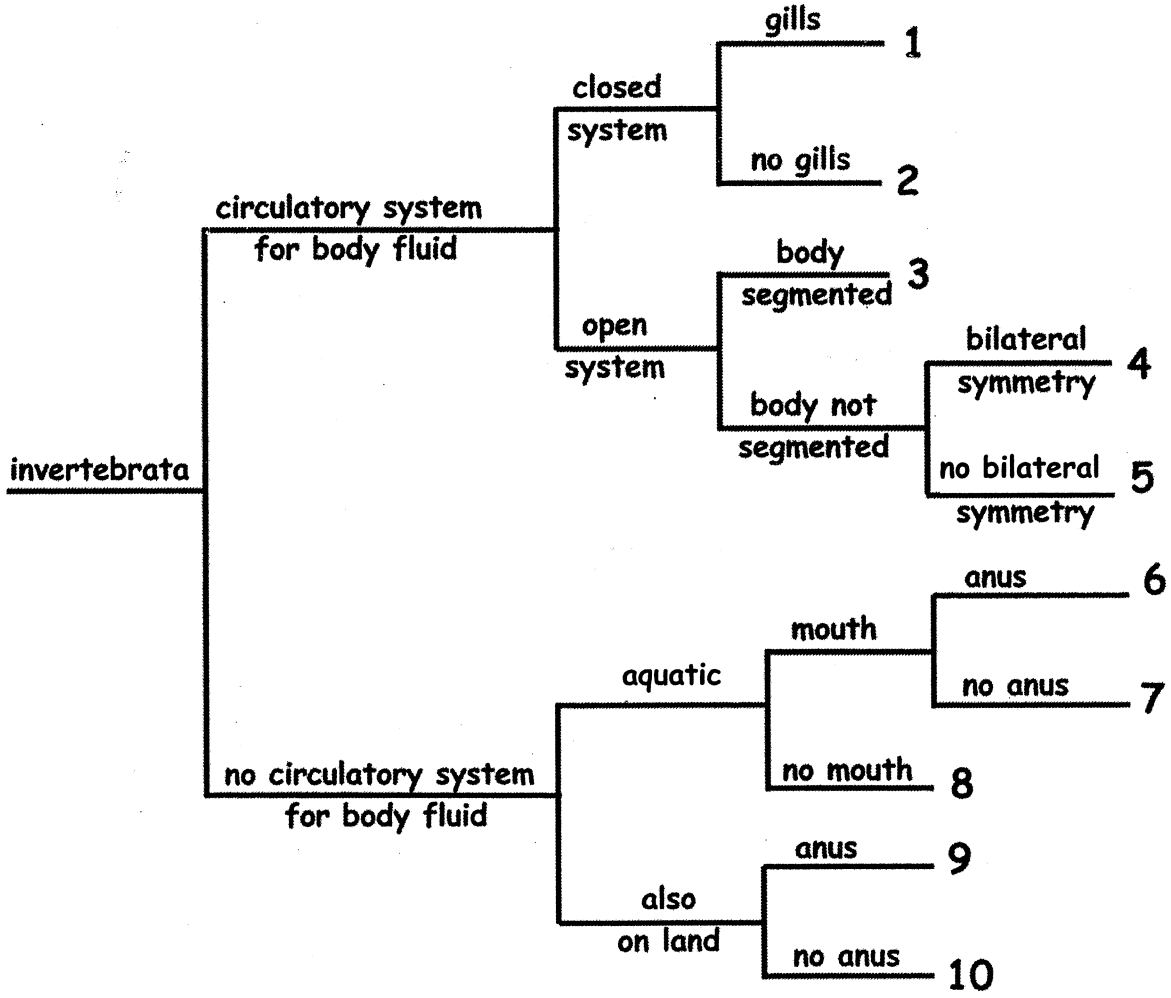
d.



Put a tick mark (√) in the appropriate box.

a.	b.	c.	d.

42. (5 points) A classification chart based on certain characteristics of invertebrates is shown below:



Fill in the appropriate numbers from the classification chart against the respective groups in the table below:

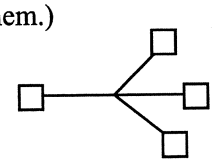
Group	Number	Group	Number
Annelida (Earthworms)		Mollusca (Land snails)	
Arthropoda (Crayfishes)		Mollusca (Squids)	
Cnidaria (Jellyfishes)		Nematoda (Roundworms)	
Echinodermata (Starfishes)		Platyhelminthes (Tapeworms)	
Mollusca (Bivalvia)		Porifera (Sponges)	

43. (4 points) The genetic distances between four species are provided in a matrix below. The numbers represent the percentage differences between each pair of species.

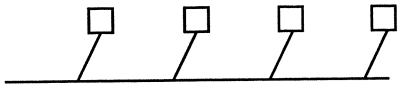
	A	B	C	D
A	-	-	-	-
B	5	-	-	-
C	13	14	-	-
D	15	16	6	-

(A) Which of the following tree structures represent the matrix data most appropriately? (Squares in the figure represent species and the lengths of the lines approximate the genetic distance between them.)

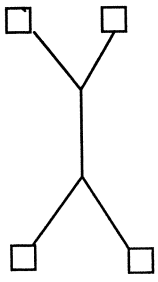
a.



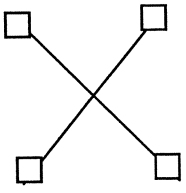
b.



c.



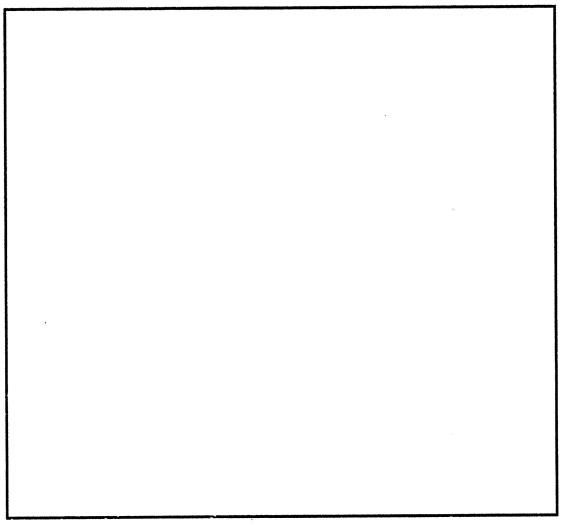
d.



Put a tick mark (√) in the appropriate box.

a.	b.	c.	d.

(B) Based on the answer selected in the previous question and using the data given in the matrix, construct the tree that correctly shows the genetic relatedness of the four species, where the numbers on the lines should approximate the genetic distance between them.



********** END OF PART B **********

ANSWER KEY TO THEORETICAL TEST

Student Code: _____

19th INTERNATIONAL BIOLOGY OLYMPIAD

THEORETICAL TEST – PART A

ANSWER KEY

Q. No.	a	b	c	d	e	Q. No.	a	b	c	d	e	Q. No.	a	b	c	d	e
1		■				22				■		43	■				
2			■			23				■		44		■			
3		■				24	■					45	■				
4				■		25				■		46				■	
5				■		26	■					47			■		
6		■				27		■				48		■			
7			■			28				■		49		■			
8			■			29				■		50	■				
9			■			30		■				51		■			
10	■					31	■					52					
11		■				32		■				53		■			
12		■				33			■			54			■		
13			■			34				■		55			■		
14			■			35		■				56	■				
15	■					36			■			57					
16		■				37		■				58	■				
17			■			38			■			59				■	
18	■					39	■					60				■	
19		■				40		■				61			■		
20		■				41				■		62					■
21	■					42				■		63	■				

Score Obtained:

Signature of Invigilator

Student Code: _____

19th INTERNATIONAL BIOLOGY OLYMPIAD

13th – 20th July, 2008

Mumbai, INDIA

THEORETICAL TEST – PART B

ANSWER KEY

CELL BIOLOGY (26 points)

1. (2 + 1 + 2 = 5 points)

a. Answer: 0.33×10^{-8} M

b. Answer: 1.36×10^{-3} m

c. Answer: 2.27×10^{11} cells

2. (0.5 x 6 = 3 points)

	Organ/Cell	SER extensively present	SER not extensively present	Function/s (if extensively present)
a.	Adrenal gland	√		I
b.	Sebaceous glands	√		I
c.	Intestinal villi	√		I
d.	Muscles	√		III
e.	Liver	√		II and IV
f.	Pancreas		√	

3. (0.5 x 4 = 2 points)

Situation I: A

Situation II: B

Situation III: B

Situation IV: A

4. (2 + 1 = 3 points)

a. Answer: 40 %

b. Answer: 1.5

5. (0.5 x 5 = 2.5 points)

1	2	3	4	5
E /A	A /E	B	C	D

6. (0.5 x 8 = 4 points)

I. 5.6

II. 6.3

III. 0.5

IV. 0.21

V.

	True	False
a.	√	
b.		√
c.		√
d.	√	

7. (1 + 1 + 2 = 4 points)

I.

a.	b.	c.	d.
		√	

II.

a.	b.	c.	d.
√			

III.

a.	b.	c.	d.
	√		

8. (0.5 x 5 = 2.5 points)

Protein	Mode of regulation			
	I	II	III	IV
A		√		
B				√
C	√			
D		√	√	

9. (0.5 x 8 = 4 points)

No.		Answer
I	Cell/s that is/are not alive when functional.	A, B, F
II	Plasmodesmata can be found associated with this/these cell/s.	C, D, E
III	When you eat potato, you eat the tissue formed of this/these cell/s.	D
IV	Cell/s that harden/s the nut skin.	F

10. (0.5 x 3 = 1.5 points)

Graph	Plant type
A	II
B	III
C	I

11. (0.5 x 4 = 2 points)

(A)

Region	Water potential
P	- 1 atm
Q	- 5 atm
R	- 8 atm

(B)

a.	b.	c.	d.
	√		

12. (1 for each row x 4 = 4 points)

	Chlamydomonas	Cyano-bacteria	Green-sulphur bacteria	Purple-sulphur bacteria
Phototrophic autotrophs	√	√	√	√
Photosystem II absent			√	√
Respiratory enzymes located on plasma membrane		√	√	√
Chlorophyll *a* as the major photosynthetic pigment	√	√		

13. (0.5 x 7 = 3.5 points)

Process	Does affect	Does not affect
1		√
2	√	
3	√	
4		√
5	√	
6	√	
7		√

14. (2 points)

a.	b.	c.	d.
		√	

15. (0.5 x 4 = 2 points)

	P	Q	R	S
Liver				√
Brain	√			
Thymus			√	
Gonads		√		

16. (0.5 x 4 = 2 points)

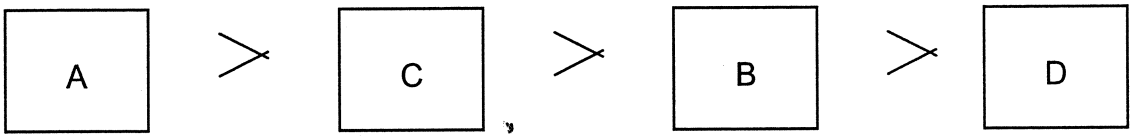
	True	False
a.		√
b.		√
c.	√	
d.	√	

17. (0.5 x 4 = 2 points)

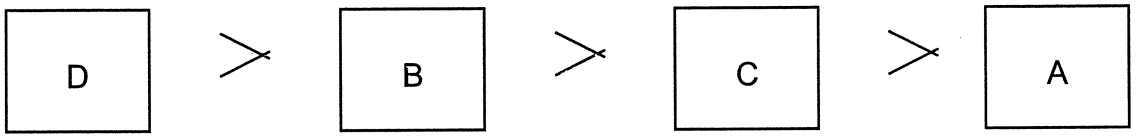
Set	Condition	True	False
I	Curve I. Normal blood pH and Curve II. Acidosis	√	
II	Curve I. 40°C and Curve II. 30°C		√
III	Curve I. Elephant hemoglobin and Curve II. Cat hemoglobin	√	
IV	Curve I. Fetal hemoglobin and Curve II. Maternal hemoglobin	√	

18. (1 x 2 = 2 points)

Surface area per unit volume of the body



Total volume of blood in the body



19. (1 + 1 + 0.5 x 6 = 5 points)

a.

a.	b.	c.	d.
	√		

b.

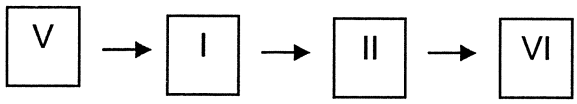
a.	b.	c.	d.
		√	

c.

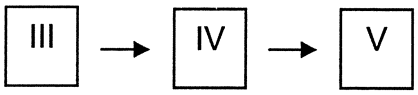
Options	True	False
a.		√
b.	√	
c.		√
d.	√	
e.		√
f.		√

20. (0.5 x 7 = 3.5 points)

A.



B.



21. (2 points)

Answer: 27/64 or 0.4219

22. (0.5 x 4 = 2 points)

	I	II	III
Lactose hydrolysis by β-galactosidase			√
Reduction of *lac* repressor's affinity for the *lac* operator		√	
Binding of the CAP-cAMP complex to the *lac* promoter		√	
Utilization of glucose	√		

23. (2 points)

Answer: 47.9 % or 48%

24. (2 points)

Answer: 1/6 or 0.1667

25. (2 points)

Answer: 9

26. (1 x 2 = 2 points)

a.

Yes	No
√	

b. Answer: 0.24

27. (1 x 2 = 2 points)

a. Answer: 0.5192

b. Answer: 0.3696

28. (2 points)

Answer: 1/10 or 0.1

29. (1 x 2 = 2 points)

I.

a.	b.	c.	d.
		√	

II 18.6 kDa

30. (1 + 0.5 x 3 = 2.5 points)

(A)

p	
q	
r	√

(B)

Distance between *p* and *q*	28.5 mu
Distance between *p* and *r*	17.5 mu
Distance between *q* and *r*	11 mu

31. (0.5 x 3 = 1.5 points)

Growth curve	Survivorship curve	Age-structure
S	P	T

32. (1 x 3 = 3 points)

(A)

a.	b.	c.	d.
	√		

(B)

a.	b.	c.	d.
	√		

(C)

a.	b.	c.
		√

33. (0.5 x 4 = 2 points)

Number	A	B	Type of interaction
1.	+	0	II
2.	+	+	IV
3.	+	–	V
4.	+	+	IV

34. (1 x 4 = 4 points)

(A)

a.	b.	c.	d.
√			

(B)

a.	b.	c.	d.
		√	

(C)

a.	b.	c.	d.
√			

(D)

a.	b.	c.	d.
√			

35. (0.5 + 0.5 + 0.5 + 1 + 0.5 + 0.5 + 0.5 + 0.5 + 1 + 0.5 = 6 points)

(A)

I.

a.	b.	c.	d.
		√	

II.

a.	b.	c.	d.
√			

III. Answer: 8

IV. Answer: 0.72

V.

a.	√
b.	

(B)

I.

a.	b.	c.	d.
		√	

II.

a.	b.	c.	d.
	√		

III. Answer: 1

IV. Answer: 1.82

V.

a.	√
b.	

36. (2 points)

(A)

a.	
b.	√

(B)

a.	b.	c.	d.
		√	

37. (0.5 x 6 = 3 points)

(A)

		Opponent	
		Hawk	Dove
Attacker	Hawk	-25	+50
	Dove	0	+15

(B)

Statement	True	False
a.		√
b.		√

38. (0.5 x 4 = 2 points)

Physiological change	Option/s
A	IV or I
B	III
C	II
D	IV or I

39. (2 x 2 = 4 points)

(A)

a.	b.	c.	d.
		√	

(B)

a.	b.	c.	d.
			√

40. (2 points)

Taxon	Option
T3	VII
T2a	VIII or X or VI, respectively
T1a	XVI or XV or XIII, respectively
T2b	VIII or X or VI, respectively
T1b	XVI or XV or XIII, respectively
T2c	VIII or X or VI, respectively
T1c	XVI or XV or XIII, respectively

41. (2 points)

a.	b.	c.	d.
√			

42. (0.5 x 10 = 5 points)

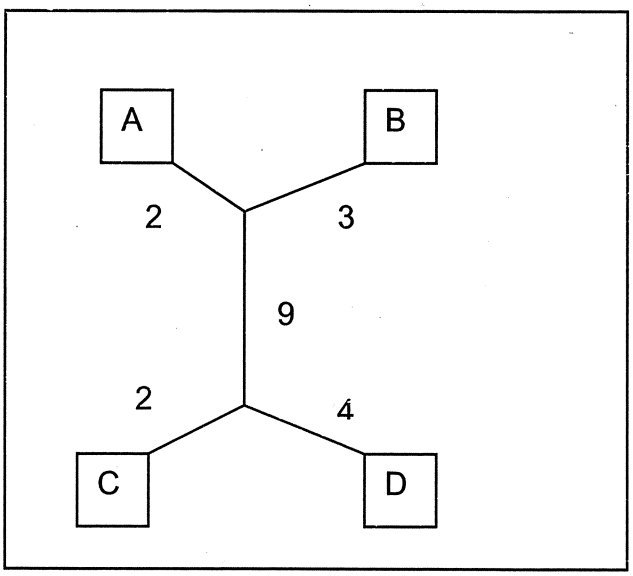
Group	Number	Group	Number
Annelida (Earthworms)	2	Mollusca (Snails)	5
Arthropoda (Crayfishes)	3	Mollusca (Squids)	1
Cnidaria (Jellyfishes)	7	Nematoda (Roundworms)	9
Echinodermata (Starfishes)	6	Platyhelminthes (Tapeworms)	10
Mollusca (Bivalvia)	4	Porifera (Sponges)	8

43. (1 + 3 = 4 points)

(A)

a.	b.	c.	d.
		√	

(B)



********** END OF PART B **********

FINAL RESULTS

	Name	Raw Scores								T-Scores						Final T score	Country	Meda
		Lab 1	Lab 2	Lab 3	Lab 4	Lab Total	Th A	Th B	Th Total	Lab 1	Lab 2	Lab 3	Lab 4	Lab Total	Th Total			
1	TAE YOUNG CHOI	34.5	52	19.25	39.75	145.5	54	102.5	156.5	67.51	57.46	64.29	58.75	62.00	74.39	68.20	Korea	G
2	Yayun Dong	28.5	57	27	42.25	154.75	49	94.25	143.25	59.92	63.46	75.40	62.08	65.21	68.90	67.06	China	G
3	Jonathan Liang	32.5	49	20.5	41	143	49	101.5	150.5	64.98	53.87	66.08	60.42	61.34	71.91	66.62	USA	G
4	Byung Woo Yoo	33	56	21	42.5	152.5	55	86.5	141.5	65.61	62.26	66.80	62.41	64.27	68.18	66.22	Korea	G
5	YiFei Men	33.5	52	23.5	36	145	53	94	147	66.24	57.46	70.39	53.78	61.97	70.46	66.22	Singapore	G
6	YUNG-TSAI CHU	35	52	17	33.5	137.5	54	98.5	152.5	68.14	57.47	61.07	50.45	59.28	72.74	66.01	Chinese Taipei	G
7	Thai Le Tran	34.5	59	20	40.75	154.25	48	89.25	137.25	67.51	65.86	65.37	60.09	64.71	66.42	65.57	Germany	G
8	TZU-YANG CHEN	37.5	52	13.75	44.25	147.5	53	88.75	141.75	71.30	57.47	56.42	64.74	62.48	68.29	65.38	Chinese Taipei	G
9	Thana Thongsricome	28.5	60	22.5	40	151	53	83	136	59.93	67.06	68.95	59.09	63.76	65.90	64.83	Thailand	G
10	Jonathan Marwick	33.5	53	17.75	37.25	141.5	55	88	143	66.25	58.67	62.15	55.44	60.63	68.80	64.71	Australia	G
11	Artsiom Marhunou	29	57	26.75	33	145.75	51	85.75	136.75	60.56	63.47	75.04	49.79	62.21	66.21	64.21	Belarus	G
12	Atiporn Therdyothin	38	51	20.75	39.75	149.5	51	83	134	71.94	56.27	66.45	58.76	63.35	65.08	64.21	Thailand	G
13	Haocheng Lu	24	56	14.75	35.5	130.25	53	95.75	148.75	54.24	62.27	57.85	53.11	56.87	71.19	64.03	China	G
14	Ruby Kwong	29	41	24.25	47	141.25	51	83.75	134.75	60.56	44.28	71.46	68.39	61.17	65.39	63.28	Australia	G
15	Weirong, Joshua Sng	32	55	22.75	40	149.75	43	81.5	124.5	64.35	61.07	69.31	59.09	63.46	61.14	62.30	Singapore	G
16	SHIH-SHIUAN KAO	28.5	57	17.75	42	145.25	49	79	128	59.93	63.47	62.15	61.75	61.82	62.59	62.21	Chinese Taipei	G
17	Jung Sunwoo	32	37	23.5	40	132.5	47	88.75	135.75	64.35	39.48	70.39	59.09	58.33	65.80	62.06	Korea	G
18	David Huang	26	56	15.75	41.25	139	52	80.25	132.25	56.77	62.27	59.28	60.75	59.77	64.35	62.06	USA	G
19	Seungsoo Kim	28	52	9.5	40.5	130	51	87.75	138.75	59.29	57.47	50.33	59.76	56.71	67.04	61.88	USA	G
20	Chaow Charoenkitkajorn	28	55	20.75	39.75	143.5	50	76	126	59.29	61.07	66.45	58.76	61.39	61.76	61.58	Thailand	G
21	Jonathan Gootenberg	24.5	48	19	43.75	135.25	51	80	131	54.87	52.67	63.94	64.08	58.89	63.83	61.36	USA	G
22	Subhrashis Guha Niyogi	25	57	19	40.75	141.75	40	86	126	55.50	63.47	63.94	60.09	60.75	61.76	61.25	India	G
23	HSU-HANG YEH	30	44	18.5	45.5	138	48	80	128	61.82	47.87	63.22	66.40	59.83	62.59	61.21	Chinese Taipei	S
24	Hua Zou	31.5	55	12.25	40.5	139.25	49	79	128	63.72	61.07	54.27	59.76	59.70	62.59	61.15	Canada	S
25	Thomas Flint	33.5	52	13.5	41.75	140.75	49	77.5	126.5	66.25	57.47	56.06	61.42	60.30	61.97	61.13	United Kingdom	S
26	AGNIESZKA GRZYB	24	55	21.5	35	135.5	52	76.5	128.5	54.24	61.07	67.52	52.45	58.82	62.80	60.81	Poland	S
27	Ji Soo Park	25.5	42	5	43.75	116.25	53	91	144	56.13	45.48	43.88	64.08	52.39	69.22	60.81	Korea	S
28	Min De, Timothy Lim	27.5	42	21.5	43	134	44	84	128	58.66	45.48	67.52	63.08	58.68	62.59	60.64	Singapore	S
29	Paul Waldron	30.5	52	22.75	43.5	148.75	43	72.25	115.25	62.45	57.47	69.31	63.74	63.24	57.31	60.28	United Kingdom	S

30	Anthony Martinelli	23.5	51	20	42	136.5	46	78.25	124.25	53.61	56.27	65.37	61.75	59.25	61.04	60.14	United Kingdom	S
31	Martin Frodl	32.5	52	18	39	141.5	47	73.5	120.5	64.98	57.47	62.51	57.76	60.68	59.48	60.08	Czech Republic	S
32	Chi Chuen, Kevin Choy	30	45	20.75	38.75	134.5	48	76	124	61.82	49.07	66.45	57.43	58.69	60.93	59.81	Singapore	S
33	Georgy Nosov	30	57	19.5	39.25	145.75	46	68.75	114.75	61.82	63.47	64.66	58.09	62.01	57.10	59.55	Russia	S
34	Jiyuan Yang	32.5	53	12	33.75	131.25	47	78.75	125.75	64.98	58.67	53.91	50.79	57.09	61.66	59.37	China	S
35	Siddharth Iyengar	21	50	13.75	35	119.75	46	87.5	133.5	50.45	55.07	56.42	52.45	53.60	64.87	59.23	India	S
36	PAWEL STAPINSKI	15.5	60	7.75	35.75	119	53	82	135	43.49	67.06	47.82	53.44	52.96	65.49	59.22	Poland	S
37	Jort Bosman	30	50	8.5	42	130.5	48	77.5	125.5	61.82	55.07	48.90	61.75	56.88	61.55	59.22	(The) Netherlands	S
38	David Leitinger	28	50	10.5	43	131.5	49	73	122	59.29	55.07	51.76	63.08	57.30	60.10	58.70	Australia	S
39	Pakawat Chongsathidkiet	32.5	47	10	38	127.5	51	73.5	124.5	64.98	51.47	51.05	56.43	55.98	61.14	58.56	Thailand	S
40	Keshinie Rasaratnam	27	39	22	43.75	131.75	39	79.5	118.5	58.03	41.88	68.24	64.08	58.06	58.65	58.35	Australia	S
41	Miao Jing	24.5	40	25.75	35	125.25	46	76	122	54.87	43.08	73.61	52.45	56.00	60.10	58.05	China	S
42	MARTÍN LEANDRO PALEICO	23.5	54	22.5	38	138	44	69	113	53.61	59.87	68.95	56.43	59.72	56.37	58.04	Argentina	S
43	GopaNandan Parthasarathy	22.5	51	18.5	33.5	125.5	44	76.5	120.5	52.34	56.27	63.22	50.45	55.57	59.48	57.53	India	S
44	KATARINA JURIKOVA	18	57	12.5	41.25	128.75	45	71.75	116.75	46.65	63.47	54.63	60.75	56.37	57.93	57.15	Slovakia	S
45	Yu Uchiumi	28.5	55	7	40	130.5	47	68.5	115.5	59.93	61.07	46.75	59.09	56.71	57.41	57.06	Japan	S
46	MARIANA SANCHEZ	27.5	55	13	39.5	135	44	67	111	58.66	61.07	55.34	58.43	58.38	55.55	56.96	Mexico	S
47	Bing Hang Li	30.5	38	15	38.5	122	42	77.5	119.5	62.45	40.68	58.21	57.10	54.61	59.07	56.84	Canada	S
48	Anton Kavaleuski	25.5	57	9.75	31	123.25	49	68	117	56.13	63.47	50.69	47.13	54.35	58.03	56.19	Belarus	S
49	MUHAMMAD AFFAWN ASHRAF	26.5	56	6.75	37.5	126.75	45	69	114	57.40	62.27	46.39	55.77	55.46	56.79	56.12	Pakistan	S
50	Erlaut Anugerah	26	47	18.25	39.75	131	44	63.5	107.5	56.77	51.47	62.87	58.76	57.47	54.10	55.78	Indonesia	S
51	Matthias Vanduren	32	39	15.25	42.25	128.5	36	73.25	109.25	64.35	41.88	58.57	62.08	56.72	54.82	55.77	Belgium	S
52	Katsiaryna Kastahladava	19	57	15.5	25.5	117	49	70.25	119.25	47.92	63.47	58.93	39.82	52.53	58.96	55.75	Belarus	S
53	KAI TIITSAAR	23.5	55	12	38.25	128.75	44	66	110	53.61	61.07	53.91	56.77	56.34	55.13	55.73	Estonia	S
54	KASRA AFZALI	26	41	8.75	36	111.75	49	73.5	122.5	56.77	44.28	49.26	53.78	51.02	60.31	55.66	Iran	S
55	Tomas Kesek	26	43	19.75	38	126.75	44	64.75	108.75	56.77	46.67	65.01	56.43	56.22	54.61	55.42	Sweden	S
56	Ihori Ebinuma	32.5	44	7.5	41.75	125.75	40	70	110	64.98	47.87	47.47	61.42	55.43	55.13	55.28	Japan	S
57	Christina Kuhlmey	19	55	12.25	43.75	130	44	62.25	106.25	47.92	61.07	54.27	64.08	56.83	53.58	55.21	Germany	S
58	MARYAM KHADEMIAN	27.5	56	9.25	32.25	125	39	70.25	109.25	58.66	62.27	49.97	48.79	54.92	54.82	54.87	Iran	S
59	Milda Jakutavičiūtė	32.5	55	6	35.25	128.75	46	60.25	106.25	64.98	61.07	45.32	52.78	56.04	53.58	54.81	Lithuania	S
60	Benoît Meijer	26	56	26.25	37	145.25	38	53	91	56.77	62.27	74.33	55.10	62.12	47.26	54.69	France	S
61	Pieter Valkema	35.5	37	5.5	43.25	121.25	40	70	110	68.77	39.48	44.60	63.41	54.07	55.13	54.60	(The) Netherlands	S
62	Vincent Hennion	27.5	51	19.5	41.5	139.5	44	51.25	95.25	58.66	56.27	64.66	61.09	50.17	49.02	54.59	France	S

63	JAMAL ALIYEV	22.5	41	4	26.5	94	50	81.5	131.5	52.34	44.28	42.45	41.15	45.05	64.04	54.55	Azerbaijan	S
64	Casper Hojgaard	29	51	11.5	41.75	133.25	38	62.5	100.5	60.56	56.27	53.20	61.42	57.86	51.20	54.53	Denmark	S
65	Adeline Colussi	19.5	43	8.5	41.5	112.5	46	70	116	48.55	46.67	48.90	61.09	51.30	57.62	54.46	Switzerland	S
66	Dwi Ariawan	16	52	19	37	124	46	60.5	106.5	44.12	57.47	63.94	55.10	55.16	53.68	54.42	Indonesia	S
67	Kentaro Okawara	24.5	46	10	39.25	119.75	42	67.75	109.75	54.87	50.27	51.05	58.09	53.57	55.03	54.30	Japan	B
68	Mustafa Burak TUNC	26.5	47	7.5	35.5	116.5	45	67.25	112.25	57.40	51.47	47.47	53.11	52.36	56.06	54.21	Turkey	B
69	Jean-Louis Dinh	24.5	55	18.5	44.25	142.25	38	53	91	54.87	61.07	63.22	64.74	60.97	47.26	54.12	France	B
70	Benjamin George Paterson	22.5	46	4	39	111.5	48	67.5	115.5	52.34	50.27	42.45	57.76	50.71	57.41	54.06	New Zealand	B
71	Sachit Daniel	11	46	4.75	29.5	91.25	55	75.5	130.5	37.80	50.27	43.53	45.14	44.18	63.63	53.91	India	B
72	Jelle Zijlstra	14.5	49	11.5	37	112	36	77.5	113.5	42.23	53.87	53.20	55.10	51.10	56.58	53.84	(The) Netherlands	B
73	PEDRO PINHEIRO DE NEGREIROS BESSA	7.5	52	5.5	35.5	100.5	49	74	123	33.38	57.47	44.60	53.11	47.14	60.52	53.83	Brazil	B
74	Artem Kurov	28	60	8	36.5	132.5	40	57	97	59.29	67.06	48.18	54.44	57.24	49.75	53.50	Ukraine	B
75	Catalin Ganea	17	55	9.5	28.5	110	45	69	114	45.39	61.07	50.33	43.81	50.15	56.79	53.47	Moldova	B
76	Petter Säterskog	30	38	6.75	46.5	121.25	37	66.5	103.5	61.82	40.68	46.39	67.73	54.16	52.44	53.30	Sweden	B
77	Shunichiro Mizuno	29	49	4	32.75	114.75	41	68.25	109.25	60.56	53.87	42.45	49.46	51.58	54.82	53.20	Japan	B
78	LINH NGUYEN MANH	21	48	6.75	36	111.75	45	66	111	50.45	52.67	46.39	53.78	50.82	55.55	53.18	Vietnam	B
79	MOHAMMADH OSSEIN POURNABEE	18	55	6	34.25	113.25	48	62.25	110.25	46.65	61.07	45.32	51.45	51.12	55.24	53.18	Iran	B
80	MICHAL PODGORSKI	20.5	58	10	30.75	119.25	46	59	105	49.81	64.66	51.05	46.80	53.08	53.06	53.07	Poland	B
81	Samantha Makarenko	26	47	20.5	42.5	136	38	52	90	56.77	51.47	66.09	62.41	59.19	46.85	53.02	Canada	B
82	Radoslav Aleksandrov	14.5	48	14	28.25	104.75	51	64	115	42.23	52.67	56.78	43.48	48.79	57.20	53.00	Bulgaria	B
83	Ondrej Korábek	18.5	58	6.5	31.25	114.25	45	62.75	107.75	47.29	64.66	46.03	47.46	51.36	54.20	52.78	Czech Republic	B
84	Justė Žagūnaitė	18.5	55	11	43	127.5	42	54.25	96.25	47.29	61.07	52.48	63.08	55.98	49.44	52.71	Lithuania	B
85	NICOLÁS MARCELO FULGINITI	24	52	7.75	37.5	121.25	39	62.25	101.25	54.24	57.47	47.82	55.77	53.82	51.51	52.67	Argentina	B
86	Arne Jahn	18.5	43	21.5	31.25	114.25	38	66.75	104.75	47.29	46.67	67.52	47.46	52.24	52.96	52.60	Germany	B
87	Maren Buettner	25.5	51	8	33.75	118.25	36	66.25	102.25	56.13	56.27	48.18	50.79	52.84	51.92	52.38	Germany	B
88	Homa Majd	29.5	37	7.75	30	104.25	42	70.5	112.5	61.19	39.48	47.82	45.80	48.57	56.17	52.37	Iran	B
89	JUAN FACUNDO CHRESTIA	23	40	9.5	35.25	107.75	40	69	109	52.97	43.08	50.33	52.78	49.79	54.72	52.25	Argentina	B
90	Justine Laverdeur	12.5	48	12.25	39.25	112	40	65.25	105.25	39.70	52.67	54.27	58.09	51.18	53.16	52.17	Belgium	B
91	Huub Vermeulen	32.5	41	0.75	40.75	115	38	65.25	103.25	64.98	44.28	37.80	60.09	51.79	52.34	52.06	(The) Netherlands	B
92	Olexandr Yagensky	26.5	49	1	31.75	108.25	43	65.75	108.75	57.40	53.87	38.15	48.13	49.39	54.61	52.00	Ukraine	B
93	LONG HA KIM	22.5	38	9.5	40	110	46	59.5	105.5	52.34	40.68	50.33	59.09	50.61	53.27	51.94	Vietnam	B
94	Ian Ross	30	45	7.5	41.5	124	41	53	94	61.82	49.07	47.47	61.09	54.86	48.50	51.68	United Kingdom	B

95	Alice Boilève	26	43	18.75	30.5	118.25	37	60.5	97.5	56.77	46.67	63.58	46.47	53.37	49.95	51.66	France	B
96	RUDOLF BICHELE	23	49	14.25	26.5	112.75	43	58.25	101.25	52.97	53.87	57.14	41.15	51.28	51.51	51.39	Estonia	B
97	GINTS KALNINS	14.5	60	8	34.5	117	43	54.25	97.25	42.23	67.06	48.18	51.78	52.31	49.85	51.08	Latvia	B
98	Gian Marco Messa	17.5	52	1	39.5	110	44	58.75	102.75	46.02	57.47	38.15	58.43	50.02	52.13	51.07	Italy	B
99	Anna Hartmanová	22	49	7.25	36.75	115	40	58	98	51.71	53.87	47.11	54.77	51.86	50.16	51.01	Czech Republic	B
100	Nina Turk	26.5	38	20	35.5	120	38	54.5	92.5	57.40	40.68	65.37	53.11	54.14	47.88	51.01	Slovenia	B
101	Kirsten Marshall	21.5	57	6.5	37.5	122.5	39	53.25	92.25	51.08	63.47	46.03	55.77	54.09	47.78	50.93	Canada	B
102	Yuliya Herasimchyk	18.5	48	8.75	26.5	101.75	44	63.75	107.75	47.29	52.67	49.26	41.15	47.59	54.20	50.90	Belarus	B
103	Yanuar D.P. Limasale	17.5	44	15.75	38.25	115.5	37	58	95	46.02	47.87	59.28	56.77	52.49	48.92	50.70	Indonesia	B
104	David López Martínez	24	50	6	37.75	117.75	42	52.25	94.25	54.24	55.07	45.32	56.10	52.68	48.61	50.64	Spain	B
105	Anastasiya Bondaryeva	25.5	52	7	35	119.5	37	55.75	92.75	56.13	57.47	46.75	52.45	53.20	47.98	50.59	Ukraine	B
106	Tereza Nedvědová	15.5	49	19	36.75	120.25	31	59.25	90.25	43.49	53.87	63.94	54.77	54.02	46.95	50.48	Czech Republic	B
107	Amanda Sarah Deacon	28	44	9.75	26.75	108.5	43	56.75	99.75	59.29	47.87	50.69	41.48	49.83	50.89	50.36	New Zealand	B
108	Satria C. Pamungkas	26	43	10.5	37	116.5	39	54	93	56.77	46.67	51.76	55.10	52.58	48.09	50.33	Indonesia	B
109	Emine Muleyke YUKSELEN	26	41	7.75	28.5	103.25	47	56.5	103.5	56.77	44.28	47.82	43.81	48.17	52.44	50.30	Turkey	B
110	TOMASZ KLAUS	14.5	55	8.75	31	109.25	39	60	99	42.23	61.07	49.26	47.13	49.92	50.57	50.25	Poland	B
111	Laura Leinonen	23	50	10	32	115	41	53.25	94.25	52.97	55.07	51.05	48.46	51.89	48.61	50.25	Finland	B
112	Douglas Temple	31.5	40	14	37.5	123	37	50	87	63.72	43.08	56.78	55.77	54.84	45.60	50.22	Ireland	B
113	Jessica Shailer	21.5	50	4.75	41.25	117.5	37	55	92	51.08	55.07	43.53	60.75	52.61	47.67	50.14	New Zealand	B
114	Rovshen Akmammedov	19	49	13.25	23.75	105	40	61	101	47.92	53.87	55.70	37.50	48.75	51.40	50.07	Turkmenistan	B
115	Miriam Luginbühl	14	42	2.75	45	103.75	43	58.25	101.25	41.60	45.48	40.66	65.74	48.37	51.51	49.94	Switzerland	B
116	ROBERT HELER	20	52	13.25	31	116.25	41	50	91	49.18	57.47	55.70	47.13	52.37	47.26	49.82	Romania	B
117	Anastasia Zykova	19.5	57	11	32.75	120.25	35	53.25	88.25	48.55	63.47	52.48	49.46	53.49	46.12	49.80	Russia	B
118	Sari Rytkonen	23.5	44	3	38	108.5	40	57.25	97.25	53.61	47.87	41.02	56.43	49.73	49.85	49.79	Finland	B
119	LUIS LEANDRO ZAPPANI	14	46	6	41	107	39	58.5	97.5	41.60	50.27	45.32	60.42	49.40	49.95	49.68	Argentina	B
120	Melanie Phair MacPherson	20.5	43	5.25	35.5	104.25	30	69.5	99.5	49.81	46.67	44.24	53.11	48.46	50.78	49.62	Ireland	B
121	MARIT PUUSEPP	18	49	9.5	10.5	87	48	65	113	46.65	53.87	50.33	19.89	42.69	56.37	49.53	Estonia	B
122	SAMUEL GENZOR	22.5	55	8	26	111.5	35	58.25	93.25	52.34	61.07	48.18	40.49	50.52	48.19	49.36	Slovakia	B
123	Ilkay Samil BEYDILLI	27.5	43	9	27.25	106.75	44	51.75	95.75	58.66	46.67	49.61	42.15	49.27	49.23	49.25	Turkey	B
124	Emelie Sandberg	27	47	0	40.5	114.5	35	54	89	58.03	51.47	36.72	59.76	51.49	46.43	48.96	Sweden	B
125	LAM NGUYEN NGOC	28.5	44	1	31	104.5	39	57.75	96.75	59.93	47.87	38.15	47.13	48.27	49.64	48.96	Vietnam	B
126	Alič Špela	14	51	9.5	29.75	104.25	45	50.75	95.75	41.60	56.27	50.33	45.47	48.42	49.23	48.82	Slovenia	B
127	Zhanat Koshenov	16	53	2.5	34.25	105.75	44	50.75	94.75	44.12	58.67	40.30	51.45	48.64	48.81	48.72	Kazakhstan	B
128	Gabriele Gut	21	53	9.75	35.25	119	37	46.5	83.5	50.45	58.67	50.69	52.78	53.15	44.15	48.65	Switzerla	B

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129	Arnat Balabiyev	17.5	42	6	30	95.5	44	57.5	101.5	46.02	45.48	45.32	45.80	45.65	51.61	48.63	Kazakhstan	B
130	Annageldi Tayyrov	16	42	14.25	28.75	101	41	54.75	95.75	44.12	45.48	57.14	44.14	47.72	49.23	48.47	Turkmenistan	B
131	Martin Van	17	45	14.5	37.5	114	29	56.25	85.25	45.39	49.07	57.49	55.77	51.93	44.88	48.40	Sweden	B
132	Manuela Binggeli	14	44	13	40	111	37	49.5	86.5	41.60	47.87	55.34	59.09	50.98	45.40	48.19	Switzerland	B
133	Chloe Elisabeth English	28	39	13.25	26.5	106.75	38	51.75	89.75	59.29	41.88	55.70	41.15	49.51	46.74	48.12	New Zealand	B
134	KÄRT MUST	17.5	42	9.5	35.25	104.25	34	57.75	91.75	46.02	45.48	50.33	52.78	48.65	47.57	48.11	Estonia	B
135	Galiullin Farkhat	19.5	57	3.75	38	118.25	35	47	82	48.55	63.47	42.09	56.43	52.64	43.53	48.08	Russia	B
136	Elena Malysheva	19.5	60	4	29.75	113.25	34	51.25	85.25	48.55	67.06	42.45	45.47	50.88	44.88	47.88	Russia	B
137	Laura Navasaityte	13	41	8.75	37.5	100.25	40	53.5	93.5	40.33	44.28	49.26	55.77	47.41	48.30	47.85	Lithuania	B
138	Tommaso Nelli	24.5	45	8.25	35.5	113.25	36	46.25	82.25	54.87	49.07	48.54	53.11	51.40	43.63	47.52	Italy	B
139	JUAN PABLO PANICO	19	52	0	36.25	107.25	39	48.25	87.25	47.92	57.47	36.72	54.11	49.05	45.71	47.38	Mexico	
140	Hacer Gozde GUL	21	31	6.75	32.5	91.25	43	55	98	50.45	32.28	46.39	49.12	44.56	50.16	47.36	Turkey	
141	Rustam Esanov	21.5	38	7.75	33.25	100.5	38	52.5	90.5	51.08	40.68	47.82	50.12	47.42	47.05	47.24	Turkmenistan	
142	ARTOGHRUL ALISHBAYLI	7.5	37	6.75	38.25	89.5	40	58.5	98.5	33.38	39.48	46.39	56.77	44.00	50.37	47.19	Azerbaijan	
143	Maša Bizjak	21.5	35	15	32.5	104	29	57.25	86.25	51.08	37.08	58.21	49.12	48.87	45.29	47.08	Slovenia	
144	Andrii Zhylenko	22	53	1	29.5	105.5	39	48.25	87.25	51.71	58.67	38.15	45.14	48.42	45.71	47.06	Ukraine	
145	Signe Storch Jakobsen	26	34	21.75	33.5	115.25	34	41.25	75.25	56.77	35.88	67.88	50.45	52.74	40.73	46.74	Denmark	
146	ZIGMUNDS ORLOVSKIS	20.5	53	0.75	27.5	101.75	36	52.25	88.25	49.81	58.67	37.80	42.48	47.19	46.12	46.65	Latvia	
147	SAMIA ASIF	14	46	7	28.75	95.75	35	56.25	91.25	41.60	50.27	46.75	44.14	45.69	47.36	46.53	Pakistan	
148	JURIS KIBILDS	18	49	6	35.25	108.25	37	43.5	80.5	46.65	53.87	45.32	52.78	49.65	42.91	46.28	Latvia	
149	Tytti Turkia	19.5	39	7	29.5	95	41	48	89	48.55	41.88	46.75	45.14	45.58	46.43	46.00	Finland	
150	KARINA VANADZINA	14.5	58	3	22.75	98.25	37	48.75	85.75	42.23	64.66	41.02	36.17	46.02	45.08	45.55	Latvia	
151	RUFAT AHMEDZADE	13.5	33	3	22.25	71.75	48	56.25	104.25	40.96	34.68	41.02	35.50	38.04	52.75	45.40	Azerbaijan	
152	AZAD ALIZADE	7	47	4	25	83	37	58.75	95.75	32.75	51.47	42.45	39.16	41.46	49.23	45.34	Azerbaijan	
153	Francesco Faustino	10.5	44	0	33.5	88	44	47.5	91.5	37.17	47.87	36.72	50.45	43.06	47.47	45.26	Italy	
154	Bram Weytjens	20	43	4.5	34	101.5	34	46.5	80.5	49.18	46.67	43.17	51.12	47.54	42.91	45.22	Belgium	
155	GUILLERMO RAMIREZ	12.5	43	6	32.5	94	31	54.5	85.5	39.70	46.67	45.32	49.12	45.20	44.98	45.09	Mexico	
156	Anja Strmšek	29.5	41	3	35.25	108.75	29	45.25	74.25	61.19	44.28	41.02	52.78	49.82	40.32	45.07	Slovenia	
157	GEORGETA BONTAŞ	16	44	8.75	32.5	101.25	37	41.75	78.75	44.12	47.87	49.26	49.12	47.59	42.18	44.89	Romania	
158	PAUL- ADRIAN BULZU	17	53	0.75	27.5	98.25	36	46	82	45.39	58.67	37.80	42.48	46.08	43.53	44.81	Romania	
159	VERONIKA GABRISOVA	23	47	6.75	25.25	102	33	45.25	78.25	52.97	51.47	46.39	39.49	47.58	41.98	44.78	Slovakia	
160	EVA BACINSKA	15.5	44	3.75	27.25	90.5	37	50	87	43.49	47.87	42.09	42.15	43.90	45.60	44.75	Slovakia	
161	Vasileios Ntriankos	23	42	11.5	29.75	106.25	29	44.25	73.25	52.97	45.48	53.20	45.47	49.28	39.91	44.59	Greece	
162	Sergiu Stirbu	14.5	54	3	28.75	100.25	31	46.25	77.25	42.23	59.87	41.02	44.14	46.81	41.56	44.19	Moldova	
163	Samat Kadyrov	12.5	48	3	37.5	101	38	38	76	39.70	52.67	41.02	55.77	47.29	41.05	44.17	Kyrgyzstan	

164	Justina Kulikauskaitė	19.5	31	5.5	34.25	90.25	37	46.25	83.25	48.55	32.28	44.60	51.45	44.22	44.05	44.13	Lithuania	
165	Ioannis Stefanou	17	46	12.75	34.5	110.25	29	38.75	67.75	45.39	50.27	54.99	51.78	50.61	37.63	44.12	Greece	
166	GEORGIANA EMMANUELA GÎLCĂ	26	38	0.75	21	85.75	33	54.5	87.5	56.77	40.68	37.80	33.84	42.27	45.81	44.04	Romania	
167	Bakhytbek Zhalmagambetov	17	49	7	18.25	91.25	36	47	83	45.39	53.87	46.75	30.19	44.05	43.95	44.00	Kazakhstan	
168	Michalis Georgiou	14.5	42	7	32	95.5	27	51.25	78.25	42.23	45.48	46.75	48.46	45.73	41.98	43.85	Cyprus	
169	MOAZ BIN ZIA	18.5	39	0.75	38	96.25	32	45.75	77.75	47.29	41.88	37.80	56.43	45.85	41.77	43.81	Pakistan	
170	DANIEL PATROCINO ZEN	6.5	47	1	19.5	74	45	50.5	95.5	32.12	51.47	38.15	31.85	38.40	49.12	43.76	Brazil	
171	Antoan Garev	17.5	43	2	22	84.5	38	49	87	46.02	46.67	39.59	35.17	41.86	45.60	43.73	Bulgaria	
172	Xavier Gavilan	9.5	40	12.25	29.75	91.5	34	45.75	79.75	35.91	43.08	54.27	45.47	44.68	42.60	43.64	Belgium	
173	PEDRO SABINO GOMES NETO	11.5	42	3.5	29	86	32	52	84	38.44	45.48	41.74	44.47	42.53	44.36	43.44	Brazil	
174	Nikolaos Papachristou	21	36	1.5	26.75	85.25	28	56	84	50.45	38.28	38.87	41.48	42.27	44.36	43.31	Greece	
175	JOEL HERRERA	23	43	5.75	31.25	103	28	42	70	52.97	46.67	44.96	47.46	48.02	38.56	43.29	Mexico	
176	Ruslan Kalizhan	12.5	40	7	23.25	82.75	35	50	85	39.70	43.08	46.75	36.83	41.59	44.77	43.18	Kazakhstan	
177	Carol-ann Gallager	24.5	37	5	33	99.5	28	43.25	71.25	54.87	39.48	43.88	49.79	47.01	39.08	43.04	Ireland	
178	Mariya Tsaneva	9	44	5	25.5	83.5	37	46	83	35.28	47.87	43.88	39.82	41.71	43.95	42.83	Bulgaria	
179	Víctor Fanjul Hevia	11	53	0.75	32.5	97.25	29	42.75	71.75	37.80	58.67	37.80	49.12	45.85	39.28	42.57	Spain	
180	SHERZOD MUMINOV	22.5	38	4.75	33.5	98.75	30	39.25	69.25	52.34	40.68	43.53	50.45	46.75	38.25	42.50	Kyrgyzstan	
181	Emer Patsy O Connell	15	36	6.75	31.75	89.5	31	44.75	75.75	42.86	38.28	46.39	48.13	43.91	40.94	42.43	Ireland	
182	Sonia Rodríguez Fernández	21	43	2	33	99	29	39.5	68.5	50.45	46.67	39.59	49.79	46.62	37.94	42.28	Spain	
183	Laura Witt Zehngraff	19	41	7.75	29.25	97	30	38.75	68.75	47.92	44.28	47.82	44.80	46.21	38.04	42.12	Denmark	
184	PEDRO ROGERIO MENDONÇA DE ALENCAR	4	38	4	23.5	69.5	38	52	90	28.96	40.68	42.45	37.16	37.31	46.85	42.08	Brazil	
185	OLUCHI NNEOMA OZOEMENA	12.5	36	2	30	80.5	35	44.75	79.75	39.70	38.28	39.59	45.80	40.84	42.60	41.72	Nigeria	
186	Camilla Rotvel	15.5	33	6	35	89.5	37	34	71	43.49	34.68	45.32	52.45	43.98	38.97	41.48	Denmark	
187	Dumitru Muntean	18	41	3.5	36	98.5	24	39	63	46.65	44.28	41.74	53.78	46.61	35.66	41.13	Moldova	
188	Wajihullah Walizade	11	31	0	35.25	77.25	33	44.5	77.5	37.80	32.28	36.72	52.78	39.90	41.67	40.78	Afghanistan	
189	Lea-Maaria Borg	9	44	5	26.75	84.75	26	44.75	70.75	35.28	47.87	43.88	41.48	42.13	38.87	40.50	Finland	
190	NGA TRAN PHUONG	12	34	3	29.5	78.5	31	43.75	74.75	39.07	35.88	41.02	45.14	40.28	40.53	40.40	Vietnam	
191	Solongo Baatarkhuu	17	48	0	21.5	86.5	32	37.75	69.75	45.39	52.67	36.72	34.51	42.32	38.46	40.39	Mongolia	
192	Harry Anastos	12	36	1	37.75	86.75	27	40.5	67.5	39.07	38.28	38.15	56.10	42.90	37.52	40.21	Cyprus	
193	Dimitar Epihov	12.5	43	0.75	23	79.25	41	32.5	73.5	39.70	46.67	37.80	36.50	40.17	40.01	40.09	Bulgaria	
194	KHABIBULLIN TIMUR	7.5	35	0	15	57.5	38	51.75	89.75	33.38	37.08	36.72	25.87	33.26	46.74	40.00	Tajikistan	
195	Chinzorig Damjin	12	45	1	24.5	82.5	28	42.25	70.25	39.07	49.07	38.15	38.49	41.20	38.66	39.93	Mongolia	

196	ZUNAIRA FATIMA	8.5	47	5	25.5	86	25	41.5	66.5	34.64	51.47	43.88	39.82	42.46	37.11	39.78	Pakistan	
197	ASKHATBEK TEMIRKULOV	9.5	45	2	23.25	79.75	26	45.25	71.25	35.91	49.07	39.59	36.83	40.35	39.08	39.71	Kyrgyzstan	
198	DILNOZA ULUGOVA	13.5	28	6	23.75	71.25	28	47.75	75.75	40.96	28.68	45.32	37.50	38.12	40.94	39.53	Tajikistan	
199	Mihai Nazaria	4.5	50	2	17	73.5	32	42.75	74.75	29.59	55.07	39.59	28.52	38.19	40.53	39.36	Moldova	
200	MIRZOALII IKROMZODA LOLAI	12.5	30	0	22.75	65.25	32	47.5	79.5	39.70	31.08	36.72	36.17	35.92	42.50	39.21	Tajikistan	
201	Andrea Mariello	9.5	36	3.25	36	84.75	28	35.75	63.75	35.91	38.28	41.38	53.78	42.33	35.97	39.15	Italy	
202	Kyros Kyrou	24.5	47	3	27.25	101.75	20	31.25	51.25	54.87	51.47	41.02	42.15	47.38	30.79	39.08	Cyprus	
203	HALIMA IBRAHIM ABBA	12.5	42	0	33	87.5	22	36.5	58.5	39.70	45.48	36.72	49.79	42.92	33.79	38.36	Nigeria	
204	Erdenechimeg Munkhbat	14.5	39	2	15.75	71.25	29	35.75	64.75	42.23	41.88	39.59	26.86	37.64	36.38	37.01	Mongolia	
205	Suvd Sainjargal	13	32	1	20	66	32	35.75	67.75	40.33	33.48	38.15	32.51	36.12	37.63	36.87	Mongolia	
206	Helena Alonso Valencia	10.5	36	10.5	28.75	85.75	14	37	51	37.17	38.28	51.76	44.14	42.84	30.69	36.76	Spain	
207	EMEKA JUSTUS DURU	2	38	4.5	24	68.5	32	32	64	26.43	40.68	43.17	37.83	37.03	36.07	36.55	Nigeria	
208	Vasiliki Syrmou	11.5	39	4	19.75	74.25	22	37.75	59.75	38.44	41.88	42.45	32.18	38.74	34.31	36.52	Greece	
209	ABDULLAH ALQALLAF	12	37	1.5	31	81.5	22	30.75	52.75	39.07	39.48	38.87	47.13	41.14	31.41	36.27	Kuwait	
210	OLORUNFUNMI MICHAEL OYESANYA	3.5	42	0	24	69.5	28	33.5	61.5	28.32	45.48	36.72	37.83	37.09	35.04	36.06	Nigeria	
211	Sadeq Shah Laiq Shah	7.5	29	1	19.75	57.25	25	37.25	62.25	33.38	29.88	38.15	32.18	33.40	35.35	34.37	Afghanistan	
212	Waisuddin Ibrahimi	11	29	1.75	16.5	58.25	20	37	57	37.80	29.88	39.23	27.86	33.69	33.17	33.43	Afghanistan	
213	Shohrat Berdiyev	10	38	0	20	68	19	29.75	48.75	36.54	40.68	36.72	32.51	36.61	29.76	33.18	Turkmenistan	
214	FATEMAH ALSHAWAF	14	33	4.5	16	67.5	13	35	48	41.60	34.68	43.17	27.20	36.66	29.44	33.05	Kuwait	
215	Georgia Dimitropoulou	11.5	30	0	17	58.5	24	30.5	54.5	38.44	31.08	36.72	28.52	33.69	32.14	32.91	Cyprus	
216	LAILA SHAH	7	40	6	17.25	70.25	23	18.25	41.25	32.75	43.08	45.32	28.86	37.50	26.65	32.07	Kuwait	
217	Omid Mohammad Hakim	6	24	4.5	20	54.5	19	27	46	31.48	23.89	43.17	32.51	32.76	28.62	30.69	Afghanistan	
218	FATEMAH ALDALAL	11	26	0	18.25	55.25	20	25.25	45.25	37.80	26.29	36.72	30.19	32.75	28.31	30.53	Kuwait	
219	DAMIRBEK ABIBILLAEV	2	25	0	8	35	25	34.5	59.5	26.43	25.09	36.72	16.56	26.20	34.21	30.20	Kyrgyzstan	
220	HILOLA HAKIMOVA	4.5	7	0	24.5	36	26	30	56	29.59	3.50	36.72	38.49	27.07	32.76	29.92	Tajikistan	

STATISTICAL ANALYSIS OF RESULTS

A total of 220 students competed at the 19th International Biology Olympiad in Mumbai, India. These students were given four experimental tests and a single theory test comprising of Part A and B. The statistical analysis of the marks obtained by the students is presented below.

THEORETICAL TEST

The following table presents some statistical data related to the theoretical test.

	Theory A	Theory B	Theory Total
Max. Obtainable marks	61	120.5	181.5
Max. Obtained marks	55	102.5	156.5
Min. Obtained marks	13	18.25	41.25
Mean	39.02	58.59	97.61
Relative Mean (%)	63.97	48.62	53.78
Median	39	56.63	95.75
SD	8.67	16.51	24.13
CV = SD/Mean	0.22	0.28	0.25

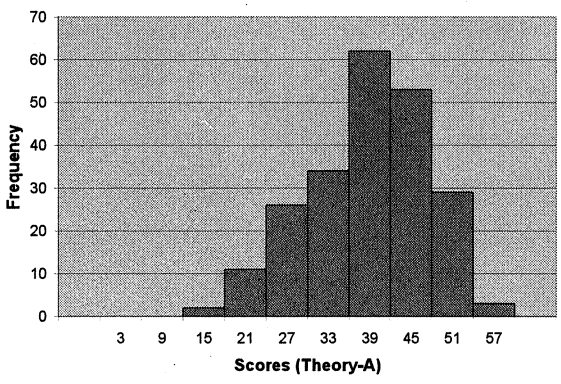
From the data table, one finds that students have performed better in Theory A (which consisted of multiple choice questions) than in Theory B.

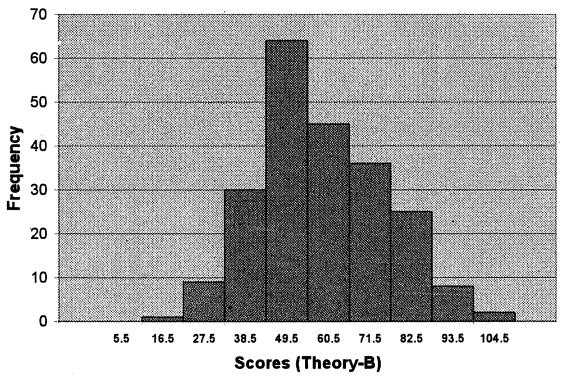
Figures supporting this conclusion are:

- Relative mean (%) of Theory A is more than Relative mean (%) of Theory B.
- SD of Theory A is less than SD of Theory B.
- Coefficient of Variation (CV) for Theory A is lower than CV for Theory B.
- Medians are almost the same as the respective means.

Lower CV indicates less discriminatory power of a test. Although there is not much difference between the discriminatory powers of Theory A and Theory B, one can say that Theory B can discriminate among the students better than Theory A.

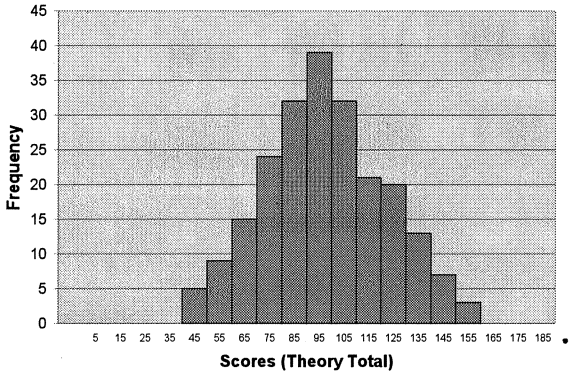
This is evident from the following histograms:



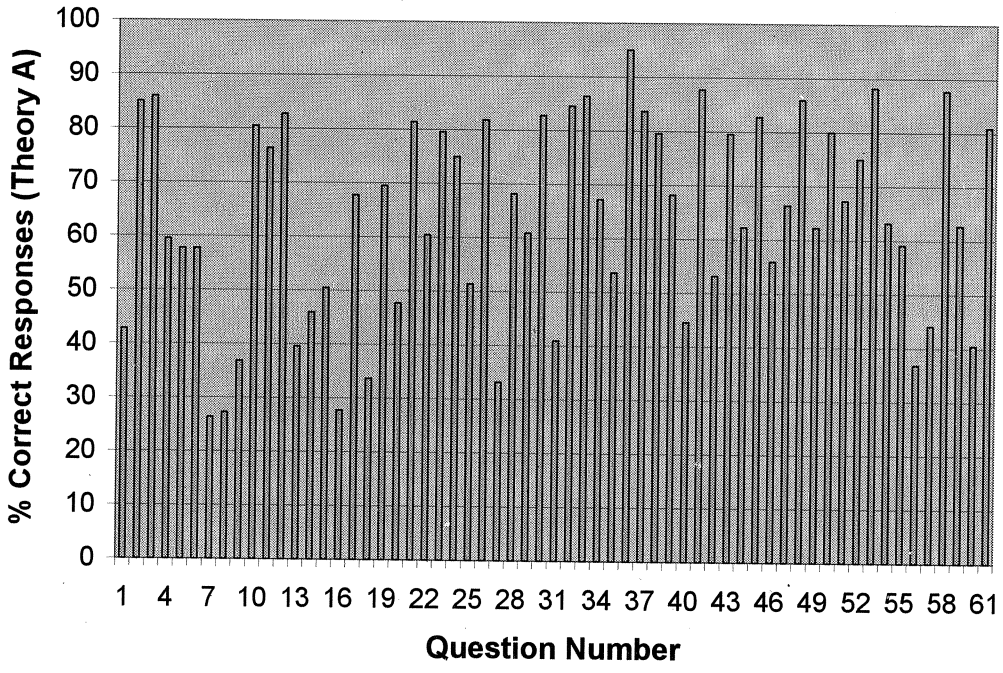


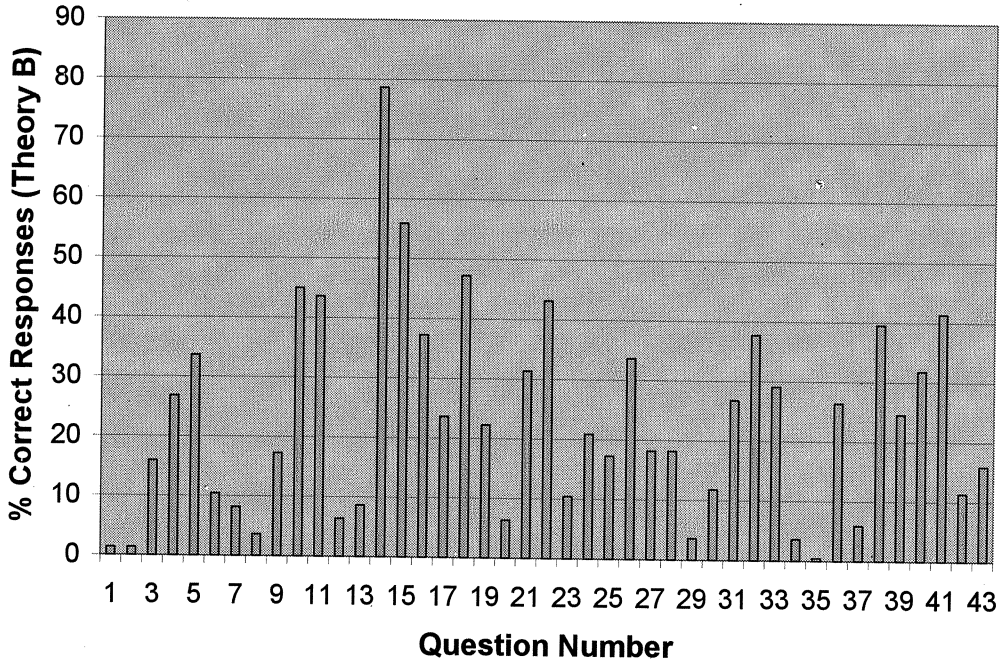
In Theory A, greater number of students scored higher points.
In Theory B, lesser number of students scored higher points.

However, the histogram of the Theory Total shows less asymmetry.

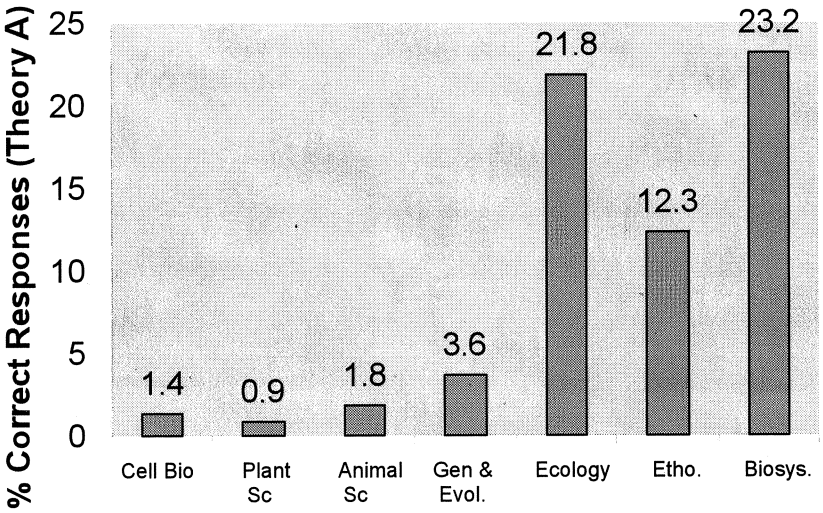


QUESTION WISE PERCENT CORRECT RESPONSES FOR THEORY A AND THEORY B

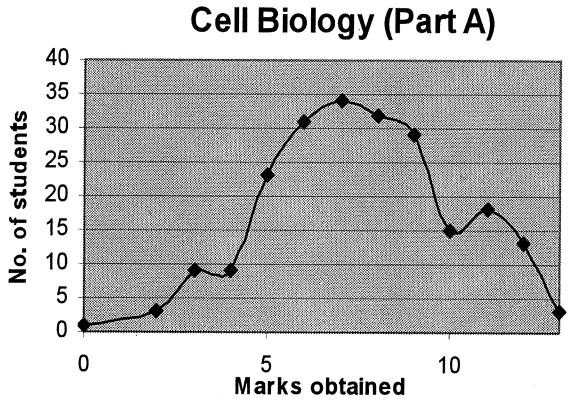


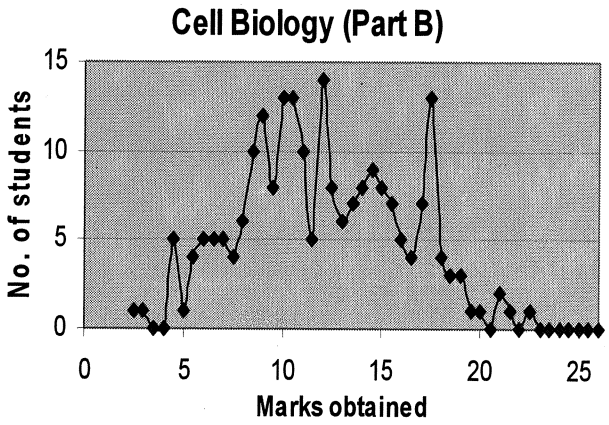


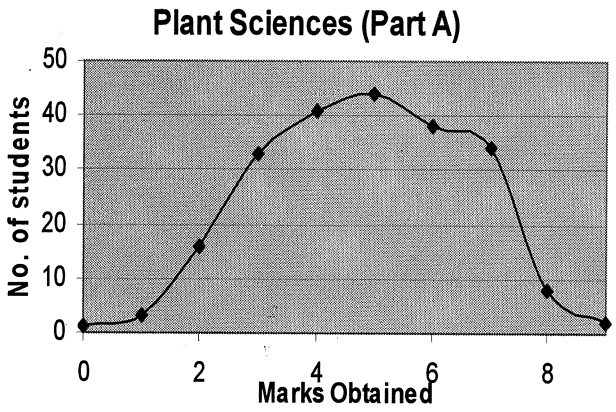
AREA WISE PERCENT CORRECT RESPONSES FOR THEORY A

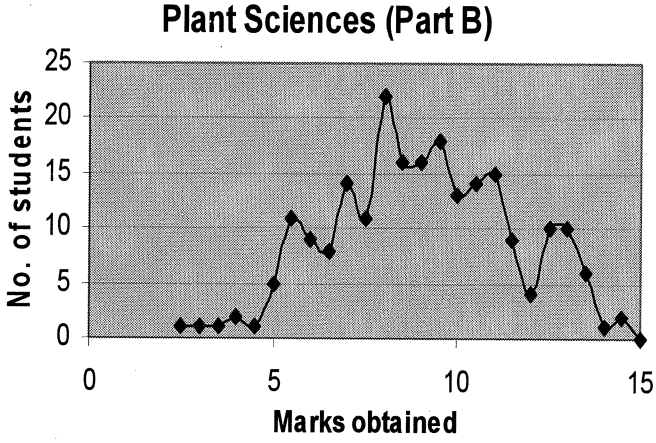


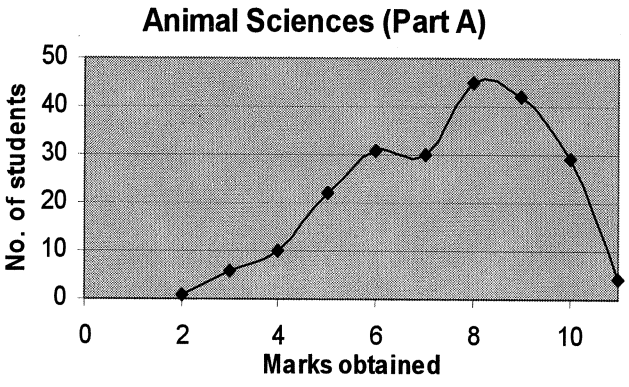
STUDENTS' DENSITY TRACE FOR THEORY A AND B

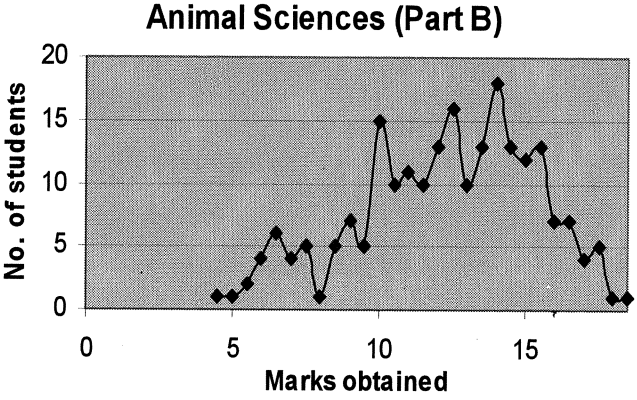


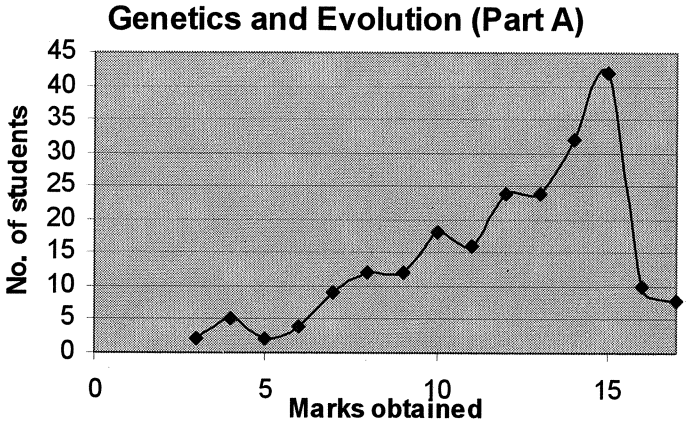


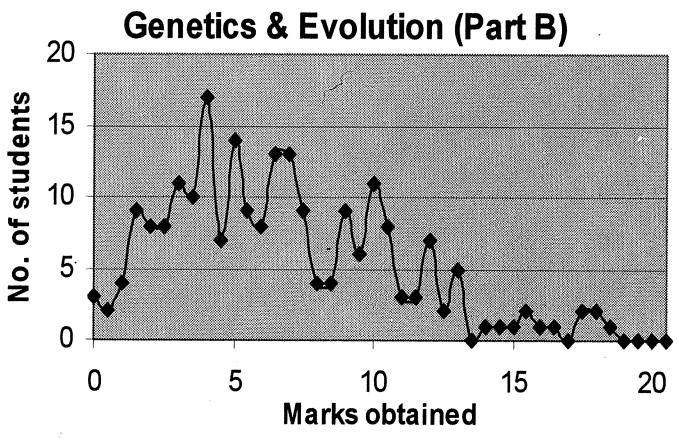


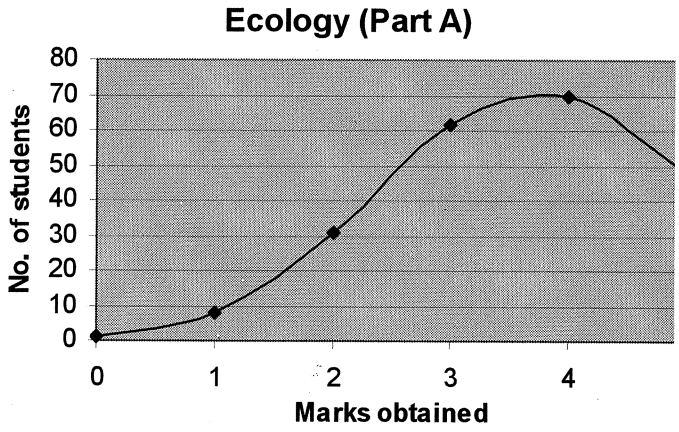


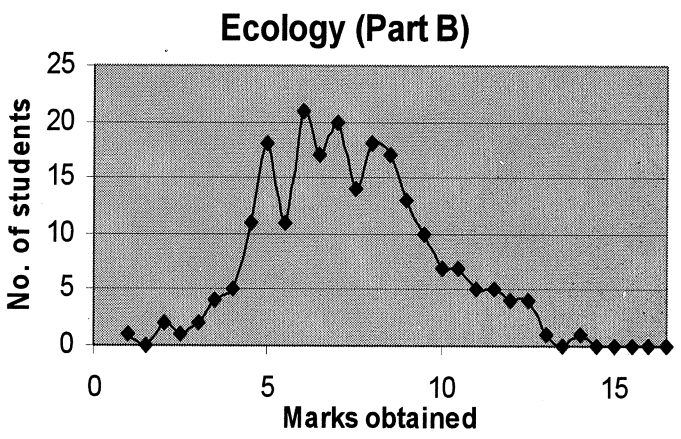


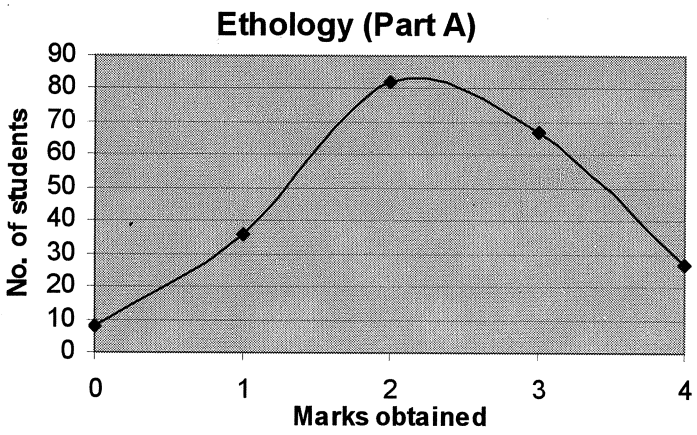


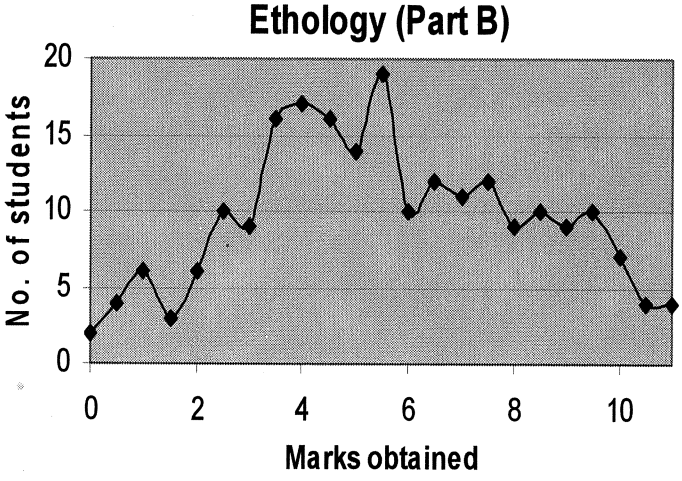

Genetics and Evolution (Part A)
No. of students
Marks obtained

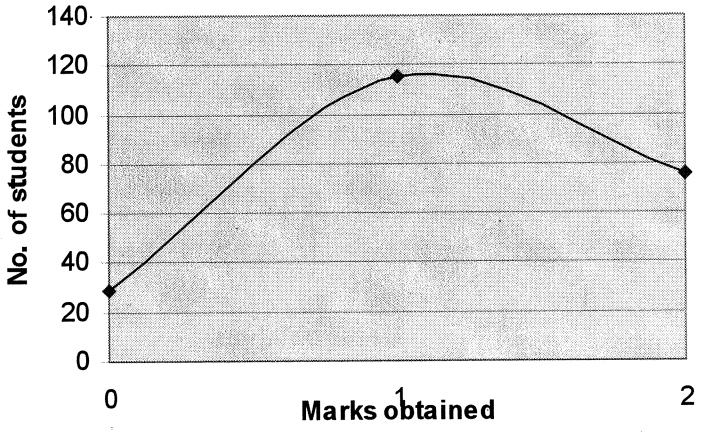

Genetics & Evolution (Part B)
No. of students
Marks obtained

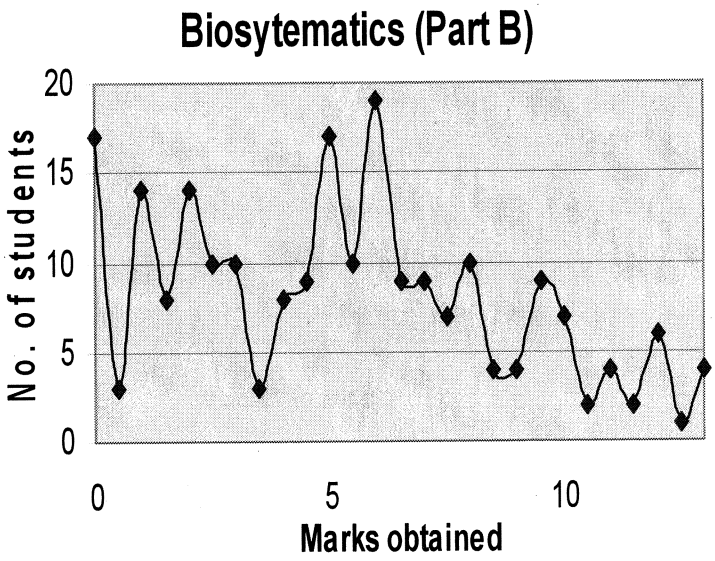

Ecology (Part A)
No. of students
Marks obtained


Ecology (Part B)
No. of students
Marks obtained


Ethology (Part A)
No. of students
Marks obtained


Ethology (Part B)
No. of students
Marks obtained


Biosystematics (Part A)
No. of students
140
120
100
80
60
40
20
0
0
1
2
Marks obtained


Biosytematics (Part B)
No. of students
20
15
10
5
0
0
5
10
Marks obtained

ESTIMATION OF TEST RELIABILITY:

The degree to which the test consistently and accurately evaluates students' performance can be quantified using Kuder-Richardson method.

$R = (K / K-1) [1 - \{X (K - X) / KS\}]$

R = test reliability
K = number of items on the test
X = mean of the raw scores from the total test
S = variance of the raw test scores from the total test.

(Reliability score of 0.70 -0.80 → good test
0.80 -0.90 → very good test
0.90 -1.0 → excellent test

R (Theory A) = 0.8675

R (Theory B) = 0.8715

EXPERIMENTAL TESTS

The statistical data for the four experimental tests have been tabulated below:

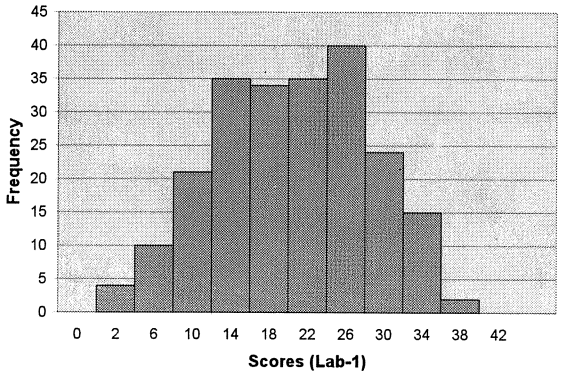
	Lab-1	Lab-2	Lab-3	Lab-4	Lab Total
Max. Obtainable marks	47	66	43	49	205
Max. Obtained marks	38	60	27	47	154.75
Min. Obtained marks	2	7	0	8	35
Mean	20.65	45.77	9.27	33.16	108.85
Relative Mean (%)	43.94	69.35	21.56	67.67	53.09
Median	21	46	7.75	34.5	110.63
SD	7.91	8.34	6.98	7.52	23.83
CV = SD/Mean	0.38	0.18	0.75	0.23	0.22

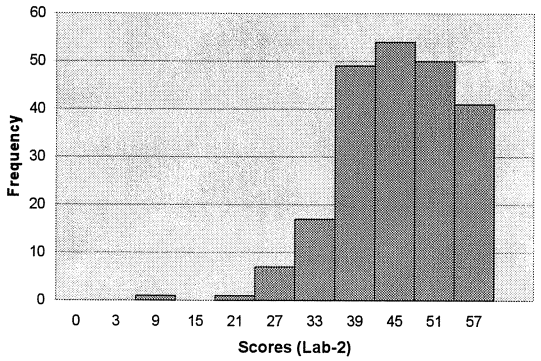
where the four experimental tests refer to:
Plant Anatomy and Physiology (Lab 1),
Animal Anatomy and Physiology (Lab 2),
Biochemistry and Cell Biology (Lab 3),
Animal Behaviour (Lab 4).

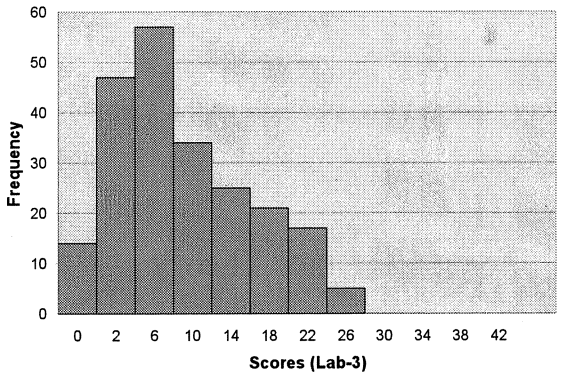
The relative mean of Lab-3 is the lowest which shows that Biochemistry and Cell Biology Lab was found to be the most difficult lab by the students. The other three labs in increasing order of difficulty were Animal Anatomy & Physiology, Animal behaviour and Plant Anatomy & Physiology.

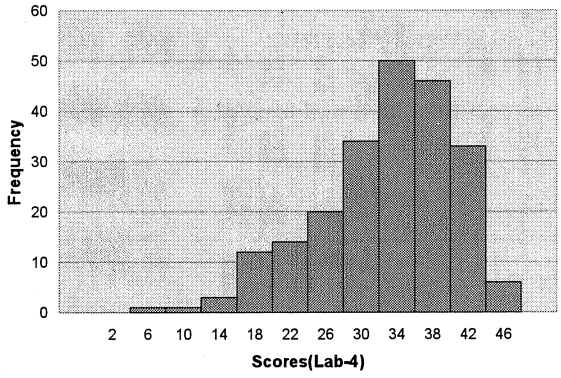
Although, the discriminatory powers (indicated by CV) of all the Laboratories vary largely, Lab-3 was the most discriminatory and Lab-2 was the least discriminatory. However, the total Lab scores are as discriminating as the theory scores.

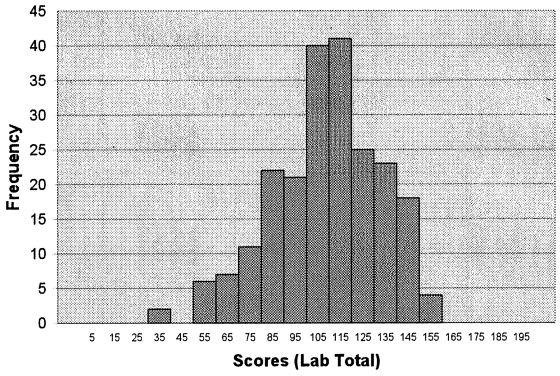
This is again evident from the following histograms:






Frequency
60
50
40
30
20
10
0
0 2 6 10 14 18 22 26 30 34 38 42
Scores (Lab-3)


Frequency
60
50
40
30
20
10
0
2 6 10 14 18 22 26 30 34 38 42 46
Scores(Lab-4)


Frequency
45
40
35
30
25
20
15
10
5
0
5 15 25 35 45 55 65 75 85 95 105 115 125 135 145 155 165 175 185 195
Scores (Lab Total)

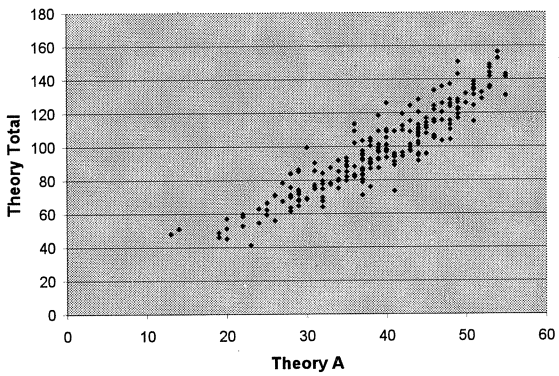
CORRELATION MATRIX:

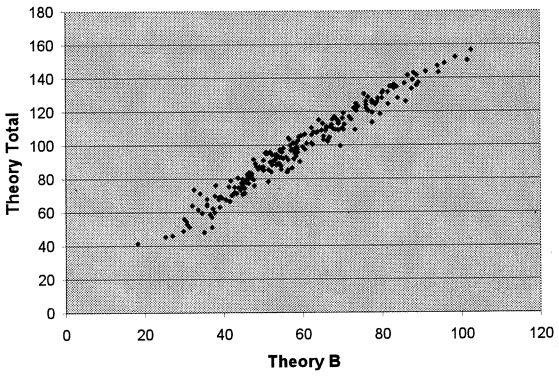
The correlations obtained on pairing each test with every other test are tabulated in the following correlation matrix.

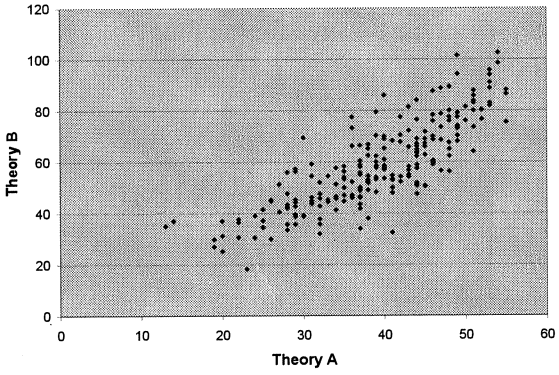
	Lab-1	Lab-2	Lab-3	Lab-4	Practical Total	Theory-A	Theory-B	**Theory Total**	Grand Total
Lab-1	1	0.39	0.56	0.62	0.83	0.56	0.67	0.66	0.79
Lab-2		1	0.36	0.39	0.71	0.55	0.49	0.53	0.66
Lab-3			1	0.51	0.77	0.52	0.65	0.63	0.74
Lab-4				1	0.80	0.51	0.58	0.58	0.74
Lab Total					1	0.69	0.77	**0.77**	0.94
Theory-A						1	0.82	0,92	0.86
Theory-B							1	0.98	0.93
Theory Total								1	0.94
Grand Total									1

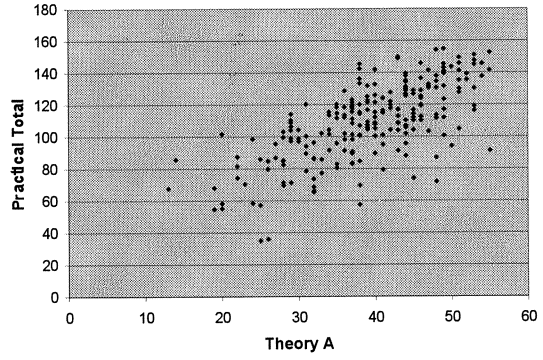
The correlation between the Theory Total and Lab Total is 0.77 which shows a high relationship between the scores, i.e. if a student scores high points in theory; she/he also scores high points in the labs.

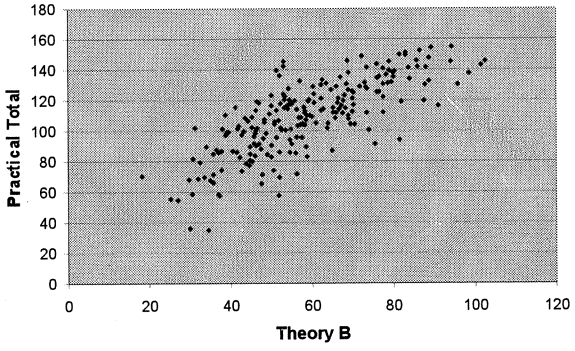
SCATTER DIAGRAMS SHOWING CORRELATION BETWEEN THEORY AND EXPERIMENTAL EXAMINATION:

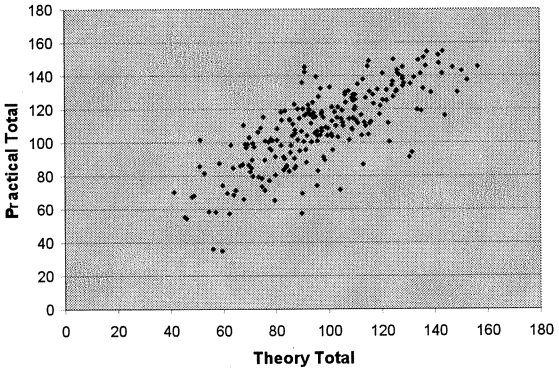












FINAL RESULTS

The final results were based on the t-scores of the students.
As already mentioned, the discriminating powers of the experimental tests vary largely as compared to the theoretical tests. Hence, the t-scores were calculated separately for the four Labs while for theory; t-score was calculated based on the theory total. Thus, the final t-score was as follows:

t-score = (t-lab + t-theory)/2

Where

t-Lab = (t-L1 + t-L2 + t-L3 + t-L4)/4

And

t-theory = t-score for Theory Total

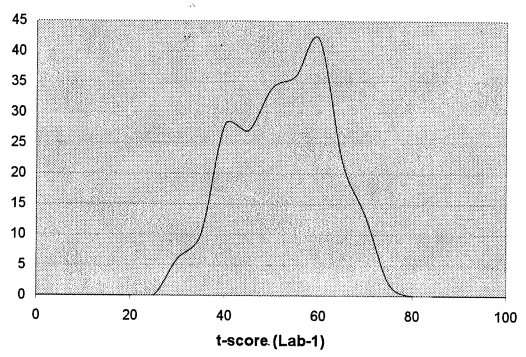
t-L1, t-L2, t-L3 and t-L4 represent the t-scores for the four Laboratories respectively.

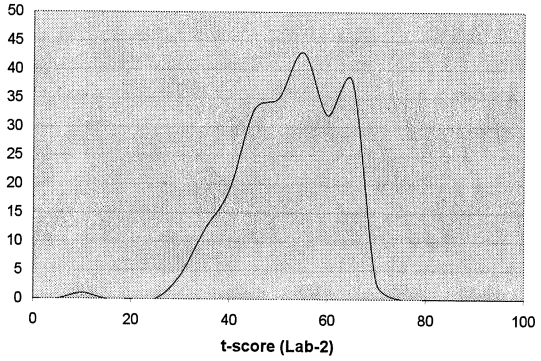
The t-score is calculated as follows:

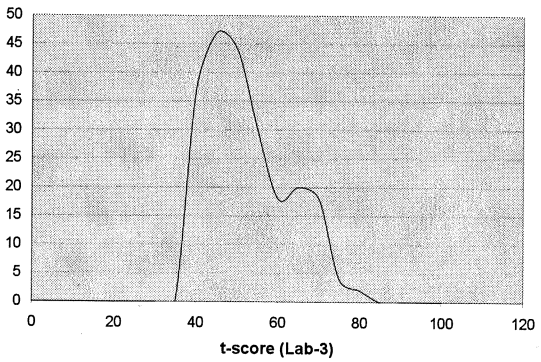
$$\text{t - score} = \left(\frac{\text{Raw Score} - \text{Mean}}{\text{SD}} \right) \times a + b$$

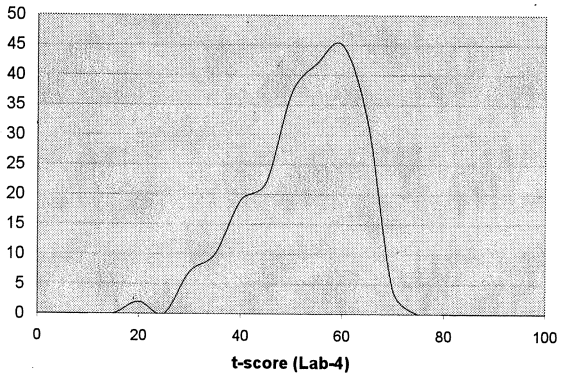
a and b are some predetermined numbers.

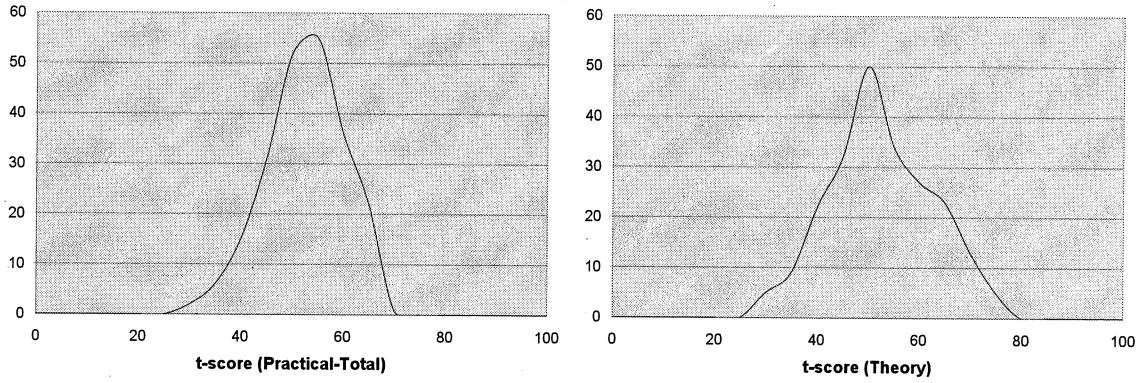
The frequency distributions of the t-scores for each experimental test, the lab test totals and the theory total are shown below:



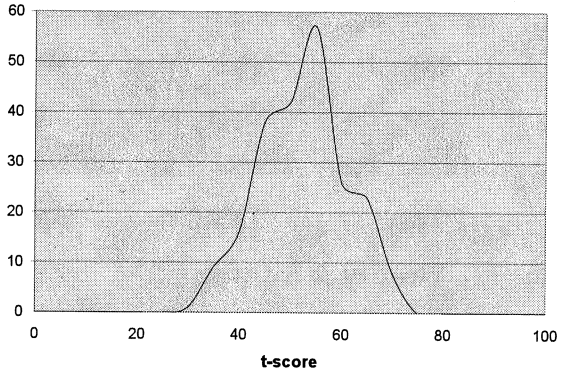




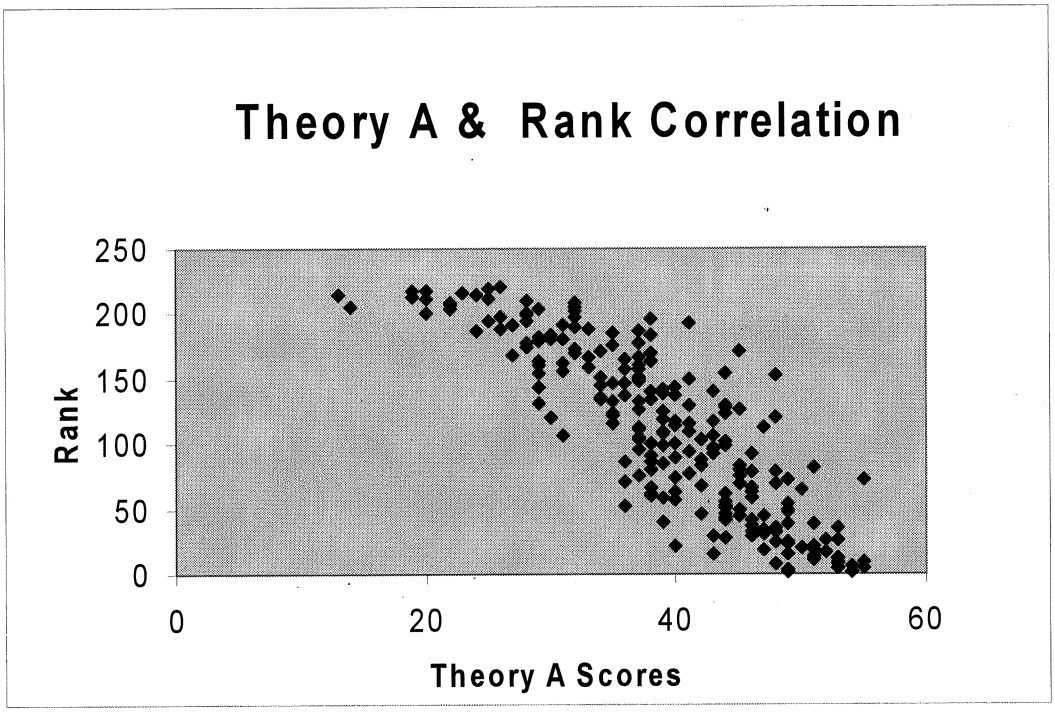


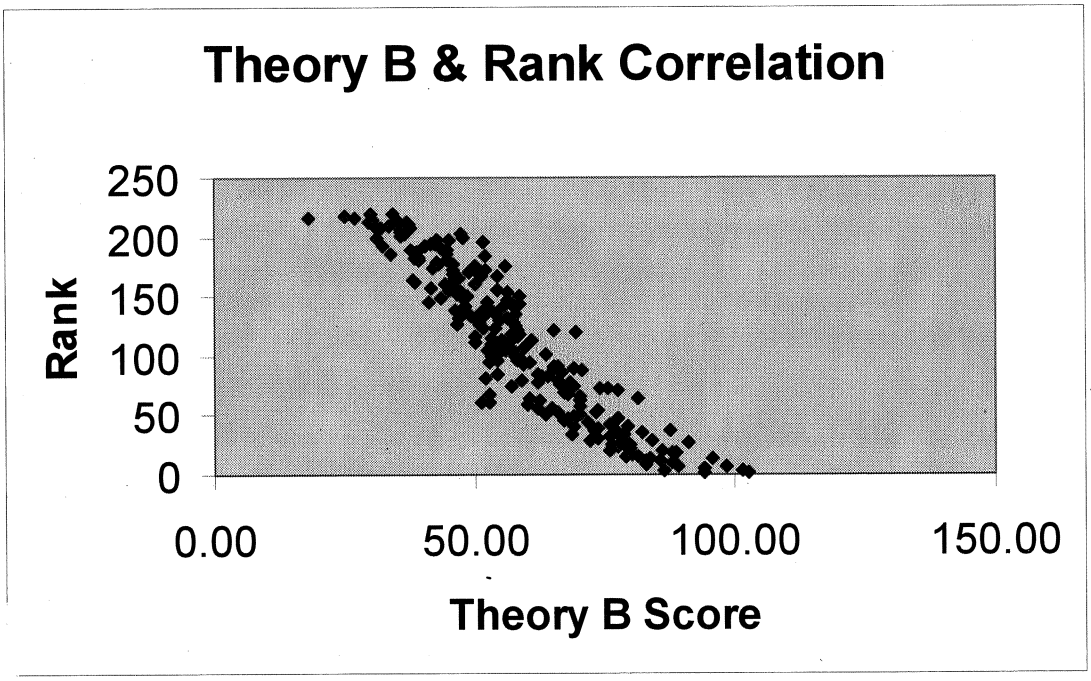


The frequency distribution of the final t-scores is shown below:

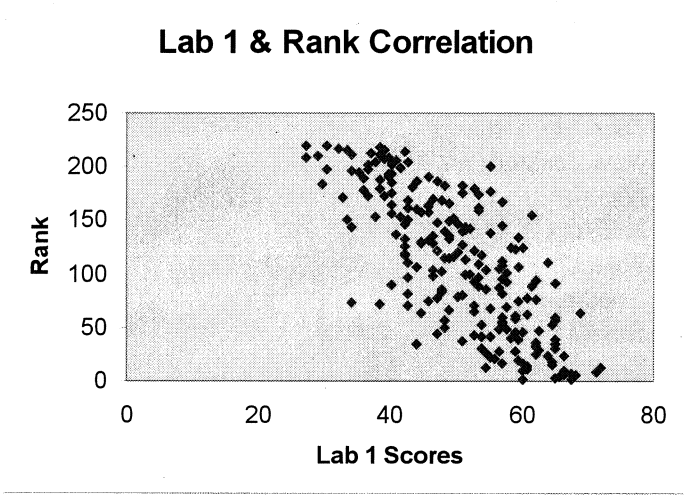


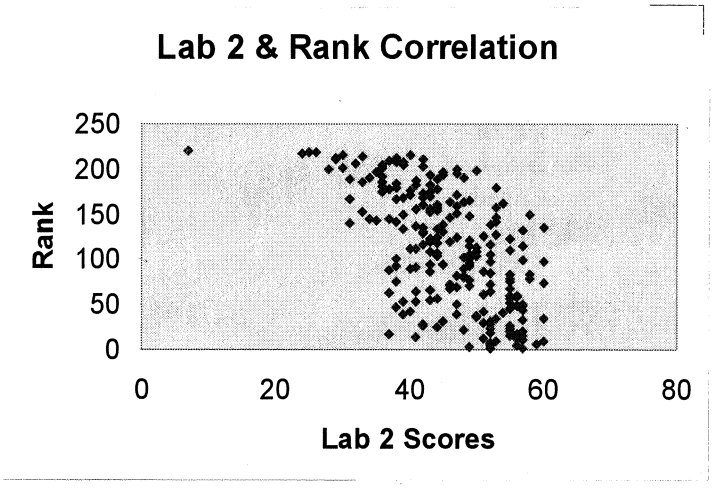
THEORETICAL TESTS: CORRELATION OF SCORES WITH THE RANKS

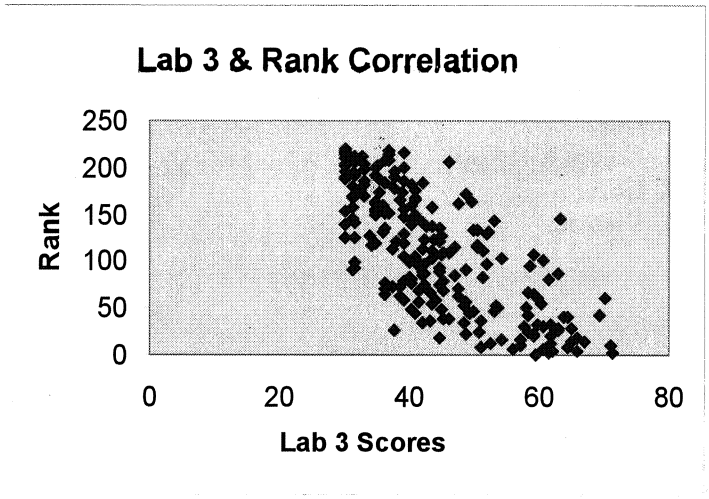


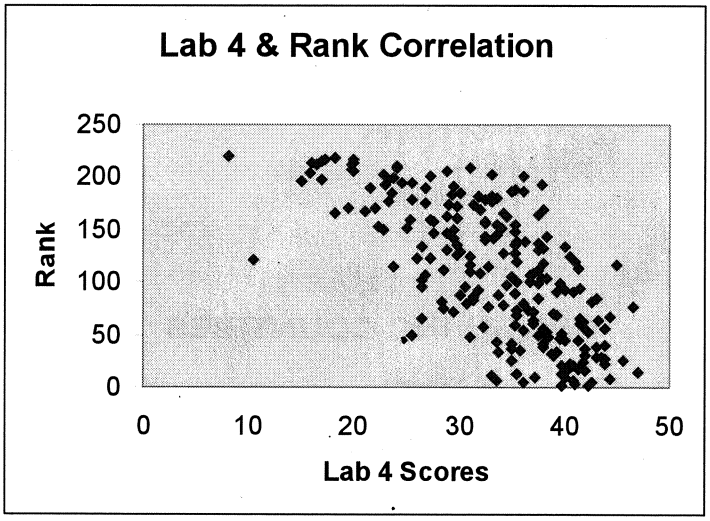


EXPERIMENTAL TESTS: CORRELATION OF T- SCORES WITH THE RANKS









LIST OF PARTICIPATING TEAMS

1. Afghanistan
2. Argentina
3. Australia
4. Azerbaijan
5. Belarus
6. Belgium
7. Brazil
8. Bulgaria
9. Canada
10. China
11. Chinese Taipei
12. Cyprus
13. Czech Republic
14. Denmark
15. Estonia
16. Finland
17. France
18. Germany
19. Greece
20. India
21. Indonesia
22. Iran
23. Ireland
24. Italy
25. Japan
26. Kazakhstan
27. Korea
28. Kuwait
29. Kyrgyzstan
30. Latvia
31. Lithuania
32. Mexico
33. Moldova
34. Mongolia
35. (The) Netherlands
36. New Zealand
37. Nigeria
38. Pakistan
39. Poland
40. Romania
41. Russia
42. Singapore
43. Slovakia
44. Slovenia
45. Spain
46. Sweden
47. Switzerland
48. Tajikistan
49. Thailand
50. Turkey
51. Turkmenistan
52. Ukraine
53. United Kingdom
54. USA
55. Vietnam

OBSERVING COUNTRIES

1. Armenia
2. Sri Lanka

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Juan Facundo Chrestia

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David Leitinger
Ruby Kwong
Keshinie Rasaratnam

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Azad Alizade
Artoghrul Alishbayli
Jamal Aliyev

Belarus
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Artsiom Marhunou
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Nikolaos Papachristou

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Homa Majd

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Gian Marco Messa
Andrea Mariello

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Kentaro Okawara
Shunichiro Mizuno

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Zhanat Koshenov
Arnat Balabiyev
Ruslan Kalizhan
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Tae Young Choi

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Fatemah Aldalal
Abdullah Alqallaf
Laila Shah

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Samat Kadyrov
Sherzod Muminov
Damirbek Abibillaev
Askhatbek Temirkulov

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Karina Vanadzina
Gints Kalnins
Juris Kibilds

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Justė Žagūnaitė
Justina Kulikauskaitė
Milda Jakutavičiūtė

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Joel Herrera
Juan Pablo Panico
Guillermo Ramirez

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Sergiu Stirbu
Dumitru Muntean
Catalin Ganea

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Suvd Sainjargal
Solongo Baatarkhuu
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Oluchi Nneoma Ozoemena
Halima Ibrahim Abba
Emeka Justus Duru

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Samia Asif
Zunaira Fatima
Moaz Bin Zia
Muhammad Affawn Ashraf

Poland
Pawel Stapinski
Michal Podgorski
Tomasz Klaus
Agnieszka Grzyb

Romania
Georgiana Emmanuela Gîlcă
Georgeta Bontaş
Paul- Adrian Bulzu
Robert Heler

Russia
Georgy Nosov
Galiullin Farkhat
Elena Malysheva
Anastasia Zykova

Singapore
Chi Chuen, Kevin Choy
Min De, Timothy Lim
Weirong, Joshua Sng
YiFei Men

Slovakia
Katarina Jurikova
Samuel Genzor
Veronika Gabrisova
Eva Bacinska

Slovenia
Alič Špela
Anja Strmšek
Nina Turk
Maša Bizjak

Spain
Víctor Fanjul Hevia
Sonia Rodríguez Fernández
Helena Alonso Valencia
David López Martínez

Sweden
Martin Van
Petter Säterskog
Emelie Sandberg
Tomas Kesek

Switzerland
Adeline Colussi
Manuela Binggeli
Miriam Luginbühl
Gabriele Gut

Tajikistan
Dilnoza Ulugova
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Atiporn Therdyothin

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Hacer Gozde Gul
Mustafa Burak Tunc
Ilkay Samil Beydilli

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Shohrat Berdiyev

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Olexandr Yagensky
Anastasiya Bondaryeva

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Paul Waldron
Thomas Flint
Ian Ross

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Jonathan Gootenberg

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Jae Geun Kim
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Joon Kim
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Nyambayar Dashzeveg

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Eva Elisabeth Deinum

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Pitiwong Tantichodok
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Theerapat Wechaprasit

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David Rigby

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William Stuart
James Saunders

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Lap Van Lap
Hung Nguyen Mong
Tuan Mai Sy
Long Dinh Doan
Linh Nguyen Thi
Nha Nguyen Phong
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Gayane Ghukasyan

Sri Lanka
Hiran Amarasekera

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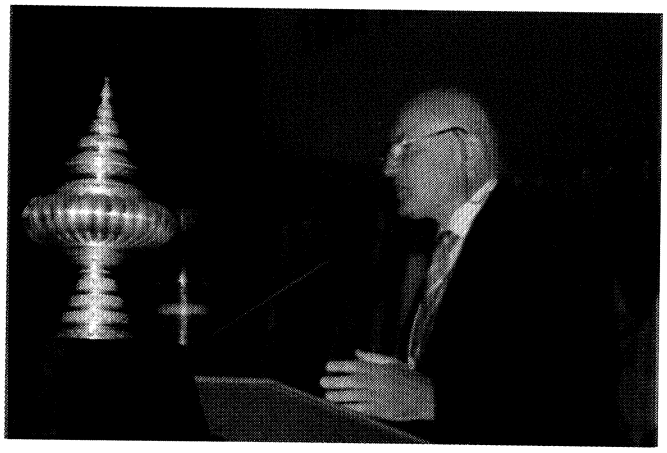
7.	Brazil	Dhirendra Gupta
8.	Bulgaria	Shubhra Mishra
9.	Canada	Manish Punjabi
10.	China	Shriya Samchita
11.	Chinese Taipei	Amey Dhone
12.	Cyprus	Ashwini Mane
13.	Czech Republic	Pranita Sawant
14.	Denmark	Vishal rasal
15.	Estonia	Bhagirath Mishra
16.	Finland	Kratika Nayak
17.	France	Jyotsna Arora
18.	Germany	Rahul Dubey
19.	Greece	Kalpana Salve
20.	India	Dinar Jadhav
21.	Indonesia	Sameer Gunye
22.	Iran	Mohsin Khan Pathan
23.	Ireland	Rambahadur Subedi
24.	Italy	Ganesh Gajare
25.	Japan	Avinash Warankar
26.	Kazakhstan	Chandrakant Gadipelly
27.	Korea	Andrea D'souza
28.	Kuwait	Tasneem Dabir
29.	Kyrgyzstan	Casmilo D'sa
30.	Latvia	Sneha V.
31.	Lithuania	Kiran Jaiswal
32.	Mexico	Varada Purohit
33.	Moldova	Sameer Surve
34.	Mongolia	Lawrence Fernandes
35.	Netherlands	Deepak Sankpal
36.	New Zealand	Anup Suralkar
37.	Nigeria	Aditi Parab
38.	Pakistan	Anuja Farkade
39.	Poland	Eliza Waghamare
40.	Romania	Mugdha Dhawde
41.	Russia	Neha Dube
42.	Singapore	Niteen Shingade
43.	Slovakia	Ajinkya Kolambkar
44.	Slovenia	Prajakta Bhoite

45.	Spain	Ankita Patel
46.	Sweden	Amruta Sawant
47.	Switzerland	Maitreyee Ganpule
48.	Tajikistan	Piyush Garud
49.	Thailand	Neha Borse
50.	Turkey	Rohini Sawant
51.	Turkmenistan	Rakesh Yadav
52.	United Kingdom	Chetan Munde
53.	Ukraine	Neha Bajpayee
54.	USA	Manas Manjrekar
55.	Vietnam	Apurva Jivannavar

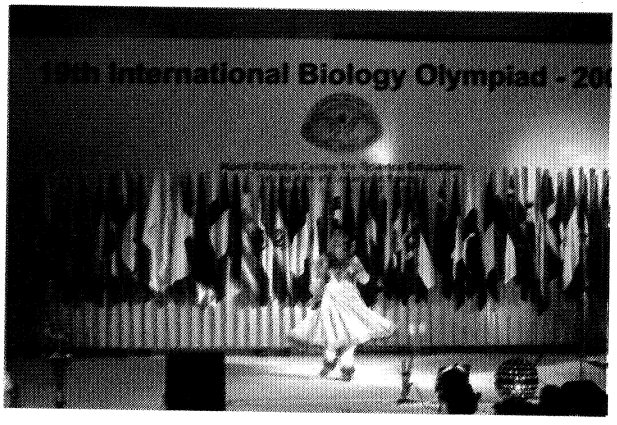
PHOTOGRAPHS

A FEW MOMENTS FROM IBO – 2008

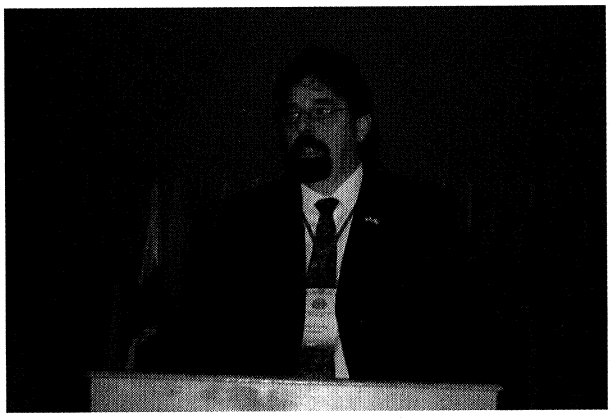
Welcome to the teams at the Opening Ceremony

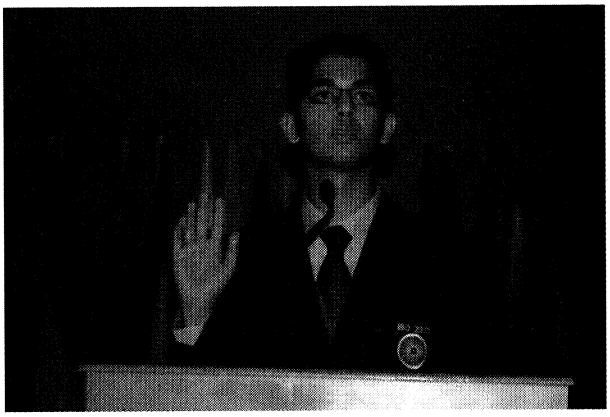


Welcome address by Dr. Hans Morelis

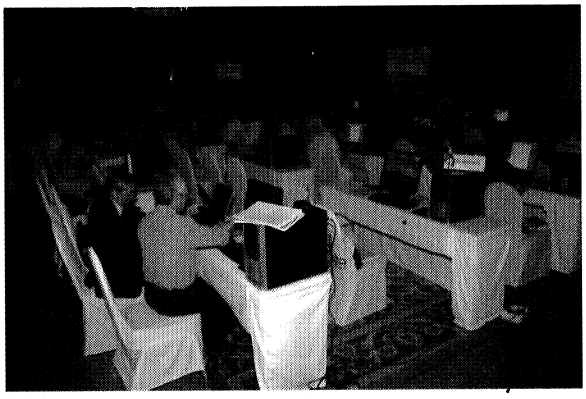


Cultural programme at the Opening Ceremony

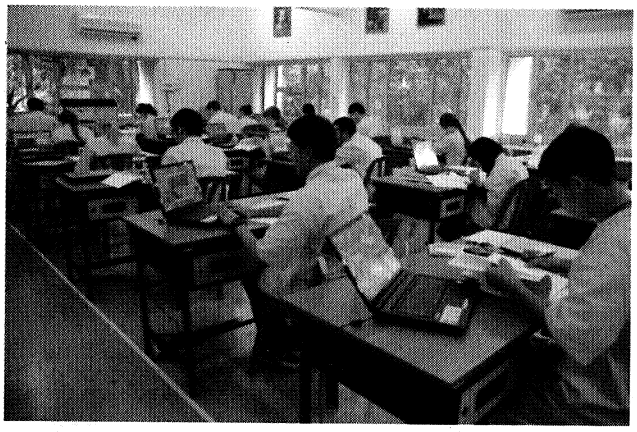
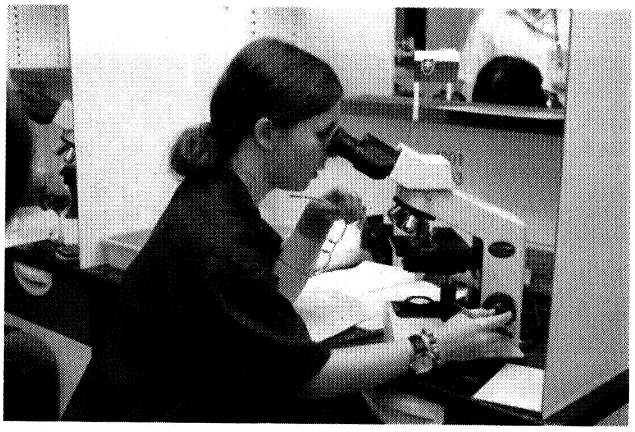
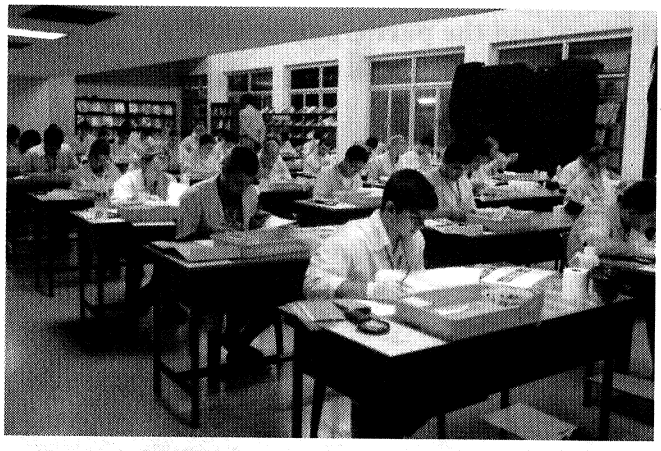
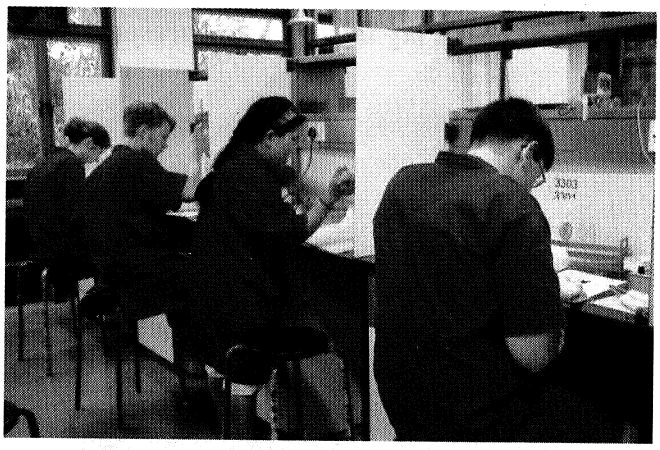




Oath of Fair Play taken by a representative of the jury and the participating students

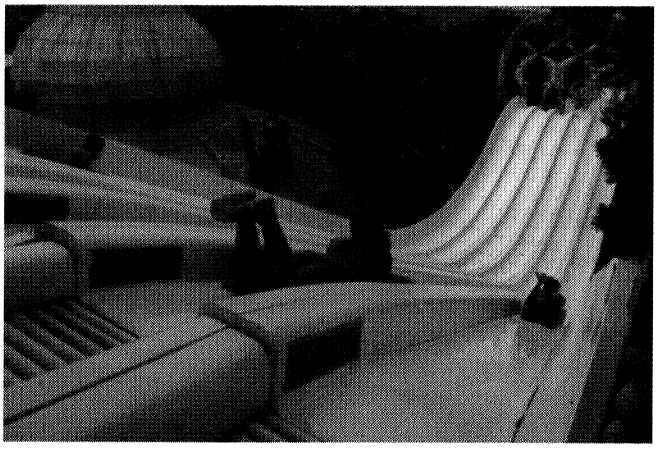


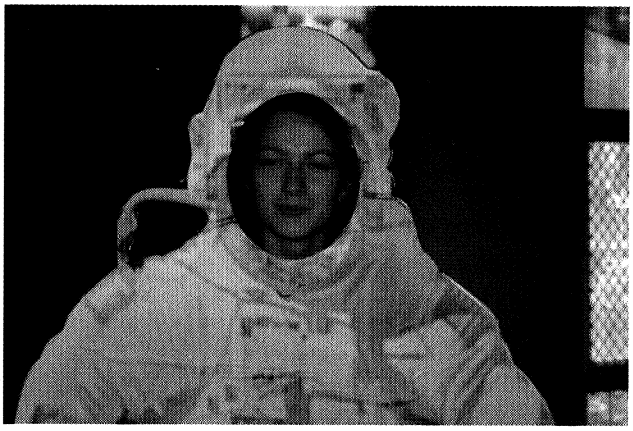
The Jury Sessions in Progress at Intercontinental, The Grand

The Experimental Tests at the Homi Bhabha Centre for Science Education

A Relaxed team after the test!!





Fun Time At The Amusement Park & Nehru Science Centre

The Indian Village Fair (Haat) at HBCSE

Dr. Tomas Soukup hands over a memento for India

A Thank You to Dr. Hans Morelis, Chairman of IBO CC

The IBO Trophy is passed on from India to Japan (Organizers of IBO – 2009)

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