Eckhard Klieme
Eckhard R. Lucius
Erwin Zabel (Eds.)

Report of the 9th International Biology Olympiad

ipn – materialien

IPN

And in the background was a lady,
who organized almost everything:
Renate Glawe, "Mrs. IBO 1998"

Thank you very much for all.

Eckhard R. Lucius

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Report of the 9th International Biology Olympiad in Kiel, July 1998

Concepts, Programme, Tasks, Results and Statistics of the Competition in Kiel, from 19th to 26th,July, 1998

Institut für die
Pädagogik der Naturwissenschaften

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1 Foreword

In 1995 the Federal Government of Germany agreed to coordinate the 9th International Biology Olympiad during its period in office. At the 6th IBO in Bangkok (Thailand), the co-ordinators agreed to the proposal of the then German coordinator, Professor Erwin Zabel, and his successor, Dr. Eckhard R. Lucius, to organize the 9th IBO 1998 in Kiel.

Customarily, the organizing country of an International Olympiad is also its host, and for the participants themselves, the chosen venue is of particular interest. The capital city of Schleswig-Holstein, with less than a quarter of a million inhabitants, might from the outside have appeared an unlikely venue. From the inside, the reason for the choice was clear. The Institute for Science Education IPN (*Institut für die Pädagogik der Naturwissenschaften*) in Kiel has been responsible for national selection of the German team for the International Biology Olympiad since 1995 (and of the International Olympiads in Physics and Chemistry for more then 25 years). And with the University of Kiel so close, effective cooperation between biologists and educationists, a vital element in the organization of an international science competition of this kind, was guaranteed.

The organization of the 9th IBO commenced in 1995. Two preparation committees were established, a tasks committee chaired by Professor Zabel and an organization committee chaired by Dr. Lucius. The early start reflected the fact that more than 30 nations were expected to participate, and indeed, a total of 33 countries entered competitors (Argentina, Australia, Azerbaijan, Belarus, Belgium, Bulgaria, Czech Republic, China, Estonia, Finland, Germany, Ireland, Kazakhstan, Kirghizia, Republic of Korea, Kuwait, Moldova, Mongolia, Latvia, Netherlands, Poland, Romania, Russian Federation, Sweden, Slovakia, Tajikistan, Thailand, Turkey, Turkmenistan, Ukraine, United Kingdom, Uzbekistan, Vietnam). In addition, three more nations joined as observing countries (Republic of Iran, Mexico, Taiwan), bringing the total number of guests who stayed in Schleswig-Holstein for the week July 19 - 26 to more than 260.

The opening and closing ceremonies took place at *Kieler Schloss*, the city's premier civic concert and festival venue.

1.1 The President of the IX. IBO 1998

Horst Bayrhuber

Parliamentary State Secretary, Mr Neumann,
Vice President of Schleswig-Holstein, Mr Steenblock,
Mayor of Kiel, Mr Gansel,
Rector of the University of Kiel, Prof. Haensel,
Members of the international jury,
Participants in the Biology Olympiad,
Ladies and Gentlemen,

Thanks to the dedicated work of many people from different countries, the International Biology Olympiad has established itself as a positive tradition. Its aim of offering talented students the opportunity to compete with others in a fair contest and to prove their abilities in the field of biology as well as the opportunity to establish friendships regardless of nationality, culture and religion belongs to those global embracing aims which we desire in the interest of a peaceful and worthwhile future.

It is a great honour and pleasure for me, in the name of the preparatory committee to be able to greet all participants, people in charge and guests of the 9th International Biology Olympiad in Kiel. The preparatory committee has put a great deal of effort into ensuring that this biology competition can take place under optimum conditions and that all of you can take home many new impressions and experiences.

Many have helped: our thanks goes to all of you, especially the commission that worked out the tasks, which was composed of biology professors from the universities of Kiel and Rostock, above all its chairman, Professor Erwin Zabel, whose long-standing experience with Biology Olympiads has been invaluable for the entire organization.

Furthermore I would like to thank the organization committee consisting of members of the IPN, in particular its chairman Dr. Eckhard Lucius and my secretary Renate Glawe who was in control of everything during preparation.

As well as this I would also like to express my deep gratitude to the Federal Government of Germany and our sponsors for their generous financing of the Olympiad and the Government of the State of Schleswig-Holstein and the city of Kiel for their extensive support in the organization.

Finally, I would like to express a word of thanks to all those who will help with the realization of the 9th International Biology Olympiad.

It is our wish that the 9th International Biology Olympiad – and all Olympiads – will inspire as many young people as possible to deal with biology in the interest of a lasting development in all fields of social life on all continents. You, as participants, have already proved that you do much more in the field of biology than schools usually demand from young people, and we can expect that you will take more responsibility for the biosphere than others. You understand living nature, feel related to the variety of organisms and are acquainted with the conditions for life on our planet. From the broad knowledge and the practical abilities in the field of biology which you have proved to possess during the preparations for the Olympiad come the conditions for limiting the local, regional and global problems of the biosphere in a competent way.

I wish all the participants in the 9th International Biology Olympiad every success, as well as pleasure and enriching experiences. Of course, "winning" is of great importance, but taking part is even more important.

I wish all of you a pleasant stay in our town, at our university and in our country.

1.2 The Parliamentary State Secretary at the Federal Ministry of Education, Science, Research and Technology (BMBF)

Bernd Neumann

– The spoken word is valid –

Distinguished participants in the 9th International Biology Olympiad,
Ladies and gentlemen,

I am very happy to see so many young people here today who enjoy competing with others in an Olympic contest in the field of biology. 33 nations are participating this year, five more than last year.

I would like to ask the adults to understand that my initial, special greetings are addressed to the students present here: So, let me welcome you to Kiel! While many other students all over the world are unable, or unwilling, to get beyond their normal school work, you are meeting here in Kiel in order to rack your brains poring over papers – of your own free will.

In talks I have conducted in my role as politician, I have often been asked about the alleged unwillingness of young people to work hard to achieve something. I am sure you know what I mean: In the past everything was much better, young people today only want to have fun, they do not want to study hard at school, etc., etc. I do not believe this. You are the finest example that even today, a substantial number of young people

- want challenges so that they can prove what they are capable of achieving, and
- consider it desirable, and in fact an honour, to be good at school, because they feel it pays to aim high.

Let me encourage you to continue along this path. In my role as education politician in Germany, I am very much in favour of paying much more attention once again to the principle of high achievement in our schools. The notion of high achievement, of course, means that some are more capable and achieve more than others. High achievement requires hard work, but I am sure you all know how much joy it gives you to have mastered a task that has cost you some effort.

In general, the idea of competition, and more especially competition among brains, needs to be given greater weight in education as well as in education and research policy. Against this background, the International Biology Olympiad must be seen in the context of the Federal Government's policy of funding a total of 19 competitions for high-school students. Competition is the motor of human cultural and economic development.

We live in an exciting age.

New branches of science and technology open up undreamt-of perspectives. We are fascinated with the opportunities open to young people today - fascinated also with the thirst for new knowledge, the urge to explore and the capacity for discovery and invention displayed by our young scientists and scholars. There is a pervasive frontier spirit, a desire to advance the frontiers of the biosciences, which are considered to be among the most important fields of research for the 21st century throughout the world:

This new spirit will benefit pharmacy and medicine, agriculture and the environment, but also branches and disciplines which have so far made only little use of biotechnological innovations - for example materials research or energy and information technology:

- molecular *medicine* opens up new prospects for the treatment of diseases so far considered incurable (for example, Alzheimer's disease, multiple sclerosis)
- As regards *drugs*, today more than two thirds of all new developments come from biotech pipelines. About 10 years ago it was only about 5%.
- Biotechnology also holds a large development potential for *environmental protection*. Optimized biological systems, as a rule microorganisms or plants which facilitate natural cycles in the environment can be used systematically for environmentally benign techniques.
- Another important application of the biosciences is *nutrition*. Every year about 10 million people starve to death. It is therefore necessary to develop high-yielding crops that are resistant to disease as well as foods that keep longer. The growing world population makes larger harvests and improved quality urgently necessary.

The German Federal Government wants transparency in all bioscience activities so that the opportunities become clear while the risks can be assessed. People can make their own decisions only if they have unhindered and open access to all findings. Secretiveness is counterproductive. The Federal Government is therefore in favour of a comprehensive, but practicable labelling of genetically modified food. We also pay attention to the potential hazards that might result from this field of technology as well as to people's fears.

We do not fail to acknowledge that there are some applications of biotechnology, and particularly of human genome research, which raise legal, social and ethical questions that need to be answered by politicians and scientists. Nature does not take a stand in favour of or against any one technique - it is up to us to make the decisions.

Germany has very strict and unambiguous rules, for example, under the Genetic Engineering Act and the Embryo Protection Act. Manipulation of human hereditary material (for example, through germline therapy), cloning humans or research consuming human embryos are therefore prohibited in Germany. Of course, we have to take international developments into consideration. Anything that happens in other countries in the field of genetic engineering also has an impact on developments in Germany. It is therefore important that the Federal Government should voice its convictions at the European and international levels and ensure that they are anchored there to the greatest possible extent. It is our goal to create a binding international framework which supports the positive aspects of genetic engineering while limiting its risks and preventing abuse. For there is one thing that must not happen: namely, that - over the need for a debate on the risks - we fail to make use of the tremendous opportunities inherent in biotechnology.

The German Federal Government has declared support for biotechnology one of its research policy priorities.

- Under its "Biotechnologie 2000" programme, it gives systematic support to the widening of the scientific basis while contributing to advancing application of the technology in practice: its focus is on methods and techniques which benefit human health and protect the environment. Altogether, the BMBF makes available about one billion marks worth of support for biotechnology and molecular medicine every year.
- In the framework of the BioRegio competition initiated by the BMBF in 1996, German regions embarked upon a competition for the best BioRegio - a kind of Olympic contest at national level. The purpose of the competition is to pool the resources available in the strongest German biotechnology regions and to support development of the best possible basis for research, innovation and investments.

  Even today, the BioRegio competition is a success story. Thus the number of new biotechnology businesses has increased by a factor of four since 1995 (from 75 in 1995 to 300 at present).
- With a view to giving systematic support to young scientists, the Federal Government initiated the BioFuture Competition. The purpose of this competition is to get young researchers started on the road to a top career in science or on a - hopefully successful - entrepreneurial track. Up to 50 groups of young scientists are to be funded over a period of five years. Both German and foreign applicants are eligible to take part in the competition. Young scientists are to be given an opportunity to run their own working groups, on their own responsibility and independently of German research or university institutes. A total of 150 million marks is available for a five-year period.

Before concluding, let me again address in particular you, the competitors in this Olympiad, and assure you that I shall keep my fingers crossed for all of you during the next few days' tests. As with the Olympic Games, it is a fact

that not everybody can win. Let me remind you of the Olympic motto, which reminds us that it is taking part which is really important. Having qualified as participants in the 9th International Biology Olympiad for your country means that you are definitely among the best.
Last, but not least, let me say a word of thanks to the Institute for Science Education, which is hosting the present contest, and in particular to its managing director, Professor Bayrhuber, as well as to the scientific organizer, Dr. Lucius. Also, I do want to express my gratitude on behalf of the Federal Government to the many firms and organizations which have contributed to the success of this Olympiad with their contributions in kind and their donations.
In conclusion, I would like to wish all the participants in the 9th International Biology Olympiad luck, success, and friendships that survive the day.

1.3 The Vice Prime Minister of Schleswig-Holstein

Rainder Steenblock

Dear Participants of the 9th International Biology Olympiad,

I would like to welcome you most warmly to Schleswig-Holstein. It is a great honour for us to host the 9th International Biology Olympiad with students, teachers, and co-ordinators and members of the jury from 32 nations.
You, the students, are assembled here in order to measure your knowledge of biology against that of your peers. And indeed you have chosen a fascinating branch of the sciences in which to compete, because again and again biology imparts fantastic new insights into the miracles of life taking place on this planet. Moreover, as the science of life among the sciences it is especially close to us.
I don’t need to tell the experts in this area how crucial biological insights derived from your disciplines are today, above all „ecology“. They are important for assessing the consequences of our activities on the natural world in order that measures can be taken to protect the natural foundations of life. In this respect, your specialist knowledge offers an important basis for decision-making by those politically responsible for promoting sustainable development in our countries.
It is very important to me to emphasize the significance of biology as a specialist science. Equally as important, however, is the opportunity to exchange

your knowledge with peers from other countries during the next few days. The future of the earth and with this our future as members of the human species is dependent on the international responsibility for this planet and on our solidarity. A feeling for this can be experienced and developed most extensively when you have intensive contact with people from other cultural backgrounds, when you get to know their hopes, problems and attitudes to life. I would like to encourage you, despite the necessary concentration on the tasks of the competition, to take time to foster contact with your competitors.

For years now, Schleswig-Holstein, due to its geographical position, has been endeavouring, to adopt an active role in structural development in the Baltic region, in Cupertino with its partners. Exchanges among young people are especially important for us. For this reason, since 1989, the Baltic Youth conference has been taking place annually in Schleswig-Holstein. Young people from all the neighbouring Baltic countries meet to exchange ideas on subjects of common interest.

Furthermore, the Ministry for Environment has been offering the „Voluntary Ecological Year“ since 1991. Here, young people between 16 and 27 can do voluntary work for a year in the different areas of environment and nature protection. Since the beginning of this programme participants from other nations have been represented in every age group. In the current period, we have guests from the Czech Republic, France, Austria and Latvia doing a voluntary ecological year.

Perhaps maybe one or the other member of these groups would like to do a voluntary ecological year after completing their school education in Schleswig-Holstein or in another Federal state in Germany. I would be very pleased to be able to welcome you here again on that occasion.

Also in the European Union the introduction of a corresponding voluntary service is being developed at the moment. Please continue to use the opportunities for international exchange. Common understanding is the basis for peaceful coexistence and harmony of contact with the natural environment.

I would like to wish you all, in this sense, the opportunity for an intensive exchange of views and experiences. I hope you will have an exciting time in Schleswig-Holstein. You will also visit Schleswig-Holstein's tidal flats, a national park with a biological landscape which is unique worldwide and offers a fantastic variety of different species. Most of all, naturally, I would like to wish you the very best for the tasks which now lie before you.

1.4 The Lord Mayor of the city of Kiel

Norbert Gansel

Dear Participants of the 9th International Biology Olympiad,

I would like to welcome all the participants of the 9th International Biology Olympiad to Kiel. I am delighted that the Institute for Science Education, which is affiliated to our University, has been successful in bringing this event to Kiel, the capital city of Schleswig-Holstein.

Moreover, I would also like to wish all the participants the very best when carrying out their tasks, both theoretical and practical. Furthermore, I would like to extend these wishes to the members of the jury, who will certainly not have an easy time when making their decisions. A word of thanks should also be directed to the organizers for the work done so far in the hope that the „Olympic" days will run smoothly for them here in North Germany.

In Kiel, the Olympics are not a new experience for us. Twice this century already, the town has had the opportunity, in 1936 and again in 1972 , to organize the Olympic sailing regatta. But the choice of our state for these events had its reason. Once a year, the largest sailing event in the world takes place here, and this has been going on for 116 years. In the meantime it has become the largest summer festival in Northern Europe, with over two million visitors from more than 60 participating nations. Kiel also has a lot of international experience. Globalization is part of everyday life here on the fjord. As a result of regular maritime connections to all the neighbouring states, Kiel as a harbour town plays a pivotal role in Baltic trade. With over two million passengers, the capital city of Schleswig-Holstein is at present Germany's largest ferry port. The large ferries from Oslo and Göteborg anchor daily in the heart of the city. The Kiel Canal, the busiest artificial waterway worldwide, and the Baltic Sea transport more and more ocean-going liners into the harbour at the heart of the city.

Kiel, however, with its population of almost 240 000 is not only a commercial port, but also a city of shipbuilding, a naval city, and a city of education and science in the form of research institutes, technical colleges and a state university. We Kielers are also proud to point out that the eminent physicist and Nobel Prize winner Max Planck studied and taught here in April 1824. Five other Nobel Prize winners also studied and taught at Kiel's university, which still has a very good reputation today. Above all the medical faculty, the Institute of World Economics and the Institute for Marine Research have earned themselves global recognition. For the new technical faculty, which incorporates a spirit of endeavour, a new facility is being built directly on the banks of the fjord on the site of an old industrial complex. The students, about 30 000 in number, appreciate both the quality and broad scope of the opportunities for education as well as the leisure time facilities which the city offers.

And who knows, perhaps one of you will also be one of the Kiel students one day and will be able to do then what unfortunately there seems little opportunity to do now, namely to discover the fun side of Kiel.

1.5 The Rector of the University of Kiel

Ruprecht Haensel

Dear Participants,

The university, founded by Duke Christian-Albrecht of Schleswig, Holstein and Gottorf in 1665, has carried his name since then and is one of the oldest universities in Germany. I am extremely honoured that the 9th International Biology Olympiad has chosen Kiel as its location.

From the beginning, biology has had a special position at the university here: The 25-year-old (!) Cäso GRAMM was a member of the first group of professors who were appointed to teach at our philosophical faculty. It also included the subjects of "Natural history" and "Greek literature". Previously GRAMM had been a physician in Basel and Leiden.

Today biology is part of the mathematical-scientific faculty and includes institutes for botany, microbiology, zoology, domestic zoology, polar ecology. The Institute for Marine Research has departments for marine botany, marine zoology, biology of fisheries marine planktology and marine microbiology. At the Institute for Science Education (IPN) we have a special department devoted to biology education.

Therefore biology is represented in its complete spectrum in the basic and applied research, and especially in the field of marine biology because of the coastal location of Kiel.
The university realizes and supports the increasing importance of the role of biology at the threshold to the next century: after the revolutionary role of physics in this century, the next will probably be the "golden century" of biology (and medicine). There are two reasons why biology will be of major significance in the next century:

1. The development of new methods for structural research opens up unknown possibilities in investigating and understanding biological reactions. We will be able to understand in detail how "life functions". Therefore interdisciplinary Cupertino is needed between subjects such as science, medicine, agronomy and technology, as well as economics and law. The universities offer a unique basis for this interdisciplinary Cupertino.
2. The development of modern means of transport and communication networks the whole world. Questions of human nutrition, careful use of natural resources as well as environmentally compatible waste disposal are global problems and can therefore only be solved on a global basis.

Due to this enormous growth in the importance of biology for our future it is vital that an interest in biological issues should be awoken and supported as early as possible at school level. The Biology Olympiad is an excellent method of furthering this interest at school.
In this sense I wish the Biology Olympiad the best of luck!

1.6 The Chairman of the IBO-Co-ordinators and the Head of the IBO-Coordinating Centre

Hans Morelis, Tomas Soukup

Ladies and gentlemen, colleagues and last but not least, dear competitors,

The Olympiad is a competition with many interesting features, whether in stimulating young gifted students interested in biology as a career or focusing on biology as a wonderful science to study. Biology is the basis for life sciences. The quality of life and environment has to do with biology. Important decisions about environmental problems nowadays have to be considered worldwide and for these decisions biological knowledge and skills are indispensable.

Solving problems connected to nature and environment require cooperation between nations. Working together also means making friends and I like to stress that the promotion of friendly contacts between biology students is an important item in our Olympiads. So it is nice to have so many young students from all over the world involved in this Olympiad. A special welcome applies for the newcomers: competitors from Estonia, Ireland, Korea, Moldova and the United Kingdom.

It cannot be denied that we come to Kiel with some special expectations. An interesting translation study is planned concerning the tasks, and never before have bacteriogenetics and planning, observation and interpretation of a behaviour experiment been included in the practical tasks. But we have confidence in positive results of these experiments as the IPN of Kiel University is a leading institute in the world in the field of science teaching. And besides this we all know that the Germans are famous for their organizational skills. So we are glad to be here in Kiel, city by the sea, well known as the 'town in the fresh wind'.

1.7 Ion channels: their discovery, their function, and their role as drug targets

Erwin Neher

It has been known since the classical studies of HODGKIN & HUXLEY that the nerve impulse comes about through permeability changes of the nerve cell membrane. When, in 1973, Bert SAKMANN and myself set out to measure single channel currents, these electrical changes, as well as postsynaptic conductance changes at synapses during synaptic activation were well characterized on the macroscopic level. Not known at that time were the molecular mechanisms which underlie these conductance changes. Two mechanisms were under discussion: First, the mechanisms of carrier transport in which a carrier translocates ions across the membrane, one at a time. Secondly, the mechanism of ion channel transport in which channels or pores are transiently formed in the membrane, through which ions can pass at high rate.

We wanted to resolve the question of transport mechanisms experimentally by demonstrating discontinuous changes in membrane current, which are expected to occur, when channels open and close. To do so, we had to develop a new method to record membrane currents at a resolution much better than that previously possible. We succeeded by placing micropipettes with openings of about 1 to 2 µm onto the surface of cells with the aim of isolating small patches of membrane, covered by the pipettes, for the purpose of the electrical measurement. This allowed us to characterize steplike changes in current exactly as predicted for the mechanisms of ion channel conductance and, thus we could proof this concept.

When we set out to measure ion channel currents we were mainly interested in putative channels of electrically excitable cell types, such as neurones and muscle cells. We did not expect that channels existed in many other types of cells. To our surprise, the improved recording technique revealed a variety of different channel types in basically any cell type, which has so far been looked at. These include voltage-gated channels (permeable for either Na^{+}, K^{+}, Ca^{++} or Cl^{-}), channels gated by external ligands, such as basically all known neurotransmitters, as well as channels gated by intracellular second messengers and nucleotides (HILLE, 1992).

In the meantime molecular cloning has revealed the primary structure of many channel proteins. All channels studied so far have membrane spanning α-helices which transverse the membrane from 2 to 24 times. Comparison of sequences allows to group channels into a small number of families; the members within each family seem to have evolved from common ancestors. Particularly illuminating in this respect are voltage dependent channels which can either be made up as multimers of 4 subunits surrounding a central pore (K^{+} channels) or consist of a single polypeptide with four tandem repeats, each of which is somewhat similar to one of the K^{+}-channel subunits. Very recently, it has become possible to crystalize K^{+} channels and to derive the 3-dimensional structure (DOYLE et al., 1998). This has provided a detailed understanding of the basis of ion-selectivity.

The different types of channels subserve a number of different regulatory functions in different cell types. Doing so, they play a strategic role, in the sense that a small number of them can dominate cellular function. It is, therefore, not surprising that they are the targets of toxins and drugs, and that any malfunction of channels may cause severe disorders. Among the drugs which act on channels are Ca^{++} antagonists, local anaesthetics, diuretics, sulfonylureas, and many psychoactive drugs.

It has also become apparent that quite a number of hereditary diseases can be traced to mutations in channel proteins. Classical examples of such cases are many forms of myotonia, for which a multitude of mutations has been identified. Another case, which has been known for some time is mucoviscidosis, in which a major pathological element is a defect in the regulation of a chloride channel. More recently cardiac arrhythmias, kidney diseases, chronic pain, and epilepsy have been added to that list.

Erwin Zabel

2 Developing the practical and theoretical tests

2.1 The tasks committee

The International Biology Olympiad sets out to allow its participants to demonstrate their knowledge and skills by working on practical and theoretical tasks. The development of appropriate tasks was thus seen as a major aim of the preparations for the 1998 Olympiad in Kiel. To this end, in May 1997, the host Institute for Science Education (IPN) in Kiel, convened a thirteen-member tasks committee, led by Professor Erwin Zabel, comprising twelve members from the universities of Kiel and Rostock and the Max Planck Institute for Educational Research in Berlin, and one former IBO competitor.

Professor Horst Binding	Genetics/Cell biology Laboratory 3
PD Dr Christian Gliesche	Microbiology/Biotechnology Laboratory 3
Professor Ludger Kappen	Ecology
Dr Eckhard Klieme	Statistics, Max Planck Institute, Berlin
Ralf Kittler	Former IBO participant
Professor Sievert Lorenzen	Anatomy and physiology of animals and man; Systematics, Evolution
Dr Eckhard Lucius	Chair, Organization Committee
Dr Erhard Lipkow	Ecology
Professor Karl Meissner	Ethology Laboratory 4
Professor Hansjörg Rudolph	Physiology of plants Laboratory 2
Professor Jürgen Soll	Cell biology
Professor Helmut Uhlarz	Anatomy and systematics of plants, Evolution Laboratory 1
Professor Erwin Zabel	Chair, tasks committee

An agreement was reached with each committee member, most of whom contracted to produce a certain number of tasks for the IBO test. Eckhard Klieme, of the Max Planck Institute agreed to act as consultant to the tasks committee, to lead the marking process during the Olympiad and to conduct an evaluation study. The first meetings dealt primarily with the following issues:

- the number of tasks to be allowed for each of the eight subdisciplines stipulated in the Rules (COORDINATING CENTRE OF THE INTERNATIONAL BIOLOGY OLYMPIAD, 1998),
- the level of difficulty,
- the test design.

From the beginning the committee set out to increase the proportion of tasks requiring creative achievement, without devaluating the tasks requiring knowledge reproduction. The result was, particularly for the theoretical test, the distinction of three task types:

- tasks requiring mainly the reproduction of knowledge,
- tasks requiring competitors to make connections between facts and draw independent conclusions,
- complex tasks encompassing elements of problem solving and requiring a high level of independent creative achievement.

Developing tasks of the third type proved a particular challenge, and indeed the committee was not able to produce the results it had hoped for here. Experience showed that an increase in the proportion of complex tasks necessitates a reduction in the number of tasks overall. Thus several drafts were made for both the theoretical and the practical test and discussed, with reference to proposals from other participating countries. It emerged that it would suffice for each participating country to submit just five tasks, but with a focus on innovative, complex proposals.

A major phase of the development work was informal trialling. 15 former IBO competitors from Germany, who had agreed to take part in trials, worked on the theoretical and laboratory tasks under test conditions and commented on each individual item. The feedback from these informal trials was particularly valuable. Besides indicating where the tasks were difficult to understand or badly worded, they revealed that even after careful development and intensive discussion by experts, a number of tasks would not conform to diagnostic criteria, either because they were solved by all - or none - of the participants, or because they evidenced a negative correlation with the overall score. A total of 26 provisional tasks had to be withdrawn for this reason. In 24 cases a thorough reworking was recommended, particularly to adapt the level of difficulty and clarity. A further benefit of the informal trialling was the empirical support it provided in the subsequent discussions, which thus did not have to rely solely on the jury members' assumptions in the assessment of the items' capacity to test problem-solving skills rather than rote knowledge of facts.

Altogether, the members of the tasks committee came together for five plenary meetings, as well as group discussions and numerous individual exchanges. The test finally agreed by the tasks committee and released in English and Russian translation for the 1998 Biology Olympiad contained 80 multiple-choice items in Part A, another 40 tasks in Part B, and seven experiments to be performed in four laboratories with a total of 46 questions.

2.2 The tasks of the practical test

2.2.1 Objectives

The Laboratories test the participants' knowledge of and ability to apply basic methods and processes in the biological sciences. As no methods of *direct* observation and documentation (e.g. video filming) are available so far, an *indirect approach* was required. To this end, tasks were selected

- which could only be solved if the appropriate methods and procedures had been followed and
- which involved solutions largely expressed as numbers or internationally known symbols.

It proved difficult to design tasks which fitted these categories, particularly if problem-solving processes and statistical evaluations were to be achieved. With reference to the results of the informal trials, the tasks committee finally chose a number of tasks covering seven topic areas, to be processed in four Laboratories.

2.2.2 Activities planned for the Laboratories

The following activities were required of the competitors in each Laboratory.

- *Laboratory 1: Systematically – anatomically orientated* 38 points

  Activities:
  Producing a preparation (e.g. cutting, staining),
  Using the microscope,
  Observing, analyzing, assigning.

- *Laboratory 2: Physiologically orientated* 40 points

  Activities:
  Experimenting (pilot experiment),
  (e.g. preparing solutions; pipetting, analyzing),
  Utilizing laboratory equipment,
  Observing, calculating,
  Experimenting from memory.

- *Laboratory 3: Genetically – microbiologically orientated* 37 points

  Activities:
  Isolating DNA (e.g. determining working steps, precipitating),
  Producing a micro preparation (squash preparation),
  Producing sketches / drawings,
  Evaluation of results.

- *Laboratory 4: Ethologically orientated* 35 points

  Activities:
  Experimenting
  Calculating
  Statistical evaluation (t-Test)

2.2.3 Jury discussion; administering and marking the practical test

Before the scripts were translated by the delegation leaders, the task developers explained which activities the tasks required. To facilitate explanation, workplaces had been set up in the conference room, with instruments and chemicals placed as for the test, a feature which was well received. Following the discussion, one task was withdrawn (from Laboratory 4) and a portion of the available marks assigned to another. The maximum possible score was thus adjusted from 150 to 144.

In each Laboratory the candidates had 70 minutes in which to conduct the experiments and answer the questions. After 70 minutes they moved on to the next Laboratory. The work in each was guided by a task sheet. The laboratory supervisor and invigilators were responsible for ensuring that candidates were provided with all necessary equipment and, where appropriate, were also required to rate interim results (such as sketches, solutions, preparations) according to given criteria. The candidates' scores were derived from these interim results and from responses to a variety of questions about the experiments and/or their results.

According to the jury members, no particular problems or difficulties arose during the practical test.

The test was marked after completion by the task developers and assistants, using a solution and rating key. To minimize the risk of error, all papers were second-marked and both results recorded.

The evaluation of the Laboratory 4, ethology, was particularly time-consuming. Here the candidates were required to conduct their own experiments and statistical evaluation. For the first time in IBO history, the task was not merely to make an observation which could be clearly judged correct or incorrect, or to produce a preparation of a quality which could be assessed using prescribed criteria. The candidates were required to experiment, i.e. to hypothesize, obtain data, process data and draw conclusions, to show whether they were able to carry out scientific experiments independently.

Each competitor was given a dish filled with sand containing a certain number of sunflower seeds and had to use various grips and finally a tool (tweezers) to transfer the seeds to a second dish. This experiment, with variations in the type of grip, was performed 30 times. Each time the amount of time taken was recorded, together with the amount of sand removed with the seeds. These data were then interpreted as indicators of the efficiency of the grip. The candidates represented their 60 readings in a table and conducted a statistical evaluation (by calculating means/standard deviations and t-tests).

In this type of task, the assessment criterion could not be a simple comparison with a given correct solution. In order to judge the calculations and interpretations, the measurements and reflections of each competitor needed to be assessed individually. To this end, all the readings entered on the worksheets were transferred to an appropriately programmed computer, which allowed the statistical values for the readings taken by the competitor to be calculated. The results were then compared with the candidates' calculations.

More elaborate assessment procedures such as these are indispensable whenever the jury needs to take a candidate's procedure into consideration, rather than simply assessing an end product such as a preparation. Our evaluation will also reveal whether such elaborate performance assessments are worthwhile. (They could, of course, be carried out more efficiently if the candidates could enter their readings directly into the computer.)

All results were accepted unanimously by the jury.

The tasks of the practical test are shown in chapter 5.2.

2.3 The tasks of the theoretical test

2.3.1 Objectives

As for the practical test, the tasks for the two parts of the theoretical test were developed using quality criteria agreed upon by the tasks committee (see 2.1). A multiple-choice format was chosen for Part A, comprising short tasks to be completed by selecting from among three to five given options and marking

the appropriate box. For Part B more varied formats were to be produced, eliciting responses in the form of numbers, formulae or other internationally recognisable symbols. The number of complex tasks was to be increased (see 2.1). Part A was assigned 80 tasks, Part B 40. Both Part A and Part B encompass eight sub-disciplines, the ratio for which is given in the International Rules (COORDINATING CENTRE OF THE IBO, 1998, cf. 2.3.2).
The tasks committee worked out a weighted marking scheme, with different numbers of marks available for correct solutions or part-solutions. Correct solutions for 20 of the 80 items in Part A were worth two marks each. In Part B the number of possible marks varied between one and five per task.
Thus a total of 100 marks was to be obtainable for Part A, and 80 for Part B, yielding 180 marks altogether. With the marks available in the practical test, this meant a maximum possible total of 330 points.

2.3.2 Planned distribution of points

Task	**Part A**		**Part B**		**Total**		**IBO-Rules**
	Points	%	Points	%	Points	%	%
Cell biology	21	21,25	15	18,75	36	20,0	20,0
Physiology of plants	15	15,00	11	13,75	26	14,45	15,0
Physiology of animals	15	15,00	10	12,50	25	13,89	15,0
Ethology	3	2,50	8	10,00	11	6,12	05,0
Genetics/ Evolution	15	15,00	13	16,25	28	15,60	15,0
Ecology	15	15,00	10	12,50	25	13,89	15,0
Systematics	10	10,00	8	10,00	18	10,00	10,0
Microbiology	6	6,25	5	6,25	11	6,12	5,0
Total	100	100,00	80	100,00	180	100,07	100,0

Tab. 1 The distribution of points among the subdisciplines of the theoretical tasks. The planned points correspond well with the percentage of the IBO-Rules

2.3.3 Jury discussion and decisions

The translation of the tasks necessitated a thorough discussion by the jury, in the presence of the tasks committee. The jury supported the committee's intentions, although four tasks were withdrawn from Part A and four from Part B, and the maximum possible score adjusted to 162 points, 85 for Part A and 77 for Part B.

As soon as the provisional results had been ascertained after the tests, the scores and the individual tasks were subjected to intensive discussion by the jury. The laboratory results were accepted without adjustment. In the theoretical parts, nine items were withdrawn from the scoring and a further six remained points of contention[1]. It is interesting to not that errors on the part of the authors were rare. The main reasons for disregarding items, or the main causes of disagreement were

- errors in the German-English translation (three instances)
- last-minute changes made during the first jury meeting, which were either not included in all test versions or were later shown to be erroneous (three instances)
- unclear or misleading formulation of questions/tasks (three instances)
- scientific disputes over the correct solution according to most recent research findings (two instances).

This indicates that the process of task development, particularly the informal trials, had proved valuable. Queries with respect to task content were negligible. Most of the problems had emerged towards the end of the development process, through the translations and through the ad-hoc discussions of the jury itself.

If the nine items refused by the jury are removed from the total of 158 items, and also the six disputed items, reduced tests emerge, with 149 and 143 items respectively. However, they correlated at .998 or .999 with each other and with the complete version, with practically identical competitor ranking. As this could be ascertained by the jury at its closing meeting, the decision was made to award the medals on the basis of the reduced (143-item) test rather than repeating the whole evaluation process – as originally suggested by a number of jury members – which would have been time-consuming and, quite proba-

[1] The following were withdrawn: A2, A11, A43, A47, A58, B2, B16, B35 and B40.
The following were contentious: B8, B13, B19, B26, B27 and B30.

bly, equally susceptible to error[2]. In the reduced version, a maximum of 287 points was possible. The highest score achieved was 200, the lowest 59.5, with a mean score of 138.84 (= 48% of the possible maximum), and a standard deviation of 31.89. With 12 gold, 29 silver and 44 bronze medals to be awarded, as the jury had decided, this reduced test produces the same winners as the complete test (with 158 items). With regard to accuracy of measurement, again the results are almost identical: internal consistency was .93 for the complete test and .92 for the reduced test.

This approach (i.e. additional discussion following the test) is problematical in many ways and, as the statistics show, unnecessary. The International Rules should therefore stipulate that once the tasks have been confirmed by the jury before the test, no further changes may be made.

2.3.4 Administering and marking the theoretical test

The time allowed, 260 minutes, proved adequate, and all candidates worked with the requisite self-discipline. The papers were completed in accordance with the instructions in all but four cases. In Part A, two candidates had not entered their answers on the marksheet, but on the question sheet, next to each task. This variation was, however, unanimously accepted by the jury. In two further cases, two answers had been indicated, although only one solution was correct throughout Part A. These responses had to be marked as incorrect.

Part B was marked by the task developers and assistants. The data were recorded on computer, and also by hand, as an additional check to minimize the risk of error. For Part A the results were entered on two computers, working independently, also to minimize the risk of error. The results for the theoretical test as a whole were unanimously accepted by the jury. The tasks of the theoretical test are shown in chapter 5.2.

2 A complete list of the results of all competitors, including medal distribution, is provided in chapter 6.

Eckhard Klieme

3 Evaluation Report

3.1 Introduction

3.1.1 Problems of methodology in international competitions for the gifted

The term “Olympiad” might suggest that achievement in mathematics or the sciences can be measured by direct or fundamental methods, in the same way that achievement in sport is measured in the basic dimensions of time and distance. In the Science Olympiads, however, the completion of cognitive tasks is assessed by means of complex coding and scoring systems, a methodology which is designed to fulfil the requirements of pedagogical and psychological research, which has wide-ranging experience in the design of tests and mathematical models for scaling, and which draws on the findings of empirical research into the quality of measuring processes. With reference to the standards of professional test design (cf. e.g. ROST 1996), the Science Olympiads present a number of fundamental problems.

1. *Statements about generalized competence as a target of measurement*: The very fact that the tests combine a variety of task formats shows that the ranking reflects more than a point-by-point approach to performance. The aim is always to obtain a good overall measurement of achievement in each of the disciplines, and to draw conclusions from this with regard to fundamental (latent) ability. It would need to be determined whether such latent ability exists and whether the various tasks can be used as indicators of it (see 3.3 below).

   The Olympiad tests must also conform to the classic criteria of diagnostic quality, such as objectivity, reliability (see 3.2 below) and validity (see 3.4 and 3.7 below). In our view, the criterion of validity is not the prediction of future academic achievement (as Campbell & Wu 1996 suggests, following a study of previous participants), but the construct validity, i.e. the exact distinction of the ability domain covered by the Olympiad tasks. Task developers and committee members have certain expectations here. Task development for IBO 1998, for example, was focused on the eliciting of solutions to complex biological problems, without testing highly specialized knowledge, memory capacity or general intelligence. Such statements of ability, however, are often less than clearly delineated, and it is difficult to establish intersubjective agreement (see 4 below). Characterization of the intended construct by means of the tasks selected is more likely to be implicit (see 3.5 below).

2. *Small ad-hoc populations*: Science Olympiads, at least at international level, have no preliminaries. Most competitors enter once only. The tasks are developed for one event and then published. Neither the participants nor the tasks can be *calibrated* in advance.

   How then can the level of difficulty be adequately predicted and kept relatively constant over a number of Olympiads? How can tests and assessment be organized in order to lead to results in the short time at the organizers' disposal, i.e. within hours? Which theories of testing can be applied in view of the relatively small numbers of participants (usually under 200)? How can those tasks be dealt with which do not show up as unsuitable until the Olympiad is under way?

3. *International contest*: Do the cross-cultural differences lead to distortions or disadvantages? (At the IBO, for example, care would have to be taken to ensure that all participants were familiar with the required laboratory methods and that no species were mentioned which were known in some countries but not in others).

   The participants speak, read and write in several dozen languages. Is it acceptable to give them all tasks in one or perhaps two languages only? (These would be, typically, English and Russian, the latter still an important *lingua franca* among the large number of participants from former eastern bloc countries.) If – as at the Biology Olympiad, for example – the tasks are translated into the competitors' native languages, restricted resources mean that the translations have to be undertaken ad hoc within just a few hours. There is also the question of quality control. To avoid having to translate candidates' answers, closed-set responses and even multiple choice formats have to be used, which leads to the question of content restriction.

4. *Expertise of test designers and jury members:* In practice, many of these questions are addressed by delegating them to an international tasks committee and/or an international jury (which is usually comprised of the national team supervisors). But how competent are these bodies? Are their members able to assess the tasks in terms of level of difficulty and complexity and identify potential linguistic problems?

5. *Highly selective decisions:* The Olympiads and the preceding national heats are highly selective procedures. The IBO Rules, for example, allow for 10% of competitors to receive gold medals, and 20% silver. It is hardly considered that such a highly selective approach presents a particular challenge to the measuring instruments. (A point which applies generally to the diagnosis of giftedness; with the exception of HANY 1993.)

   FAY and KLIEME (1988) and KLIEME and STUMPF (1990) developed a mathematical model for the prediction of exchange effect, which occurs upon change of a selection process (known as the paternoster effect). If the selection rate is 10%, as in the case of IBO gold medals, and if a certain decision criterion (e.g. a group of tasks) is replaced by another which correlates at .65 with the first, then it is likely that more than half of the respondents selected by the first procedure will *not* be selected by its replacement. Exchange here thus encompasses more than 50%. Even with a correlation of .85, the expected impact of the paternoster effect is still 38%. Such factors need to be taken into consideration whenever test instruments and decision procedures are to be redesigned, particularly in view of the translation issue mentioned above.

The methodological problems posed by an internationally comparative, ad hoc measurement of highest achievement levels will be explored and discussed below, with reference to empirical evidence from the International Biology Olympiad. With respect to the validity question, i.e. what measurement of achievement means in terms of content and what distinguishes successful Olympiad competitors, we shall draw on models from psychology, developed for research into giftedness (GRUBER & MANDL 1992, GRUBER 1992, HELLER 1993, SCHNEIDER 1993).

3.1.2 The issues and the report sections

1. The first section (3.2) sets out the results of IBO 1998, presenting the statistics for results overall, results by sub-discipline, and results by task.

   In addition, the tasks (as task groups) are evaluated in terms of their diagnostic value. We indicate the level of difficulty and the reliability of the various scales, and the individual tasks. Problems of task development are discussed, drawing on points already raised in the national tasks committee and by the international jury, in order to ascertain which types of task have proved particularly suitable and to derive proposals for subsequent test development.

2. In the second section (3.3) we analyze the internal structure of the IBO tests. We compare multiple-choice tasks with other formats within the theoretical parts, and compare the theoretical parts with the Laboratories. Using multivariate statistical processes we investigate the dimensionality of the test: can the two theoretical parts – irrespective of subdiscipline or task format – be seen as indicators of a comprehensive, homogeneous construct of ability? Do theory and practice represent a common ability dimension, or do written tasks and laboratory tasks in principle require different skills?

3. In the third section (3.4) we examine the validity of the IBO test and its various parts, drawing on two data sources. The first is the assessment of the standard of the theoretical tasks undertaken by several members of the jury independently and with no knowledge of the empirical findings. These assessments by experts allow the tasks to be differentiated in terms of cognitive level, required knowledge and probability of being solved. The second source is an investigation of the correlation between task fulfilment and a measure of general intelligence and the level of "expertise" of the competitors. The core question of this validation study is whether the tasks committee was successful in developing problems which are complex and challenging, in other words which do not merely demand a reiteration of facts, but require the application of problem solving strategies at "expert" level.

4. In the fourth section (3.5) we characterize the abilities and knowledge requisite for gold, silver and bronze medals with reference to typical tasks which are reliable indicators of various levels of competence.

5. The fifth section (3.6) deals with the language problem, an issue of considerable importance for the Biology Olympiad. The International Rules state that an English and a Russian version of the tasks are to be produced at the beginning of each Olympiad. The leaders of the national delegations, who also form the jury, then meet during the Olympiad to discuss the items produced by the tasks committee, rework them where necessary and translate them into the appropriate language. The candidates are given either the English or the Russian version of the tasks, to which the leader of the delegation has added a hand-written translation. In some cases the whole text is translated, in others only the key terms.

   This procedure is time-consuming, takes place under considerable pressure and is can therefore be presumed susceptible to error. Time is too short to allow the translation to be checked in advance. A check by suitably qualified translators does take place, but aposteriori and with random samples only. Moreover, the multiplicity of languages precludes the use of tasks with an open format, as responses in several dozen languages would not allow for objective assessment. The IBO organizers have long debated whether this procedure could be replaced by sole use of the English and Russian versions. To obtain data relevant to this query, we planned an additional study, conducted at the end of the competition proper, in which around half of the IBO competitors participated. On a voluntary basis, candidates sat a shorter test in the standard languages which was compiled mainly of unused substitute tasks. A comparison of the results in this standard language version (*Standard-Sprach-Version*: SSV) and the results in the IBO proper would, it was hoped, give an indication whether a future restriction to the two standard languages would be feasible.

6. The sixth section (3.7) reports on the findings of a further additional study of the relationship between subject competence, intellectual ability and ex-

pertise. The voluntary participants in the additional study on the final day of the Olympiad completed a short questionnaire eliciting information about biology-related interests, a test of general intelligence (ability to think in inductive/deductive terms) and a task designed to indicate level of expertise with respect to scientific reflection, in particular in biological terms. The evaluation of these data was designed to address the relative significance of expertise (i.e. in biology) and general intelligence for success at IBO, and whether motivational factors played a complementary role.

3.2 Results and comments on task groups

3.2.1 Findings for the theoretical test

3.2.1.1 Complete test

Table 2 comprises the major characteristic values for the theoretical parts and the eight sub-disciplines. Parts A and B are placed together here, but dealt with separately below.

The level of difficulty suits the IBO target group at a near-optimum level. As 43% of the maximum possible marks were obtained on average, there is adequate scope for a variation in the distribution of points, allowing differentiation between the participants, which is also expressed in the relatively high standard deviation of 19.5 points, given a total mean of 73.26 points. In fact, the results ranged from 34 to 111.5 points, which is a span of almost 80 points. The fact that none of the participants achieved the maximum number of points possible is evidence that the tasks were able to differentiate at the highest levels of achievement – exactly as the Olympiad sets out to do.

	Number of tasks	Mean	Relative mean (perc.)	Observed Mini-mum	Observed Maxi-mum	Possible Maximum	Standarddeviation	Internal Consi-stency	Correla-tion with Theory-score
Theory	112	73,26	43	34,00	111,50	172	19,50	0,89	
Cell biology	23	16,80	48	4,00	27,00	35	5,25	0,72	0,73
Anatomy & physiology of plants	15	9,81	43	1,00	18,00	23	3,82	0,63	0,76
Anatomy & physiology of animals	14	7,60	40	0,50	14,50	19	3,00	0,44	0,62
Ethology	6	6,15	41	0,00	13,00	15	2,82	0,56	0,56
Genetics	17	6,73	26	0,00	15,00	26	3,06	0,44	0,56
Ecology	17	11,34	45	2,00	20,00	25	3,99	0,62	0,73
Systematics	12	10,05	56	3,00	15,00	18	2,66	0,48	0,57
Microbiology	8	4,79	44	1,00	9,00	11	1,75	0,04	0,40

Tab. 2 Results of the theoretical test. N.B. "Mean in per cent" is the percentage of the possible maximum represented by each mean. "Correlation with the theory score" was subjected to part-whole adjustment

The form of distribution is not significant for test assessment, but for our additional analyzes (see 3 to 6 below). Figure 1 illustrates that the test results evidence near-symmetrical distribution and conform approximately to a Gaussian normal distribution.

A comparison of the various sub-disciplines reveals that cell biology, plant anatomy/physiology and ecology, wield considerable influence in the overall result of the theoretical test, which can be discerned from their correlation with the theory score. This is linked on the one hand to the relatively high number of tasks in these sub-disciplines and on the other to the fact that these were the areas, apart from genetics, where the most points were available. But whereas the tasks in genetics proved too difficult, with a mean of only 26% of the available points being obtained, in the other three areas the figure was around 45%, whereby a relatively high dispersion was achieved.

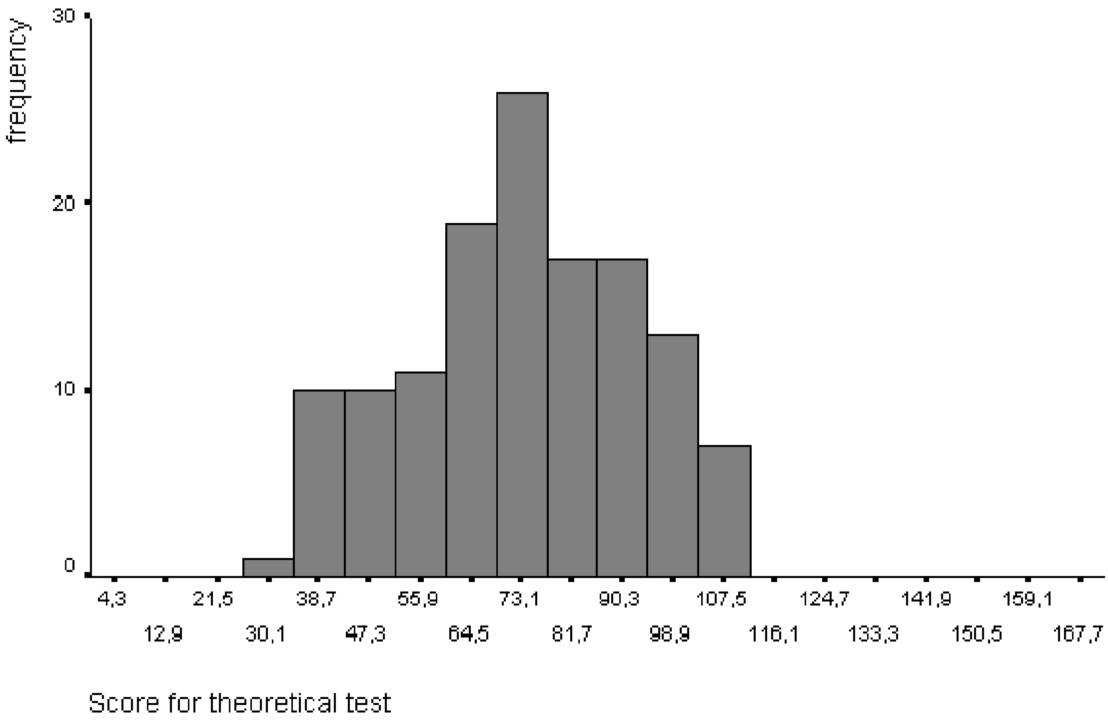

Fig. 1 Distribution of scores for the theoretical test

Of particular importance is the internal consistency of the task groups, a measurement of test reliability which should not lie below .70. In genetics, but also in animal physiology and, above all, in microbiology, the results fell significantly short of this goal. Results in the other sub-disciplines were rather more favourable, but it was cell biology alone, at .72, which achieved a level of internal consistency which could be considered adequate for diagnostic criteria. This means that an interpretation of the results at sub-discipline level is not possible, although it should be noted that this was not an intention of the test design. The aim of the IBO test is always measurement of overall competence, and with a internal consistency of .89 this aim was most certainly fulfilled.

3.2.1.2 Comparison of parts A and B

As expected, Part B, which comprised more complex and more varied task types was significantly more difficult than Part A. In Part B only around one third of the possible number of points was gained on average, whereas in Part

A it was approximately one half (cf. Tables 3 and 4; Figures 2 and 3). However, the distributions in both cases evidenced sufficient variance in an acceptable, almost symmetrical form. And the internal consistency of both task groups (.82 and .83 respectively) is very high, in other words, each of the two parts allowed competence in biology to be reliably measured.

The fact that the 36 tasks in Part B proved to be as reliable a test as the 76 tasks in Part A clearly illustrates the advantages of the more open, more varied response formats. They allow for a more differentiated evaluation and thus a more precise, more reliable measurement than the multiple choice tasks. The only sub-disciplines for which multiple choice proved more reliable than the variable task types of Part B were systematics and animal physiology. (In the case of animal physiology this was obviously due to the level of difficulty of the more open tasks. Easier tasks would have presumably enabled a higher degree of consistency to be achieved, even in Part B.) In three sub-disciplines (cell biology, plant physiology and ecology) Part B evidenced a higher consistency than Part A, despite its much smaller number of items. This experience indicates that Part B should be expanded at future Olympiads.

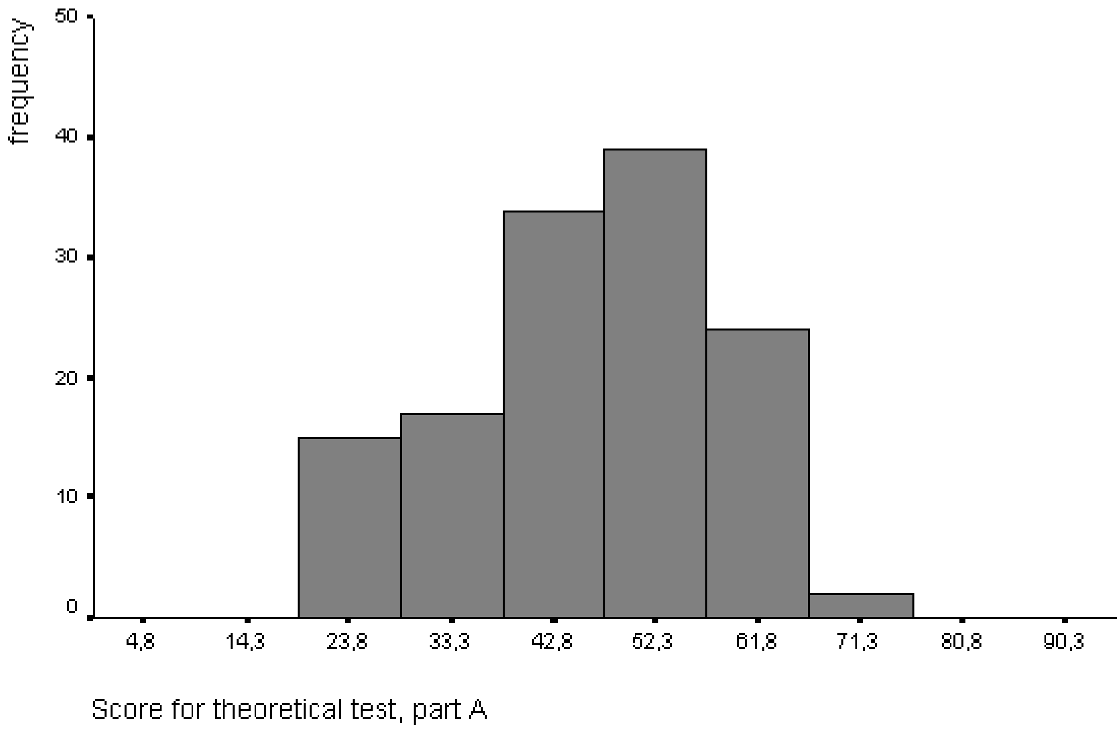

Fig. 2 Score for theoretical test, part A

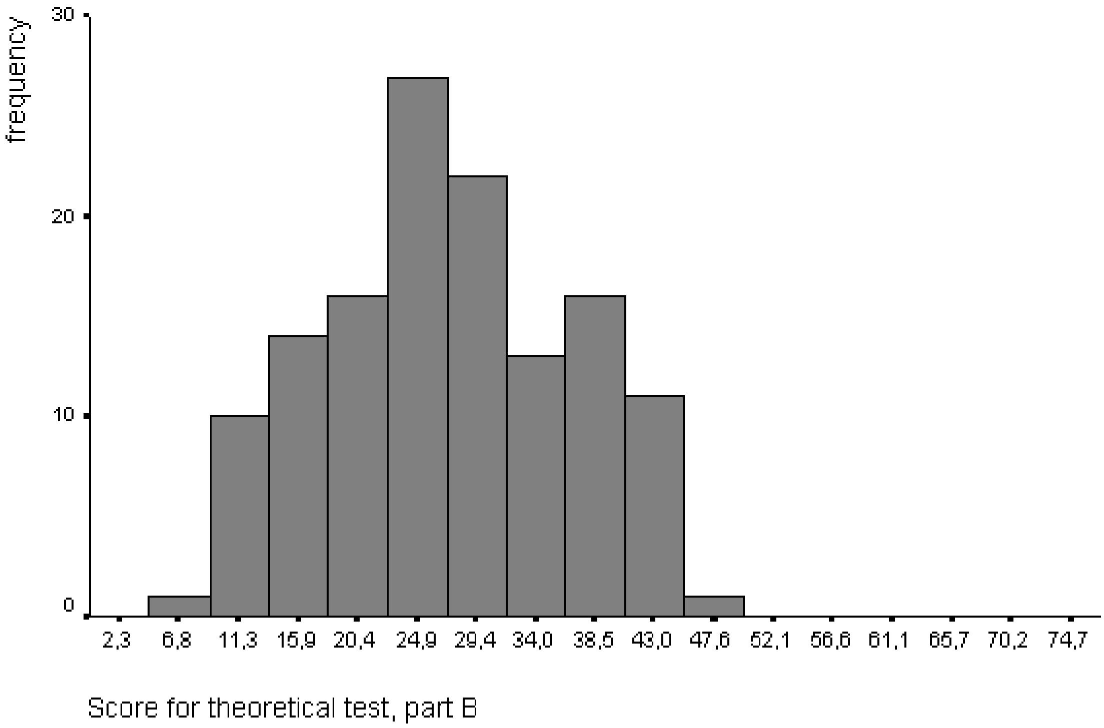

Fig. 3 Score for theoretical test, part B

	Number of tasks	Mean	Relativemean (perc.)	Observed		Possible Maximum	Standarddeviation	Internal Consi-stency	Correla-tion with Theory-score
				Minimum	Maximum				
Theory A	76	46,02	48	23,00	70,00	95	11,70	0,82	0,72
Cell biology	16	10,56	53	2,00	17,00	20	3,37	0,55	0,56
Anatomy & physiology of plants	11	6,89	49	0,00	13,00	14	2,64	0,45	0,64
Anatomy & physiology of animals	10	5,73	48	0,00	11,00	12	2,64	0,54	0,61
Ethology	2	0,58	19	0,00	3,00	3	0,77	-	0,17
Genetics	12	5,17	34	0,00	11,00	15	2,31	0,28	0,45
Ecology	12	7,60	51	1,00	13,00	15	2,72	0,47	0,56
Systematics	8	6,98	70	2,00	10,00	10	2,28	0,54	0,51
Microbiology	5	2,52	42	0,00	6,00	6	1,34	-	0,09

Tab. 3 Results of the theoretical test, Part A

	Number of tasks	Mean	Relativemean (perc.)	Observed Minimum	Observed Maximum	Possible Maximum	Standarddeviation	Internal Consi-stency	Corre-lation with Theory-score
Theory B	36	27,24	35	8,50	48,00	77	9,31	0,83	0,72
Cell biology	7	6,24	42	1,00	11,00	15	2,48	0,57	0,75
Anatomy & physiology of plants	4	2,92	32	0,00	8,00	9	1,80	0,58	0,62
Anatomy & physiology of animals	4	1,87	28	0,00	6,00	7	1,41	0,16	0,13
Ethology	4	5,56	46	0,00	12,00	12	2,67		0,55
Genetics	5	1,56	14	0,00	6,00	11	1,37	0,23	0,49
Ecology	5	3,75	38	0,00	8,50	10	2,09	0,53	0,63
Systematics	4	3,08	39	0,00	6,50	8	1,23	0,25	0,35
Microbiology	3	2,27	45	0,00	4,00	5	1,05		0,53

Tab. 4 Results of the theoretical test, Part B

3.2.1.3 Analysis of tasks

With respect to individual tasks, the data for which are given in Tables 5 and 6, the two decisive criteria are the average number of points achieved (which should be neither near zero, nor close to the maximum, in order to allow for differentiation) and the part-whole adjusted correlation between success in the individual task and overall achievement in the IBO theory test.

Task[3]	Relative frequency (percent) observed for option[4]					Correlation with Theory-score	Subject
	A	B	C	D	E		
A1	26	40	15	2	17	.38	Cell Biology
A2	9	29	8	44	9	-.05	
A3	5	64	27	3	1	.30	
A4	30	20	12	33	4	.36	
A6	43	6	5	21	22	.08	
A7	5	7	2	79	7	.40	
A8	31	3	4	62		.32	
A9	7	82	4	2	5	.39	
A10	26	6	66	2		.05	
A11	9	3	53	14	20	-.04	
A12	1	3	5	66	24	.54	
A13	29	4	62	4	2	.23	
A14	80	12	5	1	2	.21	
A15	71	20	5	2	1	.39	
A16	8	5	8	69	6	.33	
A17	79	7	5	3	2	.22	
A18	6	31	16	46	1	.20	Anatomy and Physiology of plants
A19	5	2	2	76	15	.49	
A20	3	29	48	4	16	.25	
A21	10	5	16	53	15	.21	
A22	56	31	5	1	6	.17	
A23	2	19	11	65	2	.68	
A24	9	8	26	57		.29	
A25	11	34	18	5	31	.05	
A26	3	83	8	5		.23	
A27	8	14	12	60	5	.13	
A28	26	15	15	29	13	.32	

[3] Grey = task not used for medal assignment
[4] Grey = correct solution

Task	Relative frequency (percent) observed for option					Correlation with Theory-score	Subject
	A	B	C	D	E		
A30	27	3	69	1		.41	Anatomy and Physiology of animals
A31	21	35	27	17		.10	
A32	12	73	5	9		.12	
A34	8	58	18	15		.42	
A35	8	8	7	70	6	.14	
A36	34	21	35	5	6	.35	
A37	31	8	38	8	15	.03	
A38	48	14	26	2	10	.47	
A40	20	40	22	15		.21	
A41	4	62	9	5	16	.45	
A42	6	11	44	38		.30	Ethology
A43	8	50	10	2	28	-.05	
A44	16	9	53	7	14	.36	Genetics
A45	5	22	8	60	5	.53	
A46	30	10	5	53		.13	
A47	11	12	31	11	34	.24	
A48	16	16	41	12	11	-.15	
A49	8	8	25	16	43	.05	
A50	12	50	18	5	15	.26	
A51	11	19	13	11	44	.19	
A52	9	8	33	49		.33	
A53	28	26	11	21	12	.05	
A54	7	29	18	42		.09	
A55	7	23	8	47	11	-.09	

Task	Relative frequency (percent) observed for option					Correlation with Theory-score	Subject
	A	B	C	D	E		
A56	10	8	5	72	5	.40	Ecology
A57	9	18	9	53	11	.32	
A58	5	23	50	9	9	.03	
A59	11	2	8	42	37	-.09	
A60	13	11	17	18	41	.01	
A61	58	2	7	4	29	-.01	
A62	9	9	5	63	14	.31	
A63	21	40	24	8	3	.07	
A64	3	3	21	71	2	.55	
A65	49	24	23	4		.18	
A66	11	8	65	10	5	.31	
A67	9	69	7	11	3	.37	
A68	11	10	39	21	20	.21	Systematics
A69	2	67	29	2		.35	
A70	4	63	30	4		.19	
A71	2	5	8	75	11	.24	
A72	1		97		2	.10	
A73	4	8	72	11	4	.34	
A74	70	5		23	2	.27	
A75	70	4	11	8	5	.31	
A76	21	9	22	46		.01	Microbiology
A77	12	30	26	32		.16	
A78	18	31	31	18		.07	
A79	17	8	11	17	47	-.07	
A80	7	15	75	4		.25	

Tab. 5 Item statistics for the theoretical test, Part A. N.B. The correct solutions are shaded grey. The correlation with overall theory score is part-whole adjusted.

Task	Mean	Possible Maximum	Correlation with Theory-score	Subject
B1	0,45	1	0,57	Cell Biology
B2	0,14	2	0,32	
B4	0,43	2	0,39	
B5	3,81	5	0,53	
B6	0,09	2	0,16	
B7	0,95	2	0,53	
B8	0,37	1	0,38	
B9	0,81	2	0,58	Anatomy and Physiology of plants
B10	0,70	3	0,47	
B12	0,33	2	0,34	
B13	1,08	2	0,26	
B14	0,31	2	-0,12	Anatomy and Physiology of animals
B15	0,28	1	0,46	
B16	0,79	2	-0,03	
B17	0,49	2	0,10	
B19	1,85	4	0,42	Ethology
B20	2,15	4	0,34	
B21	1,01	2	0,39	
B22	0,56	2	0,49	
B23	0,05	2	0,12	Genetics
B24	0,33	2	0,56	
B25	0,98	3	0,22	
B26	0,16	2	0,30	
B27	0,05	2	0,15	
B29	0,31	1	0,31	Ecology
B30	1,13	2	0,47	
B31	0,34	2	0,10	
B32	0,95	3	0,52	
B33	0,76	2	0,41	
B34	1,53	2	0,44	Systematics
B35	0,76	3	0,29	
B36	0,65	1	0,04	
B37	0,14	2	-0,02	
B38	1,26	2	0,53	Microbiology
B39	0,92	2	0,11	
B40	0,08	1	-0,03	

Tab. 6 Item statistics for the theoretical test, Part B. N.B. The correlation with the overall score is part-whole adjusted. Grey: Tasks not used for medal assignment.

The correlations with the overall theory scores are extraordinarily high in places: one task in every ten (seven items from Part B, four items from Part A) has a correlation of more than .50 with the overall theory score. This means that more than 25% of the achievement variance between the competitors can be elucidated by the processing of a single task.

The task A23 comes out on top here, at .68, accounting for almost 50% of the achievement variance (see chapter 5.2). The next highest correlation with the overall score was found in tasks B1 and B9, which required the interpretation of diagrams. A23 is presumably so powerful because of the combination of skills it demands, all of them particularly relevant to the IBO test: knowledge of facts (about photosynthesis), understanding of experimental arrangements (comparison of arrangements alpha and beta) and measurements, the ability to interpret diagrams and to think logically and deductively. Interestingly, this was first designed as an open task, requiring the candidate to draw correct curves. The tasks committee was doubtful that such free drawings could be assessed efficiently and objectively, and so the final version required the correct solution to be chosen from five given curves. This example therefore shows that quality is less a matter of task format than of the clarity and complexity of the underlying requirements. There is a tendency for the multiple choice format to be less successful, as the comparison of A and B showed above. Only 11 of the 76 multiple choice tasks correlated at .40 and above with the overall score, but in the case of the short answer format, the figure was 14 out of 36.

Moving on the tasks which proved less successful, i.e. those which correlated with the overall theory score at levels below .20, we find 31 in Part A and 11 in Part B. Of these, eight tasks in A and 4 tasks in B evidenced negative correlation with the overall theory score. Here, too, it is revealed that more complex task formats (Part B) yield better characteristic values for the items and thus offer a better quality of measurement.

A closer examination of the 12 tasks showing negative correlation with the overall theory score – those tasks which tended to be answered incorrectly by good candidates but correctly by weaker candidates – provides significant insights into the quality criteria for IBO tasks and allows us to characterize the tasks which function contrary to expectations.

- In half of such cases (six out of 12) the tasks were unusually presented, involving, for example, a mental experiment, the assessment of research methodology, or metatheoretical reflection on the use of biological terms (such as “fitness”). These points had been debated by the tasks committee before the Olympiad. There had been some doubt whether theoretical competence could be adequately tested by requiring metatheoretical reflection, mental experiments, consideration of fictitious species, etc. The results showed that such tasks do indeed fit badly into the IBO test as a whole, correlate particularly poorly with the overall score and thus reduce the internal consistency - however interesting they may be from the point of view of content.

- Five were characterized by their requirement of highly specific knowledge, mainly about cell biology and genetics (e.g. RNA structure, microtubules, substitution hybrids).
- In one case only, A59, does the negative correlation appear attributable to poor wording of the task.

3.2.2 Findings for the practical test

Like the theoretical parts, the practical test was found to have a high level of internal consistency (.84) and a high mean score (70.15, i.e. 49% of the possible maximum). The spread of the results (from 24 to 104.5 points, with a standard deviation of 18.39 points) and their distribution, as shown in Figure 4, demonstrate the usefulness of this procedure.

As Table 7 illustrates, the laboratories were able individually to achieve reliable ratings of achievement. The first laboratory (systematics/anatomy) was relatively easy, with the participants achieving a mean of 64%. Thus the distribution is distorted, i.e. the upper score levels do not allow for adequate differentiation. This leads to a relatively low internal consistency rate of .62 for the eight tasks in this laboratory, and overall achievement in Laboratory 1 correlates only at a very low level with the score of the other three laboratories (.35). The latter yielded more reliable results, with internal consistency ranging from .72 to .74, although the levels of difficulty were not at an optimum. Laboratory 2 (physiology), averaging 42% of the maximum, evidenced a balanced level of difficulty and a good distribution curve. Laboratory 3 (genetics/microbiology) was too difficult, as the average of 30% of the possible maximum score showed, whilst Laboratory 4 (ethology) was rather too easy, with an average of 61%. Internal consistency, variation or standard deviation, and correlation with the overall result of the practical test are, however, satisfactory on the whole.

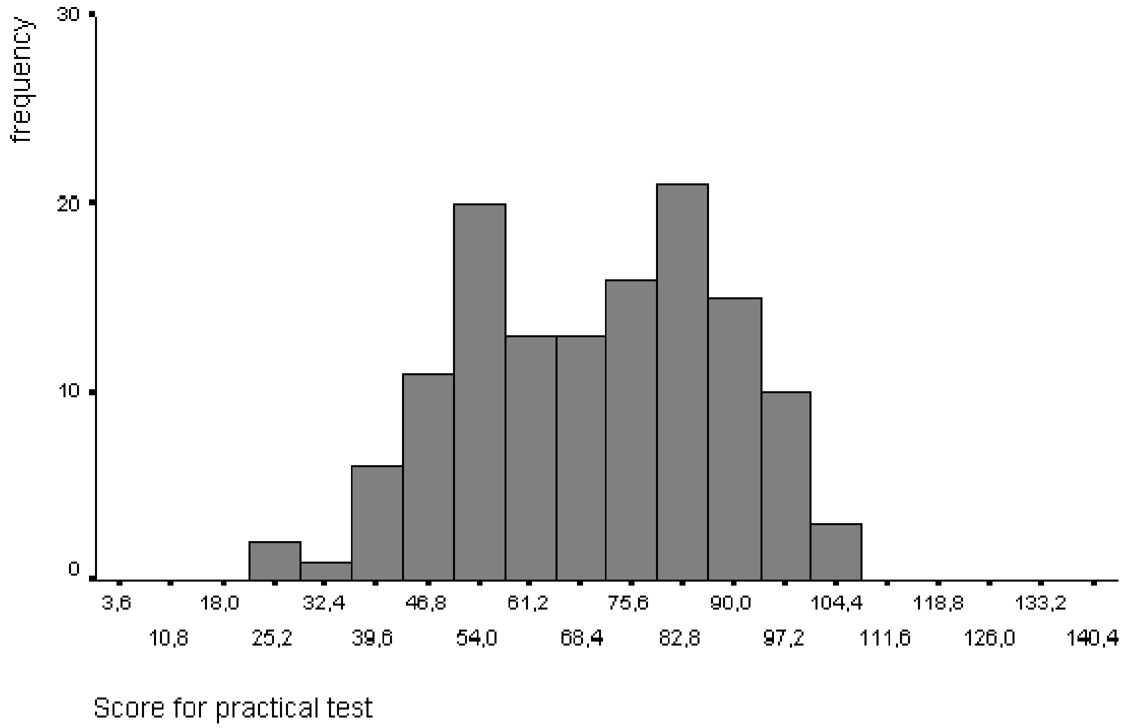

Fig. 4 Score for practical test

	Mean	Observed Minimum	Observed Maximum	Possible Maximum	Standard deviation	Correlation with score for practical test
Practical Test	70,15 (49 %)	24	104,5	144	18,39	
Lab. 1: Systematics/ Anatomy	24,50 (64 %)	10,00 (26 %)	35,00 (92 %)	38	5,61	.35
Lab. 2: Physiology	16,93 (11 %)	1,00 (3 %)	39,00 (98 %)	40	8,46	.55
Lab. 3: Genetics/ Microbiology	11,04 (30 %)	0,00 (0 %)	24,00 (65 %)	37	4,96	.56
Lab. 4: Ethology	17,67 (61 %)	2,50 (9 %)	29,00 (100 %)	29	6,04	.49

Tab. 7 Test statistics for practical tasks (Laboratories)

	Mean	Observed		Possible Maximum	Standard deviation	Correlation with score for practical test
		Minimum	Maximum			
Lab 1-1: leaf	9,85	3,00	14,00	14	2,47	.52
leaf: 1	6,75	2,00	9,00	9	1,67	.37
leaf: 2	0,99	0,00	2,00	2	1,00	.03
leaf: 3	2,11	0,00	3,00	3	1,38	.43
Lab 1-2: plants	14,66	3,00	22,00	24	4,15	.25
plants: 1	1,99	0,00	4,00	4	1,19	.38
plants: 2	6,23	0,00	8,00	8	1,87	.13
plants: 3	2,14	0,00	4,00	4	1,19	.32
plants: 4	1,60	0,00	4,00	4	1,08	.22
plants: 5	2,70	0,00	4,00	4	1,10	.13
Lab 2-1: resp. Ch.	9,24	0,00	23,00	23	5,03	.55
resp. chain: 1	1,21	0,00	3,00	3	1,48	.36
resp. chain: 2	1,42	0,00	3,00	3	1,50	.48
resp. chain: 3	1,24	0,00	2,00	2	0,98	.43
resp. chain: 4	0,89	0,00	1,00	1	0,31	.11
resp. chain: 5	0,93	0,00	1,00	1	0,25	.14
resp. chain: 6	0,79	0,00	1,00	1	0,41	.24
resp. chain: 7	0,20	0,00	1,00	1	0,40	.19
resp. chain: 8	0,36	0,00	1,00	1	0,48	.29
resp. chain: 9	0,34	0,00	1,00	1	0,48	.23
resp. chain: 10	0,58	0,00	1,00	1	0,50	.16
resp. chain: 11	1,27	0,00	8,00	8	1,95	.50
Lab 2-2: Avena	7,69	0,00	17,00	17	4,89	.50
Avena: 1	1,16	0,00	2,00	2	0,99	.30
Avena: 2	0,76	0,00	2,00	2	0,98	.17
Avena: 3.1	0,79	0,00	1,00	1	0,41	.44
Avena: 3.2	0,99	0,00	2,00	2	1,00	.39

Avena: 4	2,89	0,00	8,00	8	2,82	.48
Avena: 5	1,10	0,00	2,00	2	1,00	.43
Lab 3-1: DNA	6,73	0,00	11,00	12	2,27	.51
DNA: 1	3,66	0,00	4,00	4	0,89	.42
DNA: 2	1,16	0,00	3,00	3	0,71	.27
DNA: 3	0,45	0,00	2,00	2	0,81	.33
DNA: 4	0,39	0,00	1,00	1	0,49	.44
DNA: 5	0,42	0,00	1,00	1	0,49	.30
DNA: 6	0,63	0,00	1,00	1	0,48	.07
Lab 3-2: Mitosis	4,32	0,00	14,00	25	3,64	.48
Mitosis: 1	0,97	0,00	2,00	2	0,83	.36
Mitosis: 2	0,56	0,00	4,00	8	0,84	.35
Mitosis: 3.1	0,34	0,00	2,00	2	0,57	.39
Mitosis: 3.2	0,40	0,00	3,00	3	0,79	.30
Mitosis: 3.3	0,88	0,00	5,00	5	1,37	.42
Mitosis: 4	0,09	0,00	1,00	1	0,29	.15
Mitosis: 5	0,43	0,00	1,00	1	0,50	.23
Mitosis: 6	0,04	0,00	1,00	1	0,19	.21
Mitosis: 7	0,49	0,00	1,00	1	0,50	.38
Mitosis: 8	0,11	0,00	1,00	1	0,32	.08
Lab 4: Ethology						
Ethology: 4.1	4,24	0,00	5,00	5	1,19	.49
Ethology: 4.2	4,02	0,00	5,00	5	1,54	.46
Ethology: 4.3	3,59	0,00	5,00	5	2,01	.54
Ethology: 4.4	2,78	0,00	4,00	4	1,85	.19
Ethology: 4.5	3,04	0,00	10,00	10	2,04	.56

Tab. 8 Item statistics for practical test

Table 8 describes the results at the level of the seven experiments conducted within the four laboratories. They comprised 46 individual tasks which yielded particularly reliable measurements (correlation with overall score above .35) when

- candidates labelled anatomical diagrams (tasks 1.1.1, 1.2.1), interpreted diagrammatic models (2.1.11, 2.2.4, 2.2.5) or drew microscopy findings themselves (3.2.2 and 3.2.3), i.e. worked with different types of diagrams and drawings,
- the quality of an intermediate product was assessed by the laboratory supervisor (2.1.3, 3.1.3, 3.2.1),
- calculations had to be made (2.1.1, 2.1.2, 2.2.3.2, 4.1, 4.2, 4.3, 4.5), and
- the series of steps to be taken in a laboratory experiment needed planning (3.1.1).

These types of tasks are a fair representation of the principle of performance assessments (SHAVELSON 1991; BAKER, O'NEIL & LINN 1993; SOLANO-FLORES, JOVANOVIC, SHAVELSON & BACHMANN 1996; SALONO-FLORES & SHAVELSON 1996). The assessments they make do indeed reflect the quality of activities which are of fundamental importance in the practice of scientific experimentation and research, i.e. planning investigations, making preparations, microscopy, sketching observations, measuring and evaluating by calculation. It would appear that the IBO 1998 laboratory tasks were successful in representing the basic skills of scientific laboratory work, measuring achievement with an astonishingly high level of reliability.

The assessment of individually obtained measurements proved particularly valuable in Laboratory 4. As a reconstruction of the statistical calculations on the basis of the readings taken by the candidates showed, the marks awarded for the correctness of the statistical evaluation in task 4.5 evidenced a higher correlation with the overall score for the practical test than all other practical tasks, even higher than the total values of the seven experiments.

Good levels of correlation with the overall score are also achieved by individual questions relating to complex knowledge (e.g. 1.1.3, where a leaf was to be classified under ecological considerations, or 3.1.4, where the chemical which can destroy a cytoplasma membrane needed to be named), as well as individual questions relating to specific observations (2.2.3.1).

If, however, only responses relating to elementary knowledge are elicited, as in the case of the first two tasks in Laboratory 1, which asked for the names of certain species of plants (1.1.2 and 1.2.2), or obscure facts from the history of biology (3.2.8), the correlations with the overall score sink to unacceptable levels. The same applies to questions about observations if the latter are as simple as the identification of coloration (2.1.4 and 2.1.5).

3.2.3 Discussion of test design and recommendations

The detailed test and item analyzes yielded insights which can be immediately translated into recommendations for future IBO test design:

- Part B of the theoretical test could be expanded. Although this would involve more complex assessment, as the short responses, lists, etc. would need to be individually marked, the Kiel IBO showed that, with trained markers, this work can be completed in an afternoon.
- Laboratory tasks designed as complex performance assessments, again with appropriate marking, are worthwhile. Simple observation and classification items are best avoided. Tasks involving interpretation of diagrams or calculation have also proved valuable.
- It has been shown that highly unusual (e.g. meta-theoretical) questions and tasks requiring too specific knowledge (particularly in cell biology) should be avoided to allow rating to be consistent.

These specific recommendations for task design were not the only useful purpose served by our analysis. The findings for IBO 1998 also illustrate that the empirically obtained coefficients for difficulty and selectivity can be helpful in the discussion of tasks by the international jury[5]. Even if tasks with scores evi-

5 This was hotly debated in the jury's final meeting. A number of jury members refused to include empirical data in the discussion, maintaining that content, biological arguments, should be the sole criteria for assessment. This position, however, overlooks the fact that the IBO test not only needs to be free of error in terms of scientific i.e. biological content. Above all it sets out to be an instrument facilitating assessment which is as objective, as reliable, as fair and as valid as possible, and for this reason it can and must be subject to the quality criteria of pedagogical diagnostics. In the widest range of selection and certification procedures (testing) it is quite usual to exclude tasks from further assessment if the empirical data show them to be problematical.

dencing levels of correlation with the overall scores which are too low or negative are not to be automatically excluded, they should be carefully considered during jury discussions. In 1998, five of the 12 tasks which fell into this category were excluded by the jury, and in one further case the key was altered. Statistical evaluation of test and item characteristics immediately following the IBO test are thus to be recommended. The findings can then be drawn upon in the final consultations of the jury.

3.3 Comparisons between the test parts

3.3.1 Theory Parts A and B: The influence of format

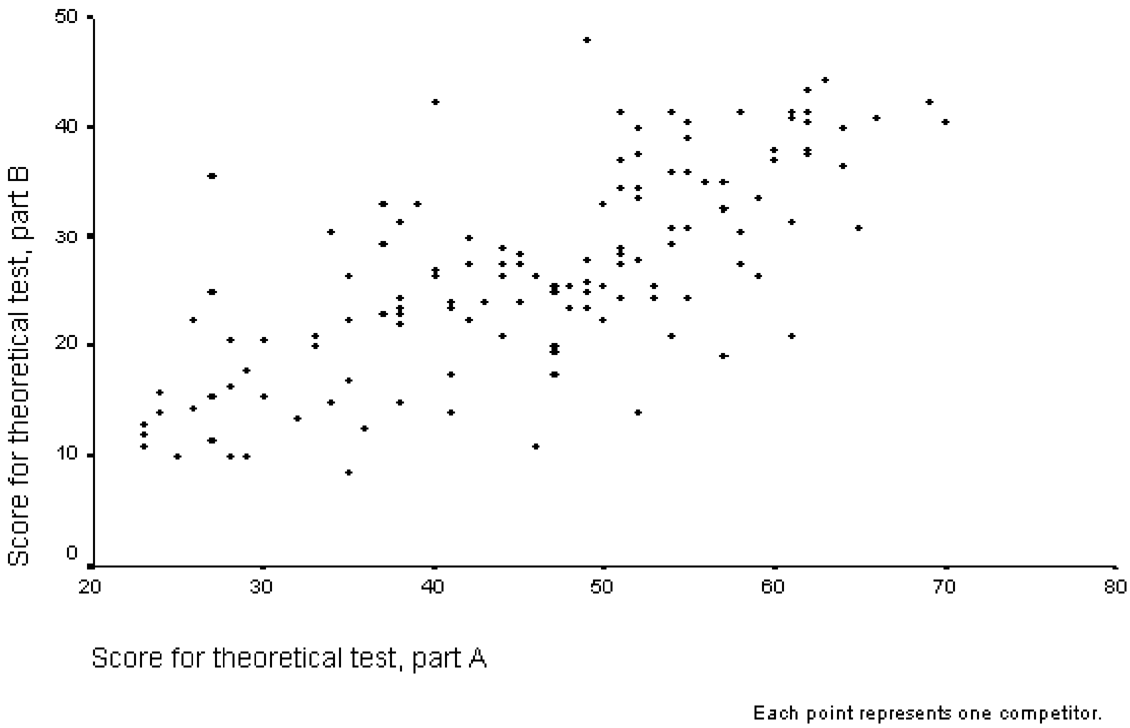

Fig. 5 Relationship between the results in the theoretical tests part A and B.

Parts A and B in the theoretical test show close agreement. The tendency for higher results in Part A to be combined with higher results in Part B is clearly apparent, although there are a number of deviations[6].

The coefficient for the correlation of the two test parts is .72. Assumption of the paternoster effect (FAY & KLIEME, 1988) here yields the following estimation: if IBO gold medals were awarded solely on the basis of either the Part A multiple choice questions or the more varied questions in Part B, only half the medal winners would be the same in each case. If gold and silver medals are taken together, the selection quota is around 30%, which would mean that around one third of the medal winners would be different.

This discrepancy, so significant from a practical point of view, has two causes: the inaccuracy of measurement in Parts A and B, and the systematic (latent) differences between the respective test constructs. If the limited reliability of both test parts is taken into account, a potential (latent) correlation coefficient of .87 is revealed. Even if this were empirically achievable, i.e. if error-free observations were available, a differential of approximately 35% would still have to be assumed for gold medals, and 25% for gold/silver medals. This illustrates that the multiple-choice tasks in Part A and the more varied, more complex response formats in Part B cover different facets of competence in biology, despite the basic agreement of the results. We shall investigate in 3.3 and 4 below how these facets can be determined.

Discussion of differentials is, of course, hypothetical, as IBO tests in practice always consists of A and B Parts. However, any changes in the weighting are likely to influence the selection of medallists. This is not, in itself, an argument against changes in the test concept. But it does necessitate reflection on the consequences of such a change, and requires a decision to be taken on the basis of the type of task best suited to the intended competence construct.

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[6] Two competitors in particular stood out here. Both achieved unusually high scores in Part B (more than 40% of the possible total), but were no more than average in Part A. Both candidates also achieved outstanding scores in the practical test. It might thus be said that the multiple choice format disadvantages participants with an obviously high level of competence. However, these are isolated cases.

3.3.2 On the relationship between theoretical and experimental competence: a comparison of theoretical and practical tasks

Data from a comparison of results in the theoretical test with those in the practical test yield a correlation coefficient of .80 (see Figure 6), or .93 when adjusted to allow for measurement error, which is indicative of a closer association than was revealed between the two theoretical parts, even when the various errors in measurement are taken into consideration. This is a point which requires clarification and for this it is necessary to examine the data in more detail.

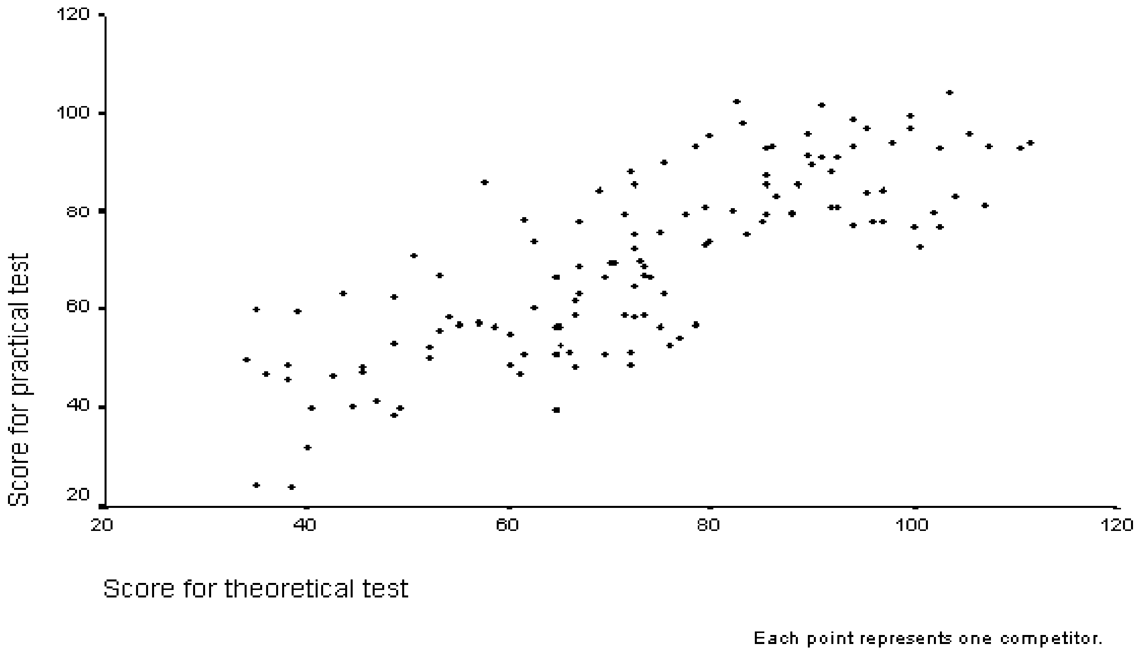


Fig. 6 Relationship between the results in the theoretical and the practical test

As a first pointer towards an explanation, it can be seen that the multiple-choice tasks in Part A correlate with the practical test at slightly lower levels than the tasks in Part B (r =.72 as opposed to r =.76), though with one interesting exception: success in the first laboratory (anatomy and physiology) correlates more strongly with success in Part A (r =51 as opposed to r =.36). In 2.2 above we showed that Laboratory 1 did not evidence a particularly strong correlation with the remaining laboratories. This allows us to suggest that both the theoretical and the practical test consist of tasks which are cognitively more challenging, particularly in Part B of the theoretical test and in Laboratory 4 (ethology), as well as those which are less challenging (Part A and Laboratory 1). This variation in level leads to relatively low levels of correlation *within* each test, whereas a higher level of correlation can be ascertained between the overall scores, because both the theoretical test and the practical test comprise a blend of the challenging and the elementary. We shall test this hypothesis below.

A further pointer can be seen in Figure 6, where above-average scores in the theoretical test (more than 80 points) were only achieved by those candidates with an above-average performance in the laboratory tasks (more than 70 points). This indicates that the capacity to think and proceed in a manner appropriate to experimental science is decisive. Without this ability there can be no excellence in theorising and discussion. The reverse tends to apply, but with more exceptions: above-average results in the laboratories (more than 70) were possible with a score of 60 in the theory test, but only appeared without exception in connection with theory scores above 80. Once this threshold has been crossed, there no longer appears to be a clear connection between theory and practice: in the region above the 80/70 threshold, the top scores were distributed with no recognisable trend. Once this minimum ability is achieved and the skills necessary for argument and experiment are present, these two areas of competence appear relatively independent of each other.

In view of this independence, awarding medals solely on achievement either in the theoretical or in the practical test would lead to significantly different medal tables. Our mathematical model based on the ideal of a bivariate distribution predicts that around one quarter of the gold medal recipients would change, even with error-free data. Given real errors in the measurement, and in view of the deviations from the distribution model, particularly in the top achievement band, substitution of around half the gold medals would be realistic. Thus the bottom line is that decisions which affect theoretical-practical weighting need to be carefully considered, as they have a significant bearing on the distribution of medals.

3.3.3 Modelling the structure of competence in biology

In view of the incomplete agreement between the theoretical and practical tests and between Parts A and B of the theoretical test, is it justifiable to assume a uniform area of competence reflected in the overall result of a Biology Olympiad? An answer lies in a comparison of structural models.

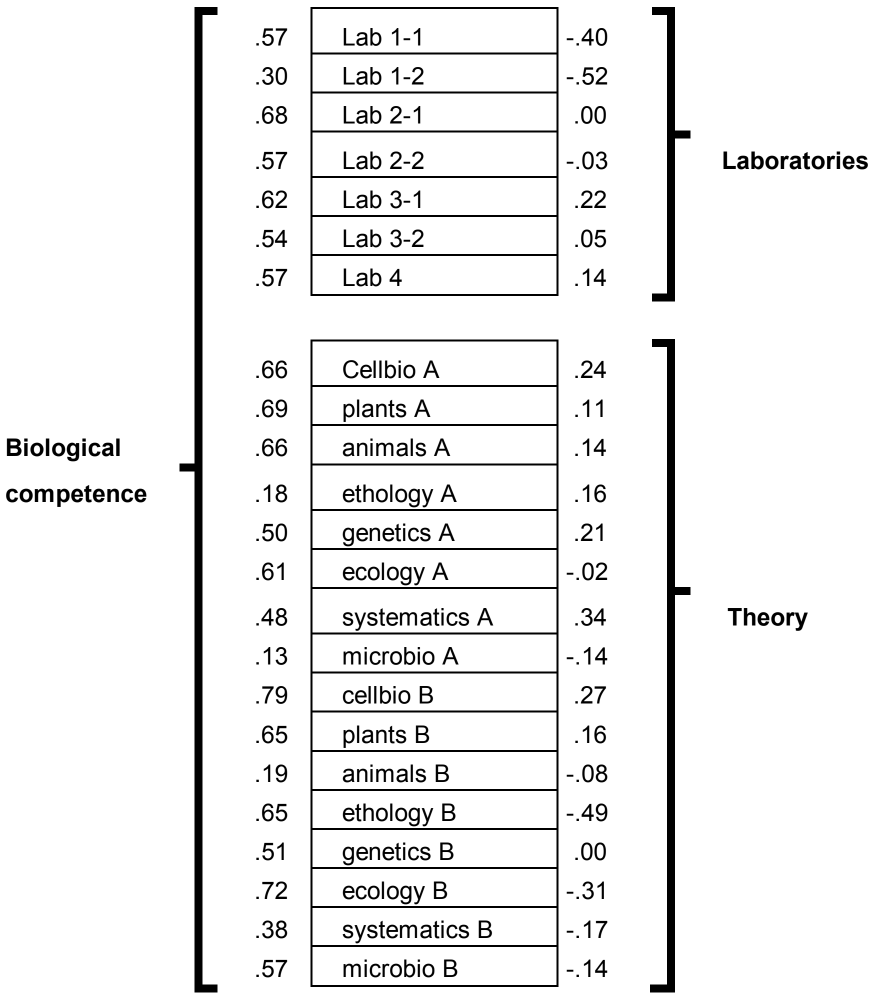


Fig. 7 Structure models for the comparision of competence in the IBO-Test

Using the program LISREL 8 (JÖRESKOG & SÖRBOM 1994) three models were constructed and tested for agreement with the observed correlation patterns. For Part A and Part B of the theoretical test, the results for the eight subdisciplines were used as indicator variables, while the practical test was indexed by means of the seven experiments.

	Number of tasks	Mean	Relativ mean (perc.)	Observed		Standard Deviation	Internal Con-sistency
				Mini-mum	Maxi-mum		
Full test	158	143,40	45	59,5	208	19,50	0,93
Reduced test (for medal assignment)	143	138,84	48	59,5	200	31,89	0,92

Tab. 9 Results of the full and the reduced tests

The statistical tests sought to elicit which of the three models corresponded closest to the empirically obtained matrix of the covariances of these 23 variables. The results are set out in Table 9.

A single-factor model, in which all IBO elements are represented by a single latent factor, certainly does not match the real situation. The model set out in Figure 7a, which includes a general factor and two specific factors - for the theoretical and for the practical test - not correlated with the general, evidenced a significantly better, though far from optimum fit. The patterns of loadings give indications of how to interpret the factors and explain the continued poor fit of the model, as do the modification indices:

- The subtests already recognized as unreliable fit badly into this model. For the variables ethology (A), microbiology (A) and animal physiology (B), a variance solution of at the most 5% was obtained.
- The loadings of the general factor "competence in biology" clearly show that this factor covers complex knowledge and logical thinking in challenging areas of biology: questions in differing formats (Part B) on cell biology and ecology, as well as multiple choice tasks and laboratory experiments in plant physiology have the highest loadings. But these are sections comprising tasks which are cognitively particularly challenging (cf. sections 2 and 4).

  The "practice" factor does represent an advanced level of thinking and procedure in an experimental, scientific context, i.e. it represents complicated laboratory techniques, as well as the registration and calculation of data. This is indicated in particular by the positive loadings from the first experiment in Laboratory 3 (DNA extraction) and by the laboratory on ethology, but also by the strongly negative loadings from both experiments in the field of systematics and anatomy, which involved the production and identification of simple plant preparations.
- The theory factor, on the other hand, appears primarily to represent knowledge of terms and facts, indicated by the particularly strongly positive loading coefficient from the multiple choice tasks in systematics and the positive loadings from most of the other multiple choice tasks. The strongly negative loadings from those groups of tasks which require logical think-

ing rather than knowledge reproduction, above all ethology (B) and ecology (B), support this interpretation.

- The fit of the model could be considerably improved by loading challenging theory elements onto the practice factor and, vice versa, loading simpler laboratory results (Laboratory 1) onto the theory factor. However, this means that the separation into theory and practice is obsolete. The significance of a task depends less on its association with either theory or practice than with its cognitive challenge.

If two uncorrelated factors are added to the structure model for theory Parts A and B, the fit is not significantly improved. (The difference in the chi-square values between model 2 and model 3, at 24.24 with df =16, is not significant.) As we explained above, the factor "theory" differentiates well between Part A with its mainly positive loadings and Part B with its mainly negative loadings.

In summary, the factor structure test revealed that the IBO test as a whole (general factor) tests knowledge and argument in biology to a high level. The specific factor "laboratory" represents a high level of experimental ability and reasoning, while the specific factor "theory" represents knowledge of terms and facts. The distinction between the theoretical and practical elements is, however, less significant than that between the level of the tasks (high/low level; more/less challenging).

3.4 Standard and validity of the IBO tasks - expert opinions

3.4.1 Propositions and method

An additional study, conducted during the jury consultations at IBO 1998 in Kiel, set out to ascertain

a) whether experts (jury members also acting as delegation leaders and supervisors of national teams) arrive at similar and (according to external criteria) valid estimations of the quality of content and level of difficulty of tasks and

b) what skills - according to the jury - are typically required by the IBO theoretical tasks.

During the discussion of the theoretical tasks by the jury, but before the empirical results were announced, all jury members were given a questionnaire in which they were asked to rate each of the theoretical tasks in three dimensions on a four-point scale:

Dimension 1: Subject knowledge

0 = no specific subject knowledge required

1 = school level

2 = academic level

3 = specialist level

Dimension 2: Thought processes

0 = no logical thinking required

1 = application or transfer of known principles

2 = problem-solving required (stepwise progression to a conclusion)

3 = independent, creative thinking to surmount new types of problem

Dimension 3: Level of difficulty

0 = very simple task

1 = simple task

2 = difficult task

3 = very difficult task

The categories were explained briefly, not in writing; there was no training.

12 out of 31 questionnaires were returned, some in English, some in Russian. This figure, low as it is due to the extreme pressures on the jury members during the discussion and translation of the tasks, need not be assumed to distort the results. Several of the respondents were former organizers or holders of international functions within IBO and as such particularly familiar with the workings of the Olympiad.

3.4.2 Reliability and validity of the expert judgements

The highest level of agreement among jury members was found with respect to the rating of required processes of reasoning (dimension 2). The coefficients, calculated in pairs (Kendall's ≥}), yielded a median of .32; 80% of these agreement coefficients were statistically significant (, < 01). Agreement with regard to level of difficulty (dimension 3) was lower, however. The coefficient yielded a median of .23. It was statistically significant in 61% of all cases. In the case of required subject knowledge, the coefficient of agreement was relatively low, with a median of .14, and only 40% of the values were statistically significant.

The jury members made a relatively clear distinction between required reasoning and required knowledge. Over all 112 tasks for which complete responses were available, both assessments correlated at .11 (not significant). Both assessments were, however, allied with the expected level of difficulty: the assessment of task difficulty correlated with the level of knowledge at .51 and with required reasoning at .50 (both figures highly significant, < .001).

Two external criteria were available to judge the validity of the experts' opinions: the empirically ascertained difficulty of the tasks[7], as an empirical measurement of the item-specific reasoning requirements, and the correlation of task solution with a test of inductive thinking[8]. For the dimension "subject knowledge required" we had no external criterion.

The level of task difficulty as judged by the jury members correlated at .35, a highly significant level, with the empirically obtained data (, <.001). Figure 8, which indicates linear regression for Parts A and B separately, illustrates that the level of difficulty can be predicted with considerably more precision in Part A than in Part B. Taken separately, estimated and empirically ascertained levels of difficulty correlate at .36 in the first case, but in the second at only .12. For the more complex, less standardized tasks in Part B, prediction of level of difficulty is therefore less successful.

7 For the correlation with other task characteristics we use the Logit value ln ((l-p))/p), which can be regarded as linear scaled, in contrast to relative solution frequencies.

8 We use these correlations in a form transformed after FISHER.

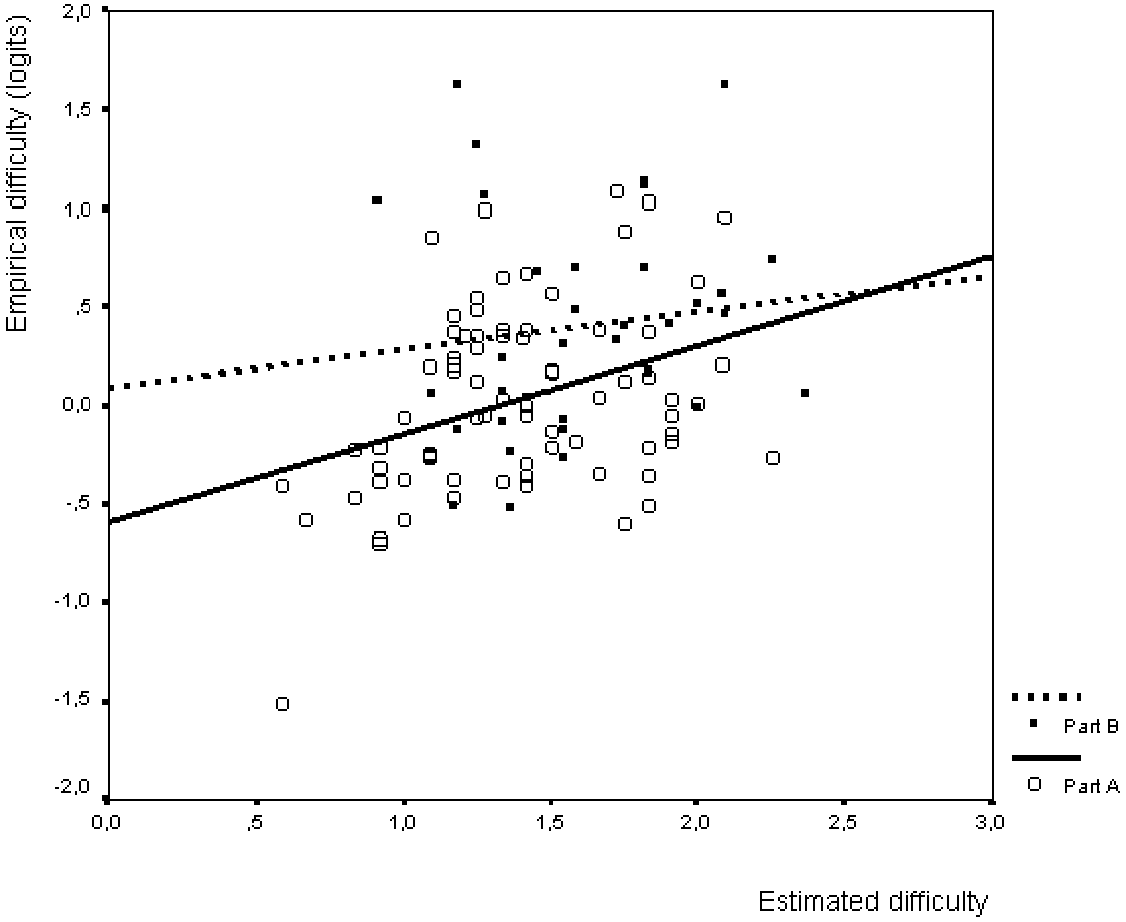


Fig. 8: Validity of jury assessment: Relationship between empirical and estimated difficulty of theoretical tests A and B

The assessment of the task-specific processes of reasoning is similarly valid: there is a highly significant correlation between the average assessment of the 12 jury members and the empirical results (r = .38; , < .001). In this case, as figure 9 shows, it is possible to make a similarly good assessment of Parts A and B; the respective coefficients for the relation between estimated and empirically ascertained requirements are .37 (, = .001) and .32 (, = .06).

In summary, jury members are apparently quite able to assess the level of required reasoning and the level of difficulty of the theoretical tasks. The experts questioned were essentially in agreement with respect to these two dimensions, which also correlate well with external criteria, whereby the difficulty of tasks in multiple choice format (Part A) could be predicted with considerably more success than that of tasks in other formats (Part B). Two recommendations can be made on this basis. On the one hand the international jury needs to be able to draw on empirical data for task discussion (from trialling or from the Olympiad itself) in order to avoid erroneous judgements of difficulty. In addition, care should be taken to familiarize the jury with the more complex and flexible task formats in Part B, if, as recommended above, this part is to be expanded in future.

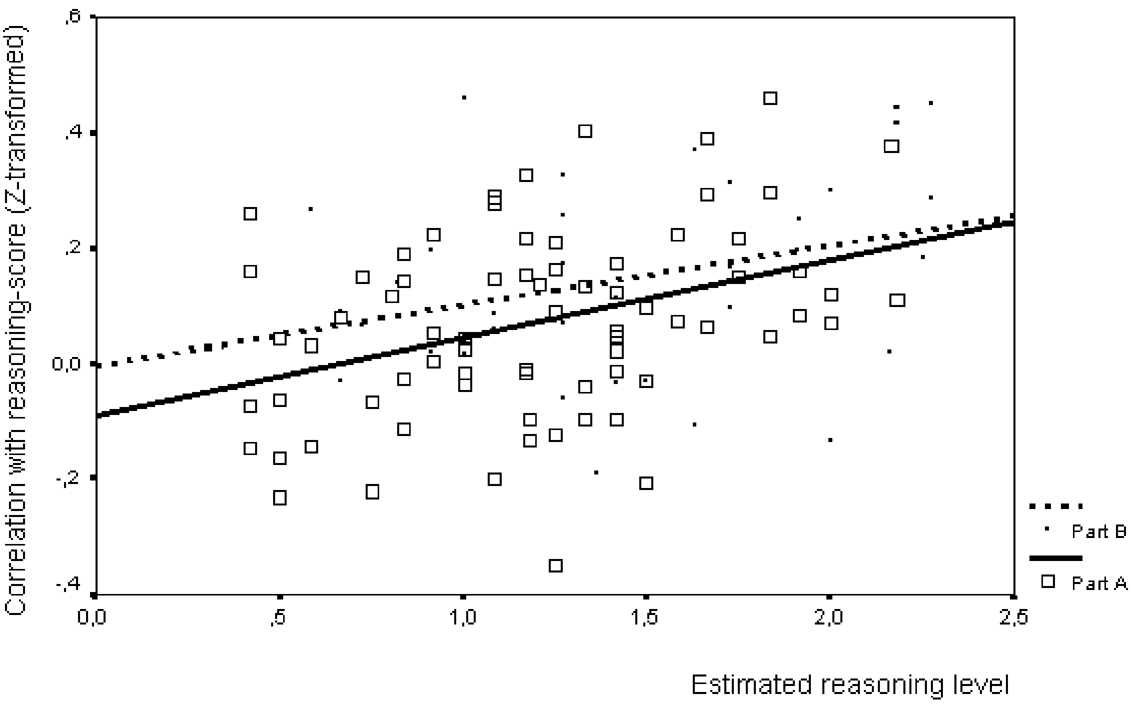


Fig. 9 Relationship between the task-specific reasoning-score and the estimated reasoning level

With respect to the third dimension, required subject knowledge, it is interesting to note that the experts did not reach any kind of consensus. Either they could not reliably state which pieces of knowledge would be needed to fulfil a task, or they differed in their categorization of knowledge as "school", "academic" and "specialist". However, the average estimation of level of knowledge is still an important descriptor for our task analysis: it may explain a part of the task difficulty which is not associated with reasoning.

Overall, the results obtained for reliability and validity of the expert ratings justify using them again to compare the content of individual tasks and groups of tasks.

3.4.3 Contents of test parts and task groups

Significant differences were ascertained between Part A and Part B, as well as significant differences among the eight sub-disciplines, with respect to the estimation of required knowledge and reasoning (Mann-Whitney test for differences between Parts: , < .05; Kruskal-Wallis test for differences between sub-disciplines: , < .01). As Figure 10 shows, within each of the three dimensions, Part B tasks are rated higher than the multiple-choice tasks of Part A. Significantly, the difference is greater with regard to required reasoning than to required knowledge.

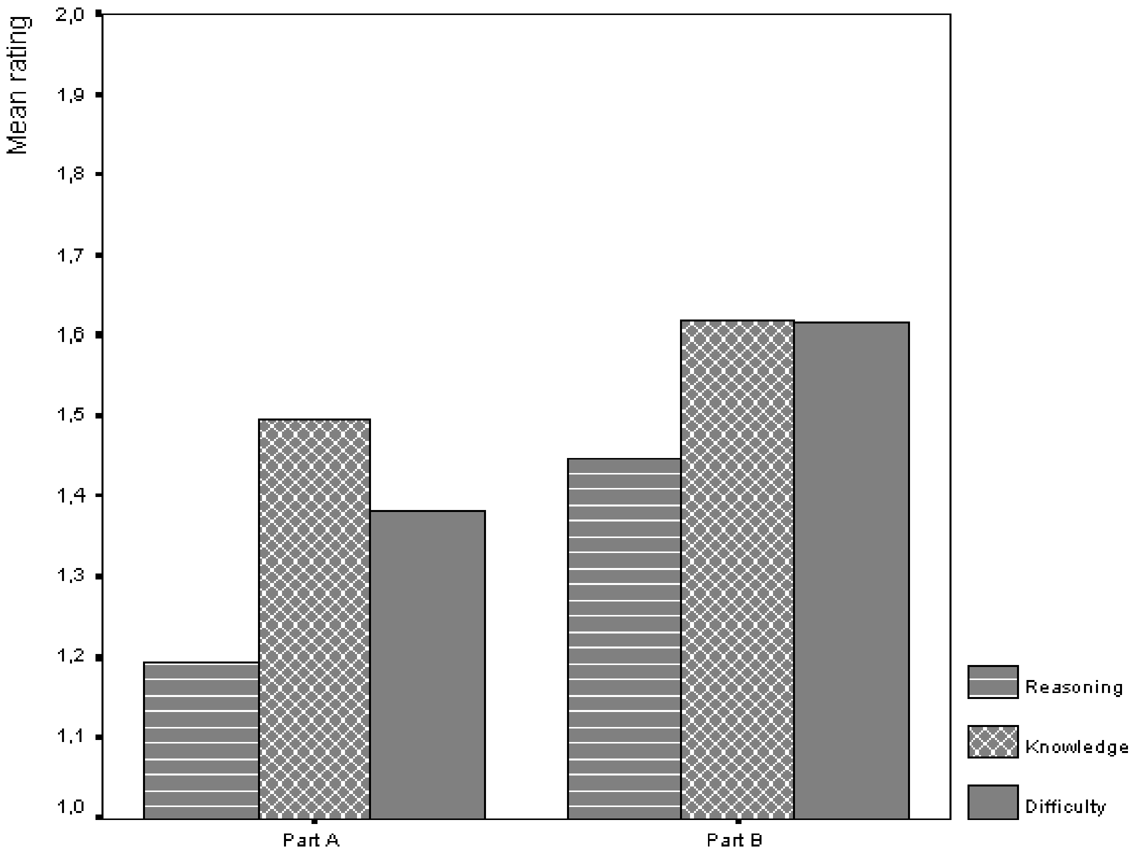


Fig. 10 Jury assessments of part A and B tests in reasoning, knowledge, and difficulty

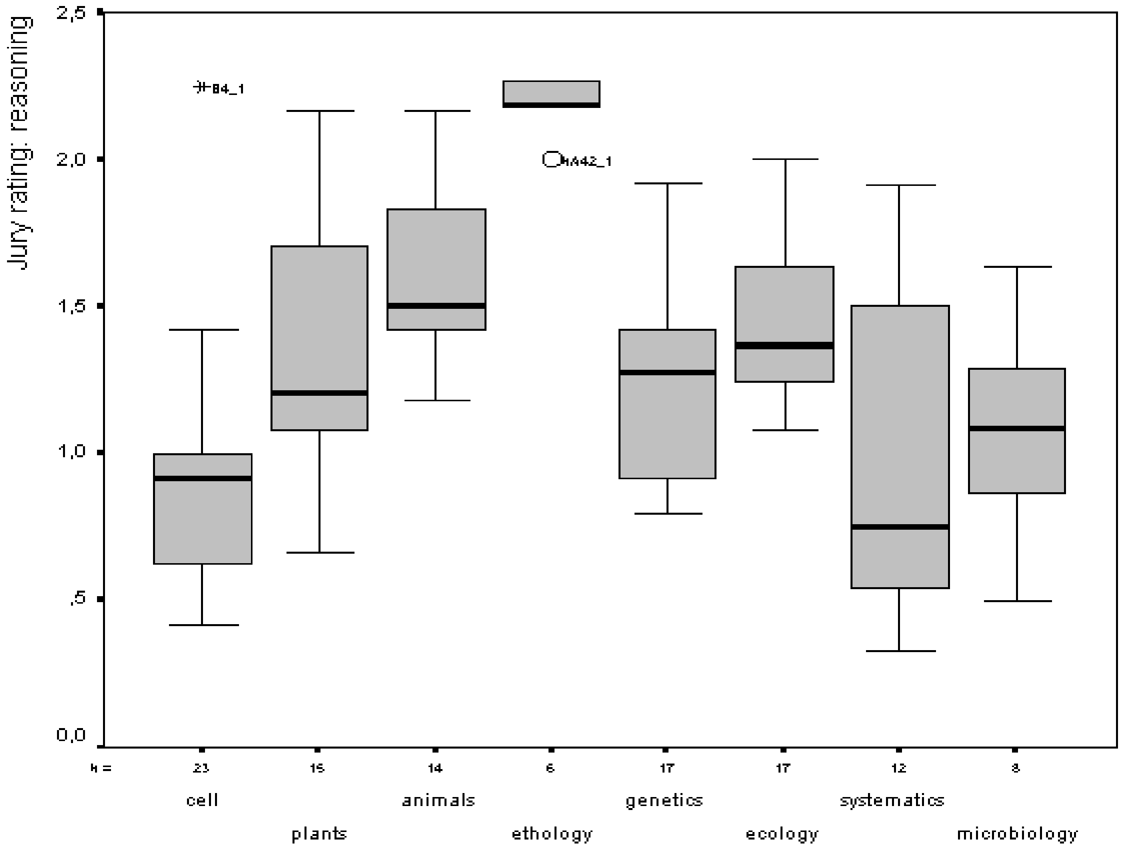


Fig. 11 Jury assessments of reasoning skills refering to biological disciplines

The differences among the eight sub-disciplines are illustrated by the example for the required reasoning dimension (figure 11). This boxplot shows the median of the predicted level of reasoning required within each sub-discipline (bold horizontal line), as well as the range within which 50% of the tasks lie (grey-shaded boxes). Ethology is revealed as the sub-discipline with clearly the highest level of required reasoning, followed by anatomy and physiology of animals, ecology and genetics. Systematics and cell biology are rated as areas requiring less reasoning. In contrast, with respect to required knowledge, ethology, animal anatomy/physiology and ecology achieve lower or mid-level ratings overall, whereas cell biology, plant anatomy/physiology and genetics were rated as areas requiring a high level of knowledge (figure 12). However, it should be pointed out that the ratings vary considerably within the sub-disciplines, a further indication that required levels of knowledge are more difficult to rate than required levels of reasoning.

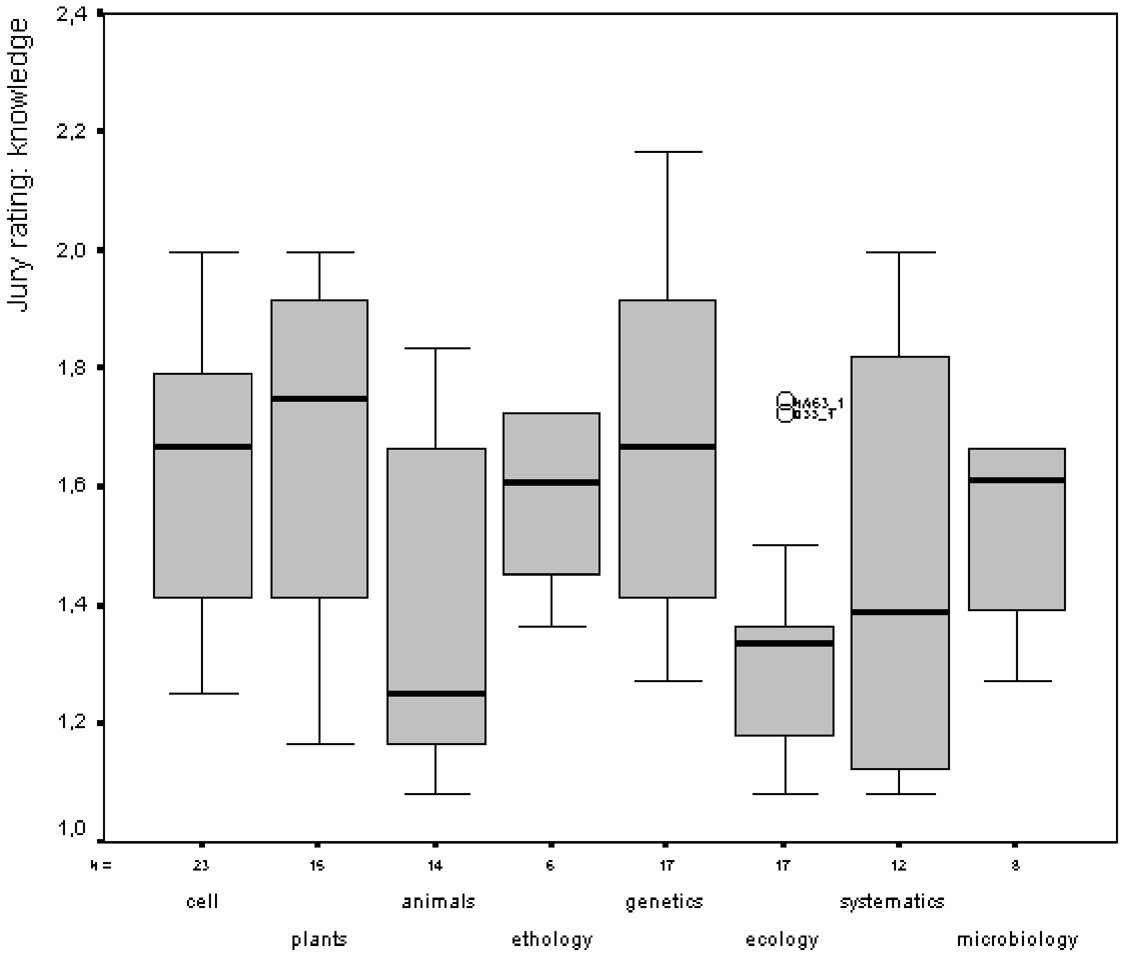


Fig. 12 Jury assessments of knowledge skills refering to biological disciplines

The ratings given by the jury members essentially confirm the statements we derived from the characteristic values of the tasks (cf. 2 above) and the factor structure (cf. 3 above). They show that the level of difficulty of a theoretical IBO task is determined by the challenges it presents to powers of reasoning and knowledge. Part B, with more varied task formats, represents an overall higher level of challenge, particularly with respect to logical thinking processes. There are also significant differences (over both parts) among the various sub-disciplines. Manifestly there are areas of biology which the Kiel Olympiad tested more through tasks of reasoning, whereas others were dominated more by requirements of knowledge.

3.5 Levels of competence in the International Biology Olympiad

Item and test analysis (3.2 above), multivariate structure analysis (3.3 above) and expert assessments (3.4 above) enable the overall measurement range of the IBO test and its components to be specified. From various perspectives we were able to describe how successful candidates differ from less successful candidates in Part A, Part B, the laboratories, and overall.

However, these analyzes characterize only the *dimensions* of ability; the level of ability achieved by the participants is not specified. In the context of a science Olympiad, a comparison of various levels of ability, with "criterion-oriented" descriptions (i.e. referring to specific aspects of behaviour and achievement) is particularly useful, especially with respect to the characteristics which distinguish the winners of gold, silver or bronze medals from the rest.

A "criterion-oriented" description of four levels of ability, corresponding to the three medal ranks and the rest, was therefore developed on the basis of a methodology proposed by BEATON and ALLEN (1992). Drawing on the adaptation of this methodology for the TIMSS study (KLIEME and BAUMERT, in press; KLIEME, in press), we shall proceed as follows.

- The lowest level of competence, that of non medal-winning IBO candidates, is characterized by all tasks completed correctly by a high percentage of candidates in the relevant group (46 individuals at IBO 1998). A high percentage is interpreted here as a solution frequency of more than 65%.
- The second level of competence, "bronze", is characterized by those IBO tasks which were highly likely to have been solved by bronze medal winners (i.e. more than 65%) but significantly less likely to have been solved by the candidates who did not win any medals (less than 50% solution frequency). All theoretical and practical tasks which fulfil these conditions together comprise the "characteristic task set" for this second level of competence.
- The third level of competence, "silver", is characterized by those tasks solved by more than 65% of silver medal winners but below 50% of bronze medal winners.

- Finally, the set of characteristic tasks for the "gold" level of competence is characterized by those tasks solved by more than 65% of gold medal winners but below 50% of silver medal winners.

In this procedure we adapt BEATON and ALLEN's (1992) idea, where tasks are characteristic for a particular level of competence when they can be solved only by the group representing that level and not the level below. Our adaptation was necessary in view of the small sample of 131 participants, which did not allow probabilistic test models to be applied and thus required classical test theory.

This procedure leads to the following characterizations of levels of competence.

1. *What can non medal winning IBO participants achieve?*

   At this lowest level of competence, typically, only multiple-choice tasks requiring the names and properties of particular species or substances can be solved, not B-type tasks. Participants who did not win medals were able to identify a family of plants whose roots contain particular symbiotic bacteria (A72), the characteristics of the cell walls of flowering plants (A14) or lipids with particular properties (A17). They also knew the reference of the endosymbiotic hypothesis (A9) and the term used for orientation with respect to the direction of light (A26).

   A small number of practical tasks can also be solved at this first level of competence. These comprise stepwise planning of a laboratory experiment (3.1-1) and tasks which require simple observation and identification: components of an anatomical structure in a microscopic preparation (1.1-1), the name of a plant species (1.2-2), colour changes in the course of an experiment (2.1 - 4, 5 and 6), and finger movements in the gripping experiment (4.1).

   Thus the first level of competence of IBO candidates may be characterized as *knowledge of biological facts* and *ability to conduct simple experimental observations*.

2. *What can bronze medal winners achieve?*

   This second level of competence encompasses the first with additional *reasoning skills* with relation to biological processes. This includes, for example, Task A23, shown in Figure 4, in which the development of readings under various experimental conditions must be recognized. In B38, a graph illustrating enzymatic reactions had to be interpreted to establish which enzymes were absent in a particular bacterium. Further questions referred to the preconditions for a rise in the number of mitochondria in cells (A3), the conditions for antibody production in lymphocytes (A12), the consequences of different levels of sensory organ efficiency for the survival of animal species (A30), the break-down of alcohol in human blood (A41) or the development of R-strategies (A64). The tasks for this level of competence also comprise a few requiring factual knowledge, including the phases of mitosis (A11), the properties of sex chromosomes (A45) and the characteristics of certain animal species (A74 and A75).

In the practical test, the bronze medal winners were also able to identify more complex processes (2.2-1) and classify observations in terms of ecosystems (1.1-3).

3. *What can silver medal winners achieve?*

   Silver medal winners are able to *apply complex knowledge, particularly in the fields of genetics, cell biology and physiology*. In Part B, this was reflected in the ability to fill in diagrams representing changes in the membrane potential of a cell (B1) or the electron flow in photochemical reactions (B9). Characteristic for this level are multiple choice tasks dealing with the effects of plasmolysis on cell structure (A21), the osmoregulation of fish in varying milieus (A38), genetic structures (A44) and heredity (A46, A52).

   In the *laboratories*, silver medal winners are typified by the ability to solve tasks involving *calculation*s (2.1-2 and 2.2-3.2).

4. *What can gold medal winners achieve?*

   The "gold" level of competence is mainly characterized by Part B tasks (B4, B22, B32) and one multi-layered Part A task (A42). B32 requires the correct labelling of a food network comprising nine components. The others all involve the analysis of tables or diagrams giving readings from experiments or systematic observations; calculations must be made and theoretical conclusions drawn. In the laboratories, the gold medallists were mostly able to solve complex experimental tasks, e.g. a flawless production of DNA extraction (3.1-3) and conduct a mental experiment on the respiratory chain (3.1-8).

Thus, IBO winners are typically those with the ability to *analyze empirical data and make interpretations with reference to theories.*

Reviewing the four levels of competence overall, the following distinctions can be made. Even participants deemed to have relatively low levels of competence have a knowledge of biological facts. Medallists are also able to draw conclusions, apply complex knowledge and argue with reference to theory. In the laboratories, participants without medals can make simple observations, whereas medal winners draw conclusions, make calculations and - at the highest level - solve sophisticated practical tasks (DNA extraction) and theoretical problems (mental experiment, interpretation of experiments).

3.6 The problem of language

3.6.1 The proposition

Neither the procedure for test development described in detail in the introduction and in section 1 above (with ad-hoc translations during the jury discussions), nor the administration of the test can be said to fulfil professional criteria for multicultural diagnostic testing, such as those set out, for example, by VIJVER and HAMBLETON (1996). The 131 competitors at the Kiel Olympiad worked with more than two dozen language varieties, a situation which precludes any aposteriori comparative survey, such as differential item analysis. We assume that difficulties arising from language problems led to errors in the test, but this hypothesis cannot be empirically tested.

However, by means of an additional, separate test, an empirical test of the following hypothesis was possible: If, instead of ad-hoc translations into the competitors' first languages, only a standard English and a standard Russian version were used, there would be no significant differences in results, i.e. in the final ranking. On the one hand, the competitors would face greater language difficulties; on the other, ad-hoc translation would no longer be a source of error, and the whole process of test administration would be simplified considerably.

3.6.2 Method

Immediately following the Olympiad, while the jury was making its final assessment, we conducted an additional investigation in which 67 volunteers, rather more than half the IBO candidates, took part. They were given a test paper similar to the IBO theoretical test, comprising 22 tasks drawn from the bank of unused supplementary tasks. The time allowed corresponded to the same time per task as that of the original test, and here too there was a combination of multiple-choice and other response formats. This test, however, was given only in English or Russian (Standard Language Version), with no further translations.

As the Standard Language Version was considerably shorter than the original test, and also could be presumed to have been less stringently processed, a lower level of reliability was to be expected. Internal consistency was thus ,=.59. The participants themselves also presented a different mix and could be seen as a positively selected group, as some delegations with particularly poor ratings did not take part in this additional test. (A t-test to compare original IBO results of participants and non-participants in the additional study yielded t = -4.366, df = 129, , = < .001). Of 12 IBO competitors with English as a first language, 11 did not take part in the additional study.

3.6.3 Findings and conclusions

The correlation between the original IBO results and the results of the Standard Language Version was .65. Even taking the limited reliability into consideration, the level is still .92. As Figure 13 shows, significant deviations occurred not only in the case of competitors who had used a first-language translation in the original and English here (crosses), but also in the case of those who had used only a Russian version (circles) or an English version (although English was not their first language; triangles).

An explanation of the differences between standard language and first language cannot be derived from competitor self-evaluation with respect to test language. This was clearly illustrated by two cases with particularly high deviations. A Korean who, in the original test, lay a standard deviation above the mean achieved a far better result in the English version, although he had indicated on the questionnaire that he had had difficulties managing with English, whilst a Belarussian who had rated himself as having a good command of Russian fell from two to one standard deviation above the mean.

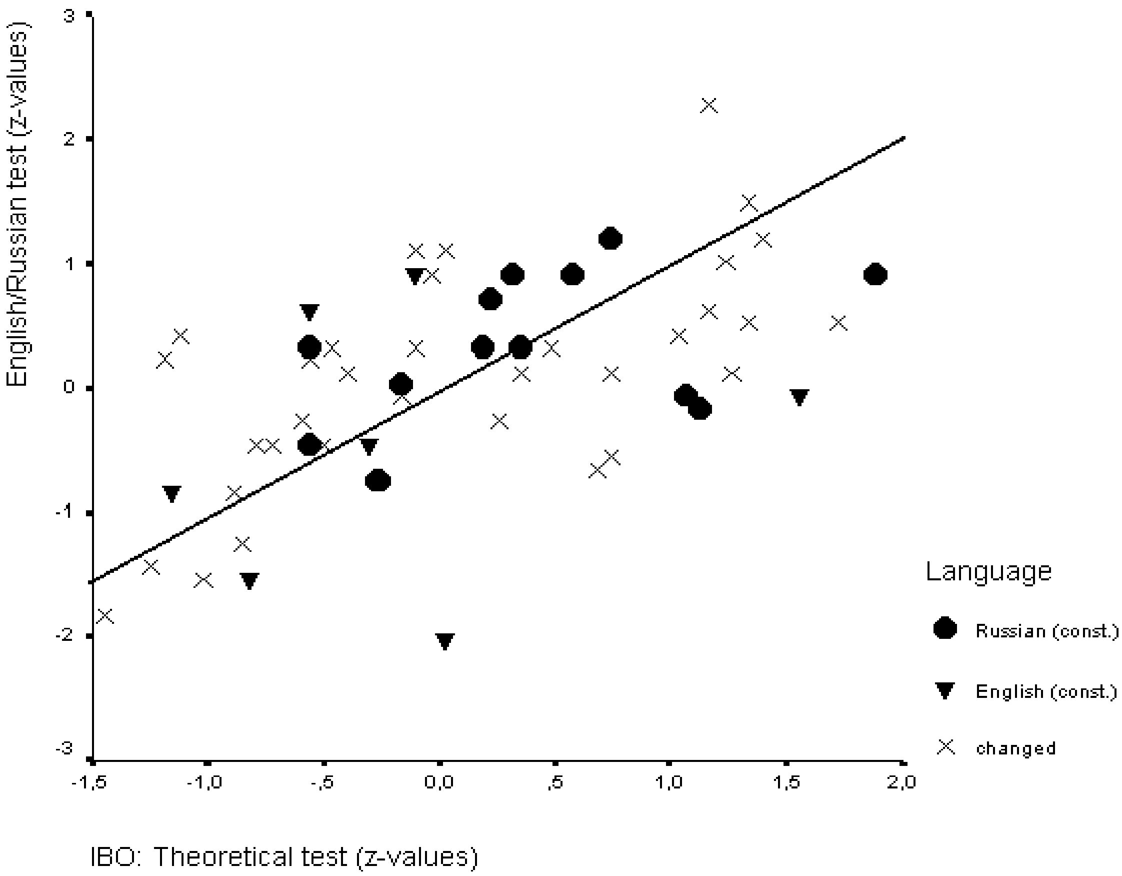


Fig. 13 Relationship between the original IBO results and the results of Standard Language (English/Russian); a symbol shows one observed case.

There was a clear tendency for the more successful of the IBO competitors to lose points on the standard language version. As Figure 17 clearly shows, the intra-individual z-values difference and the theory score in the original correlated at -.415 ($p < .001$). Even allowing for differences in motivation level between the two tests, it cannot be discounted that use of a standard language version in Russian and English only would disadvantage those candidates who scored particularly well under current procedure. Even if there were no errors of measurement to account for, the corrected correlation of .92 would mean that approximately one in four of the gold medallists would change as a result of using a standard language version.

Thus it would *not* appear to be in the interest of stability and reliability to change the IBO rules to stipulate a standard language version of the test, although fresh trials within the framework of the present IBO test approach are to be recommended.

3.7 IBO participants and scientific expertise

3.7.1 Propositions and method

The additional study was also used to obtain data relating achievement in the IBO test to other characteristics. The 67 participants completed a questionnaire eliciting information on, for example, their interests and attitudes towards biology, a test measuring their level of inductive/ deductive reasoning (intelligence test) and a task testing their depth of understanding of scientific concepts.

The study had two aims: on the one hand to investigate the content of the IBO tests and its components by means of external criteria (construct validity) and on the other to assess the IBO in terms of research into giftedness. Thus the objective was to enquire whether IBO participants, and the medal winners in particular, may be regarded as exceptionally gifted.

There is no homogeneous definition and diagnosis of "giftedness", but three main approaches can be roughly discerned (cf. HELLER 1993):

- *giftedness* – general intellectual competence, evidenced by extremely high scores in intelligence tests,
- *talent* – outstanding ability in specific fields, evidenced by excellence of performance in these fields,
- *expertise* – in-depth theoretical understanding of a discipline. Experts in a scientific discipline are not guided by the superficial when classifying and processing problems, but by laws, fundamental conceptions such as the principle of the conservation of energy, and metatheoretical rules.

The basic idea of an Olympiad, the awarding of medals for outstanding achievement in the processing of challenging tasks in a scientific subject, is clearly oriented to the concept of *talent*. The IBO test can thus be considered an indicator of subject-specific, in this case "biological" talent. An interesting and as yet unanswered question is the extent to which successful Olympiad competitors also require a) a general disposition towards high cognitive achievement (in simplified terms: high intelligence) and/or b) subject-specific expertise in the sense of a deep theoretical understanding of the discipline.

With reference to recent pedagogical research (cf. SCHNEIDER 1993), we posited a "threshold" theory of development, whereby talent is an intermediate stage on the way to expertise. Success at IBO would therefore require a minimum (a threshold) of general intellectual ability. A certain degree of talent, characterized by a "threshold score" in the IBO test, would then be the minimum requirement for expertise. If these assumptions were to be proved correct, the IBO competitors could best be described as "beginning experts" in biology.

The characteristics were operationalized as follows:

1 Concept mapping task to test scientific expertise

The participants were asked to take a while to reflect on the relationship between biology and physics, after which the instructions ran:

- Name concepts from biology which are particularly important in connection with the relationship to physics.
- Name concepts from physics, which are particularly important in connection with the relationship to biology.
- Draw a diagram (a concept map) to illustrate the major concepts and their relationships.

The participants had been shown beforehand, by means of an everyday example, how a concept map is comprised of concept nodes with labelled edges. Sixty participants worked on this task, at least in part. Their responses were rated on three dimensions.

Dimension 1:Type of concepts used

0. Everyday terms, elementary scientific concepts (such as "energy") or mere naming of sub-disciplines or topics (e.g. molecular biology, thermodynamics)
1. abstract theoretical concepts (e.g. homeostasis, first and second laws of thermodynamics)

Dimension 2:Type of relationships demonstrated between biology and physics

0. Naming of everyday phenomena, investigation instruments (e.g. microscope) or processes (e.g. osmosis, photosynthesis) relevant in both disciplines.
1. metascientific relationships (e.g. significance of the disciplines to each other).

Dimension 3:Structure of diagram

0. Naming of keywords
1. Networked representation

Thus a point was given for each dimension if it could be recognized from the representation that the participant was thinking in theoretical principles and relationships, and not simply in isolated concepts from biology and physics, or in everyday concepts. The sum of the points (one to three) is used below as a measurement of expertise.

2 Reasoning

A non-verbal test of reasoning was chosen from a standardized German bank of intelligence tests, requiring analogies to be made between schematic figures. The participants completed the exercises intended for the uppermost phase of the German secondary system, i.e. pre-university level. With a mean score of 18.2 points, the 55 participants in this test reached a level above the national average for German students.

3 Professional biology-related self-concept

A short questionnaire with 15 items was administered, eliciting data on various aspects of subject-related motivation and self-image. The intended short scales could not, however, be empirically distinguished one from another. We therefore drew up a single five-item scale, "professional biology-related self-concept".

- I am certain that I shall become a biologist.
- Biology has been my favourite school subject for a long time
- Nothing interests me as much as biology.
- It is important for me to know and to explore the practical and technological applications of biology.
- I enjoy thinking up experiments and conducting them precisely in the laboratory.

This scale is adequately reliable, with an internal consistency of , = .73.

3.7.2 Findings

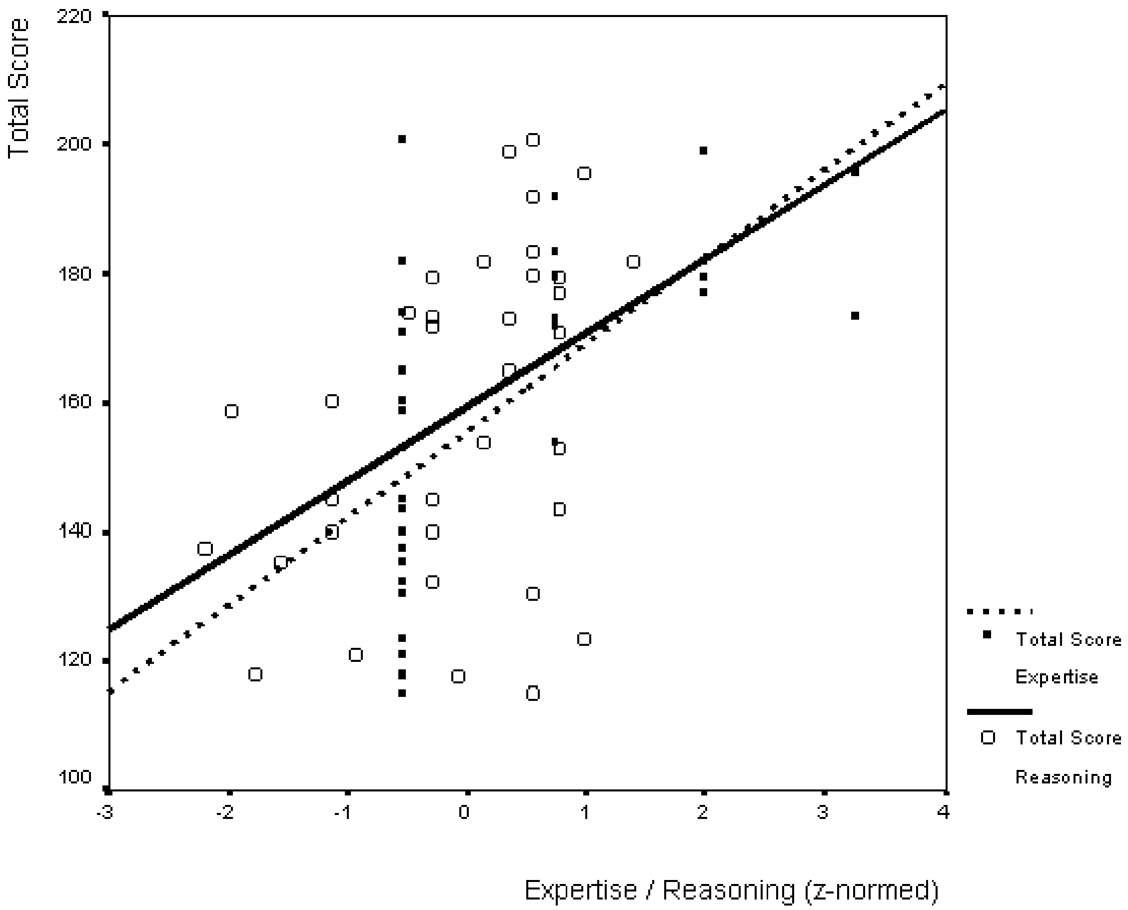


Fig. 14 Linear Relationships between skills of expertise resp. reasoning (abscissa) and the total results of the IBO-tests (ordinata)

Figure 14 provides a linear representation of the links we ascertained between the IBO results on the one hand and the test of reasoning (intelligence test) and the measurement of expertise on the other. General intelligence correlated highly significantly with the IBO results (r=.46; p<.001; n=55). The three individual indicators of expertise obtained from the concept mapping task also correlated significantly with the Olympiad results. (Type of concepts used: .31; p<.05; Type of relationships demonstrated between biology and physics: .28; p<.05; Structure of diagram: .38; p<.01). The total as an overall indicator of theoretical expertise correlated with the IBO results at .42 (p=.001; n=55).

These correlation data show that IBO results largely depend on reasoning ability and are closely allied with level of expertise. On closer inspection (cf. Figures 15 and 16) it is revealed that the link between IBO results and level of intelligence/expertise, as presumed above, is determined by thresholds, which can be characterized by reference to the distribution of medals.

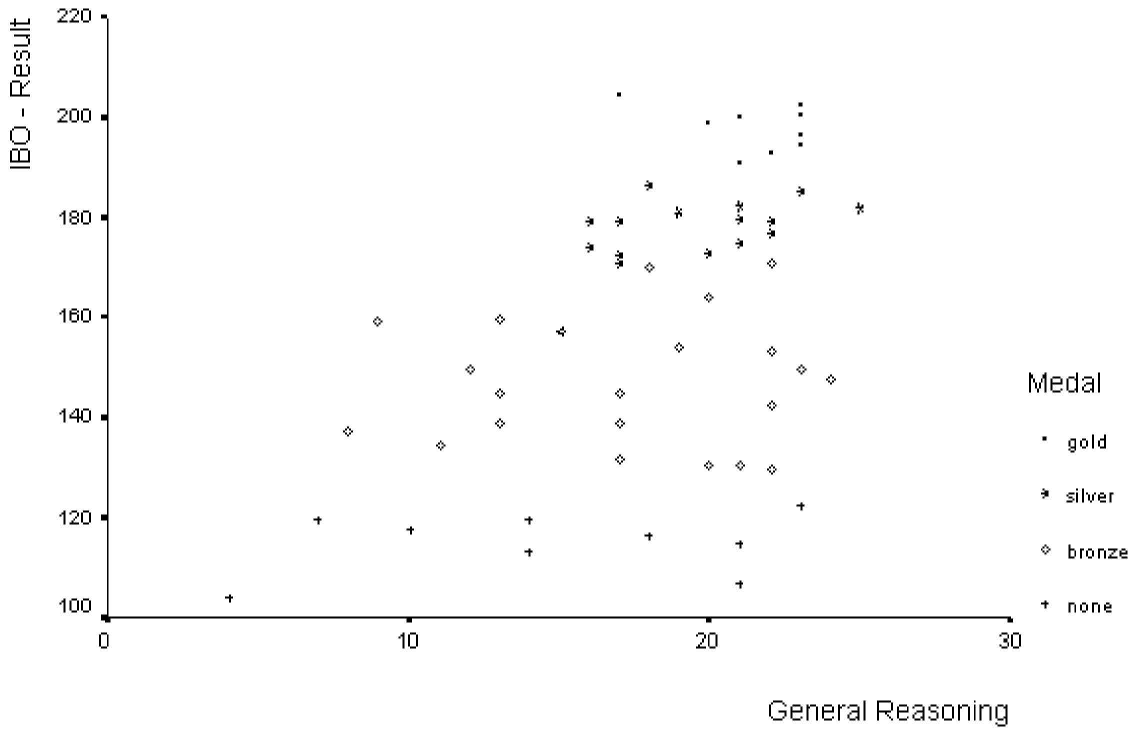


Fig. 15 Relationship between IBO-results and the results of the test regarding to reasoning; each point is one observed case.

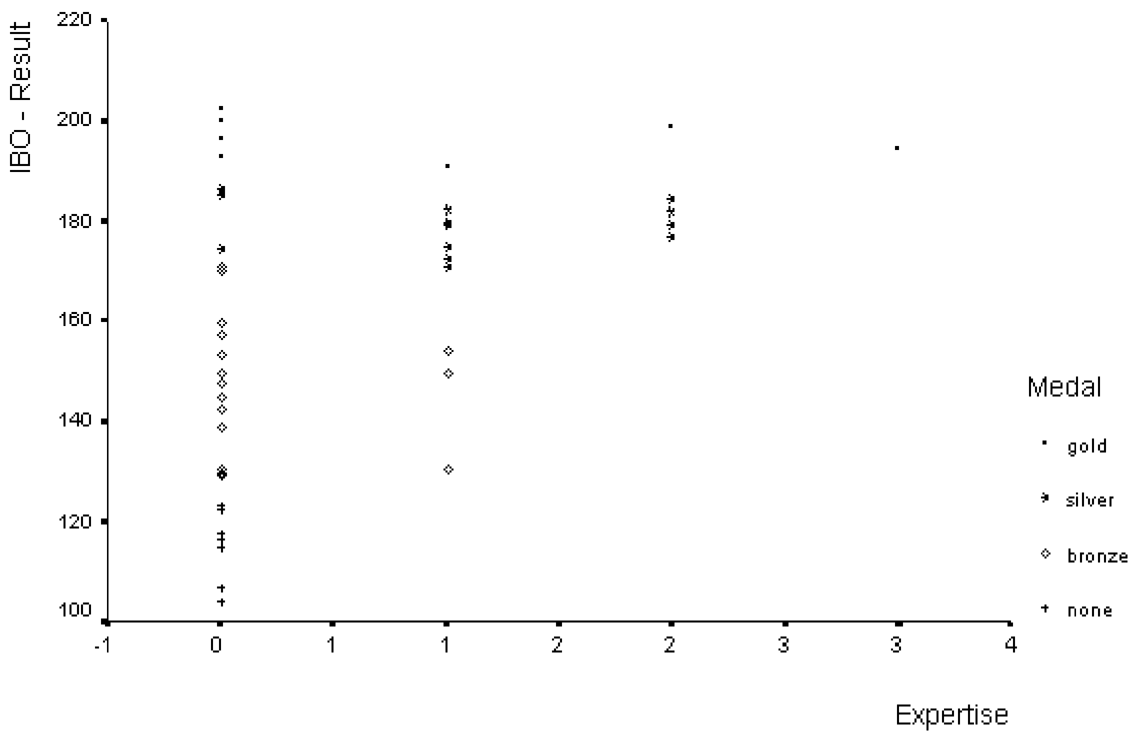


Fig. 15 Relationship between IBO-results and the results of the test regarding to expertise; each point is one observed case.

1 A minimum level of intellectual ability is required in order to win a gold or silver medal (characterized in our test by 16).

2 Biological expertise, i.e. in-depth understanding of scientific principles, is only demonstrated by medallists. Participants who fulfilled the criterion for expertise on one of the three dimensions won at least a bronze medal; those who fulfilled two gained silver. The one person with three points on the expertise scale was a gold medallist.

Thus the IBO medallists may be described as "beginning experts". It is important to note that the thresholds in both cases represent necessary, but not adequate, preconditions. There were a large number of participants with a high level of intellectual ability who were not able to demonstrate any particular subject-specific talent, and not all gold and silver medallists could be described as experts in biology. Success at an Olympiad depends on more than intelligence, and expertise is more than the ability to solve IBO tasks. This "more" presumably consists of deeper exploration of scientific issues in biology, coupled with particular interest and motivation.

The motivational factors which possibly contribute to the development of talent and expertise could not be identified in our study. The scale for "professional biology-related self-concept" described above did not correlate significantly with overall achievement in the IBO test; in fact, there was a tendency towards a negative correlation (r=-.212; p=.12). Evidently, successful Olympiad competitors do not restrict their interests to biology alone.

Finally, the links between parts of the IBO test, intelligence and expertise can be used to analyze the requirements of the test components. Table 10 sets out the correlation levels of each of the parts with reasoning ability and expertise.

Test component	Correlation with	
	reasoning ability (intelligence test) (n=55)	level of expertise (n=55)
IBO test overall	.46***	.42**
Practical	.42**	.30*
Theory	.41**	.48***
Theory Section A	.30*	.43**
Theory Section B	.45**	.41**

*Tab. 10: Relationship between IBO test results, reasoning ability and level of expertise (level of significance: * <.05, **<.01, ***<.001)*

As Table 10 shows, the practical test and the two parts of the theoretical test vary in their challenge profile.

- Success in the practical test depends not least on reasoning ability; fundamental knowledge of theory appears less significant.
- Conversely, the multiple-choice tasks in Part A of the theoretical test depend less on reasoning ability than knowledge of theory.
- Results in Part B of the theoretical test correlate highly significantly both with the results of the intelligence test and with the level of expertise. These findings support our claim that Part B contains particularly complex tasks.

Eckhard R. Lucius

4 Programme

Preparation

The organization of the 9th IBO 1998 in Kiel began three years in advance. During this time most of the questions "where – who – how many – how long" were solved. In the last year of preparation, responsibility for the different tasks required by the programme was distributed among several members of the organization committee. Renate Glawe was the secretary of the IBO. Dr. Ute Harms was responsible for the excursions. Dr. Angela Kross organized transport and accommodation. Dr. Helmut Prechtl was in charge of all (test and discussion) rooms and copying facilities. Susanne Jendrsczok helped us by advertising sponsors. Peter Nentwig maintained the contacts to newspapers and television and did the "IBO sentimental", the daily IBO newsletter. Robert Fischer, a former Olympiad medallist, was the chief of the student guides. Christiane Mühle and Ralf Kittler, also well known from as former Olympiad medallists, helped with the jury sessions and translating.

Arrivals

Pict. 1 Arriving of delegates from Belgium and Turkey in Kiel

The delegations of the participating and observing nations arrived at the airports in Hamburg and Kiel, or at the railway station in Kiel. The students were transferred by bus and car to the youth hostel in Westensee, the co-ordinators and members of the jury were taken to the Prisma Hotel in Neumünster. Those delegates who arrived in advance – more than expected – spent the additional one or two days at the youth hostel in Gaarden, on Kiel's East Bank.

Monday, July 20, 1998

Pict. 2 Entry of the German team

Pict. 3 The Open Air Museum in Molfsee

The opening ceremony took place in *Kieler Schloss*, the city's concert and festival hall, on July 20. The competing delegations entered the hall nation by nation, each behind their national flag carried by a student guide.

After the greetings and a speech by Nobel prize winner Professor Neher (see 1.7), the performance of an a cappella ensemble and an excellent meal at the *Schloss*, the students visited the open air museum at Molfsee, with its fascinating collection of original houses and buildings spanning several centuries, removed from locations around northern Germany and rebuilt on the museum site.

During this time the members of the jury held their first discussions of the practical tasks at their hotel. The excursion to Molfsee was repeated for the co-ordinators on Tuesday morning.

Tuesday, July 21, 1998

On Tuesday the competitors performed the practical tasks. Afterwards the co-ordinators could meet their students at *Kieler Klosterbrauerei*, a restaurant attached to a small local brewery, to enjoy a traditional dish of sauerkraut with cured pork, while a team of professors and representatives of the German federal states met at IPN to correct the tests.

In the evening the co-ordinators' meeting took place. Among others the three observing countries Iran, Mexico and Taiwan were accepted as participating countries for future Olympiads.

Pict. 4 The jury: Endless discussions

Pict. 5 The students: Working on practical tasks

Pict. 6 Lunch at Klosterbrauerei

Pict. 7 Dancing in Westensee

Wednesday, July 22, 1998

Pict. 8 Students in the Port of Hamburg

The day before the theoretical competition involves a great deal of work for the co-ordinators. The discussion started after breakfast and lasted until well after midnight (2 a.m. Thursday), a good opportunity for the students to devote a whole day to Hamburg. They visited the docks and Hagenbeck Zoo, with lunch at Rickmer Rickmers, an old sailing ship in St. Pauli.

Thursday, July 23 1998

Pict. 9 Lübeck, in the rain

The theoretical test was administered at the University of Kiel, while the jury was busy with the evaluation of the practical tasks. Afterwards, competitors, co-ordinators and jury met in the Lübeck, UNESCO heritage city. After some sightseeing which included a visit to the famous Church of St. Mary with its fallen bells, and Lübeck's mediaeval civic hall, the participants had dinner at Lübeck's authentic Ratskeller, returning to their respective accommodation late in the evening. Some sleep was needed in preparation for Friday's excursion.

Friday, July 24, 1998

Pict. 10 Wattenmeer National Park

Early in the morning both the co-ordinators and the competitors were transferred to the west coast of Schleswig-Holstein, to the tidal flats of the *Wattenmeer*. The weather proved typical for an ex-cursion like this: cold and rainy.

After returning to their hotel, the jury reconvened to evaluate the results of the theoretical tasks. Again the discussion went on until the early hours of the morning, with a break to visit the students at the youth hostel in Westensee for a barbecue dinner. When a local rock band started its performance after the meal, it was time for the older members of the delegations to return to the Prisma.

Pict. 11 Rhythm and Blues in Westensee

The jury was able to bring its work to a satisfactory conclusion without having to set aside Saturday morning for further talks. The decisions with respect to the theoretical tasks could be finalised, and the evaluation of the 9th IBO carried out with the help of statistics provided by Eckhard Klieme.

Last but not least, it was generally agreed that the competition had taken place under most agreeable conditions.

Saturday, July 25, 1998

Pict. 12 The medal ceremony

Pict. 13 Andreas Ehn, co-ordinator of Sweden with the IBO trophy

Having been so prompt with the evaluation of the 9th IBO, the co-ordinators had an unexpected morning to themselves on Saturday.

At 2 p.m. the Closing Ceremony began at the *Kieler Schloss.* The medals were awarded by the Minister of Education of Schleswig-Holstein, Gisela Böhrk. The IBO trophy was passed on from Germany to Sweden, represented by Swedish coordinator Dr. Andreas Ehn.

After the ceremony, the participants took to the water and boarded the Langeland ferry. The round trip to Denmark and back was a symbolic first step towards Scandinavia, with Sweden as host of the 10th IBO 1999 in Uppsala. Dinner on board was followed by music and dancing, a most convivial end to the occasion.

Sunday, July 26, 1998

Most of the delegates left by plane, train or even by car: The Australian team rented a van with the help of Renate Glawe and drove south to Frankfurt/Main airport to evaluate the facilities of the German autobahn.

Some delegations stayed one or two days longer, mostly with supervisors joining their students at the youth hostel in Westensee.

Horst Binding, Christian Gliesche, Ludger Kappen, Eckhard Klieme,
Ralf Kittler, Sievert Lorenzen, Eckhard R. Lucius, Erhard Lipkow,
Karl Meissner, Hansjörg Rudolph, Jürgen Soll, Helmut Uhlarz, Erwin Zabel

4 The Tasks of the 9th International Biology Olympiad

5.1 Theoretical Tests

5.2.1 Theoretical Test - Part A

01-10	1 B	2 C(2)	3 B	4 A(2)	5 B	6 A(2)	7 D	8 D	9 B	10 A
11-20	11 C	12 D	13 C(2)	14 A	15 A	16 D	17 A	18 B(2)	19 D(2)	20 C
21-30	21 D	22 B(2)	23 D	24 D	25 C	26 B	27 D	28 D	29 D	30 C
31-40	31 A	32 A	33 B	34 B(2)	35 D	36 A	37 C	38 A	39 C(2)	40 B
41-50	41 B(2)	42 D	43 C(2)	44 C	45 D	46 D	47 C(2)	48 C	49 E	50 B
51-60	51 B	52 D	53 C	54 B(2)	55 C(2)	56 D(2)	57 D	58 D	59 E	60 D
61-70	61 E	62 D	63 B	64 D(2)	65 B(2)	66 C	67 B	68 C	69 B	70 B
71-80	71 D(2)	72 C	73 C	74 A(2)	75 A	76 C	77 B	78 C	79 E(2)	80 C

Tab. 11: Answer codes of the following tasks, part A of the theoretical test

The following part A tasks were skipped: 2, 5, 11, 29, 33, 39, 43, 49, 48.

CELL BIOLOGY

A 1: (1 pt) **How do polypeptides find their way from the place of synthesis at cytoplasmic ribosomes to the place of their destination in the mitochondria?**

A: by specific transport along the cytoskeleton
B: by specific amino-terminal targeting signals
C: by specific carboxy-terminal targeting signals
D: it is not necessary because the synthesis takes place on the surface of the organelles
E: mitochondria synthesize all proteins inside the organelle

A 2: What is mRNA editing? (2 pts)

A: removal of a coding base triplet from the mRNA
B: alteration of the coding sequence during transcription
C: change of a single base in the mRNA
D: addition of a poly-adenylat-tail to the mRNA
E: reverse transcription from mRNA to DNA

A 3: (1 pt) **How does the number of mitochondria and plastids increase in a cell?**

A: only by de novo synthesis
B: only by division
C: by de novo synthesis and division
D: by inheritance
E: by fusion of membrane vesicles

A 4: (2 pts) **How is the distribution of light to the photosystem I (PS I) and the photosystem II (PS II) adjusted to different conditions of light?**

A: by changes in the size of antenna, in the orientation of the chloroplasts or in the thickness of leaves
B: by reversible removal of polypeptides of the reactive centre, and un packing of grana thylakoids
C: by separation of chlorophyll from PS I and PS II
D: by inhibiting the electron flow from PS I to PS II
E: by uncoupling the ATP synthesis

A 5: **Which process initiates the proteolytic degradation of proteins?**
(1 pt)

A: glycosylation C: prenylation

B: ubiquitination D: phosphorylation E: ADP ribosylation

A 6: **How do you experimentally differentiate between integral and**
(2 pts) **peripheral membrane proteins?**

A: Only peripheral proteins (but not integral) can be removed from the membrane by 1 M NaCl solution.

B: Only integral membrane proteins can be removed from the membrane by 0.1 M NaOH.

C: Only integral membrane proteins can be removed from the membrane by 1 M NaCl.

D: Only peripheral (but not integral) membrane proteins can be solubilized in detergent.

E: Only peripheral (but not integral) membrane proteins can be affected by proteases.

A 7: **How are the fibre types forming the cytoskeleton called?**
(1 pt)

A: tubuline, lignin, kinesin

B: microtubules, myosin, microfilaments

C: keratin, myosin, kinesin

D: microfilaments, intermediate filaments, microtubules

E: actin, myosin, intermediate filaments

A 8: **Animal and plant cells possess channels directly connecting**
(1 pt) **the cytoplasm of one cell to the cytoplasm of another cell. How are these structures called?**

A: plasmodesmata, desmosomes

B: plasmodesmata, Ca^{2+}-ATPase

C: porin, gap junction

D: gap junction, plasmodesmata

A 9: What is the endosymbiosis hypothesis related to?

(1 pt)
I. to bacteria living in the epithelium of gizzard
II. to plastids III. to mitochondrial IV. to ribosomes

A: I

B: only II and III D: only III and IV

C: only III E: II, III and IV

A 10: The semipermeability of which of the water-permeable membranes would be sufficient for the process of plasmolysis?

(1 pt)

I. plasmalemma
II. tonoplast
III. each biomembrane enclosing a compartment
IV. the middle lamella

A: only I C: I and II

B: only II D: only III E: III and IV

A 11: Which process are microtubules not involved in?

(1 pt)

A: cytomorphogenesis C: mitotic prophase

B: meiotic anaphase I D: transport of Golgi vesicles

E: cytoplasmic circulation

A 12: A B-lymphocyte (a cell type of the immune system) produces and secretes antibodies. Which structures of its protoplast should therefore be very well developed?

(1 pt)

A: only the smooth endoplasmic reticulum

B: only the smooth endoplasmic reticulum and the Golgi apparatus (dictyosomes)

C: only the rough endoplasmic reticulum and the lysosomes

D: only the rough endoplasmic reticulum and the Golgi apparatus

E: the rough endoplasmic reticulum, the Golgi apparatus and the lysosomes

A 13: Which of the following reactions can occur in the mitochondria?
(2 pts)

I.	NADP reduction	V.	Calvin
II.	synthesis of fatty acids	VI.	citric acid cycle
III.	endoxidation	VII.	oxidative catabolism of fatty acids
IV.	gene expression	VIII.	nitrit reduction

A: I, III, VI, VII

B: II, III, IV, VII

<u>C:</u> III, IV, VI, VII

D: IV, VI, VII, VIII

E: I, III, V, VIII

A 14: Which of the following are found in the cell wall of flowering plants?
(1 pt)

I.	apoplast	IV	intermicellar space	VII	lignin
II.	mircofilament	V	keratin	VIII	cutin
III.	microfibre	VI	chitin	IX	suberin

<u>A:</u> I,III,VII,IX,

B: II,V,VII,VIII,

C: III,IV,V,VIII

D: II,VI,IX

E: I,III,V,VI

A 15: What is a prion?
(1 pt)

<u>A:</u> a protein

B: infectious RNA without genes for a protein envelope

C: the DNA sequence which serves as a template for primer RNA

D: an early eukaryote free of mitochondria

E: a multienzyme complex for the biosynthesis of fatty acids

A 16: (1 pt) **Which statements concerning the growth factors cytokins and cytokinins are correct?**

I. The plant cytokinins are peptides.

II. The plant cytokins are peptides.

III. The plant cytokinins are purine derivatives.

IV. The plant cytokins are purine derivatives.

V. The animal cytokinins are peptides.

VI. The animal cytokins are peptides.

VII. The animal cytokinins are purine derivatives.

VIII. The animal cytokins are purine derivatives.

A: I and VII

B: II and VIII

C: II and V

<u>D:</u> III and VI

E: IV and VI

A 17: (1 pt) **Which classes of lipids have non-polar side chains and polar head groups?**

<u>A:</u> phospholipids

B: triglycerides

C: cholesterol

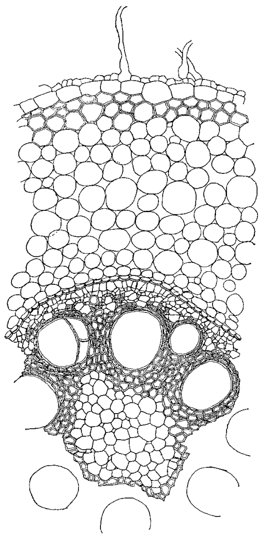
D: waxes

E: glycerol

ANATOMY AND PHYSIOLOGY OF PLANTS

A 18: (2 pts) **The figure below shows the cross-section of a plant or organ. Distinguish which of the given morphological, anatomical, systematical and ecological terms are in accordance with the cross-section. Select a combination of possibilities.**

I. stem axis
II. root
III. leaf stalk
IV. dicotyledon
V. monocotyledon
VI. swamp or water plant
VII. terrestrial plant



A: I, IV, VI
B: II, V, VII
C: II, V, VI
D: II, IV, VII
E: III, IV, VII

A 19: (2 pts) **In the following three plant species(I to III) are listed. Among 1 to 7 anatomical and physiological characteristics are mentioned as well.**

I. *Opuntia ficus-indica* (*Cactaceae*)	1. water storage tissue of cells with large vacuoles and chloroplasts
II. *Zea mays* (corn, *Poaceae*)	2. chloroplasts of bundle sheath cells with reduced grana.
III *Triticum aestivum* (wheat, *Poaceae*)	3. C_3-plant
	4. C_4-plant
	5. CAM-plant
	6. subepidermal sclerenchyma in the
	7. stomata predominantly open at night

Decide which of the following assignments are correct.

A: I: 1, 3, 6 II: 1, 5, 7 III: 2, 4, 6

B: I: 2, 4, 6 II: 3, 6 III: 1, 3, 6

C: I: 2, 4, 6 II: 2, 3, 6 III: 3, 6

D: I: 1, 5, 7 II: 2, 4, 6 III: 3, 6

E: I: 1, 5, 7 II: 3, 6 III: 2, 4, 6

A 20: A C_3-plant and a C_4-plant are kept together under an airtigthly
(1 pt) **sealed glass bell under light. How does the CO_2-concentration change under this glass bell?**

A: The CO_2-concentration does not change.

B: The CO_2-concentration decreases to the CO_2-compensation point of the C_3-plant.

C: The CO_2-concentration decreases to the CO_2-compensation point of the C_4-plant

D: The CO_2-concentration increases.

E: The CO_2-concentration drops below the value of the CO_2-compensation point of the C_4-plant.

A 21: The protoplast has detached from the cell wall after plasmoly-
(1 pt) **sis. What can mainly be found between the cell wall and the protoplast?**

A: air

B: vacuum

C: water

D: hypertonic solution

E: cell sap

A 22: What happens if you put a turgescent cell into its 'own cell sap'
(2 pts) (i.e. a solution with the same water potential as the osmotic potential of the cell)?

A: There is no change.

B: The cell loses water until its water potential is equal to the water potential of the surrounding solution.

C: Water is released until incipient plasmolysis occurs.

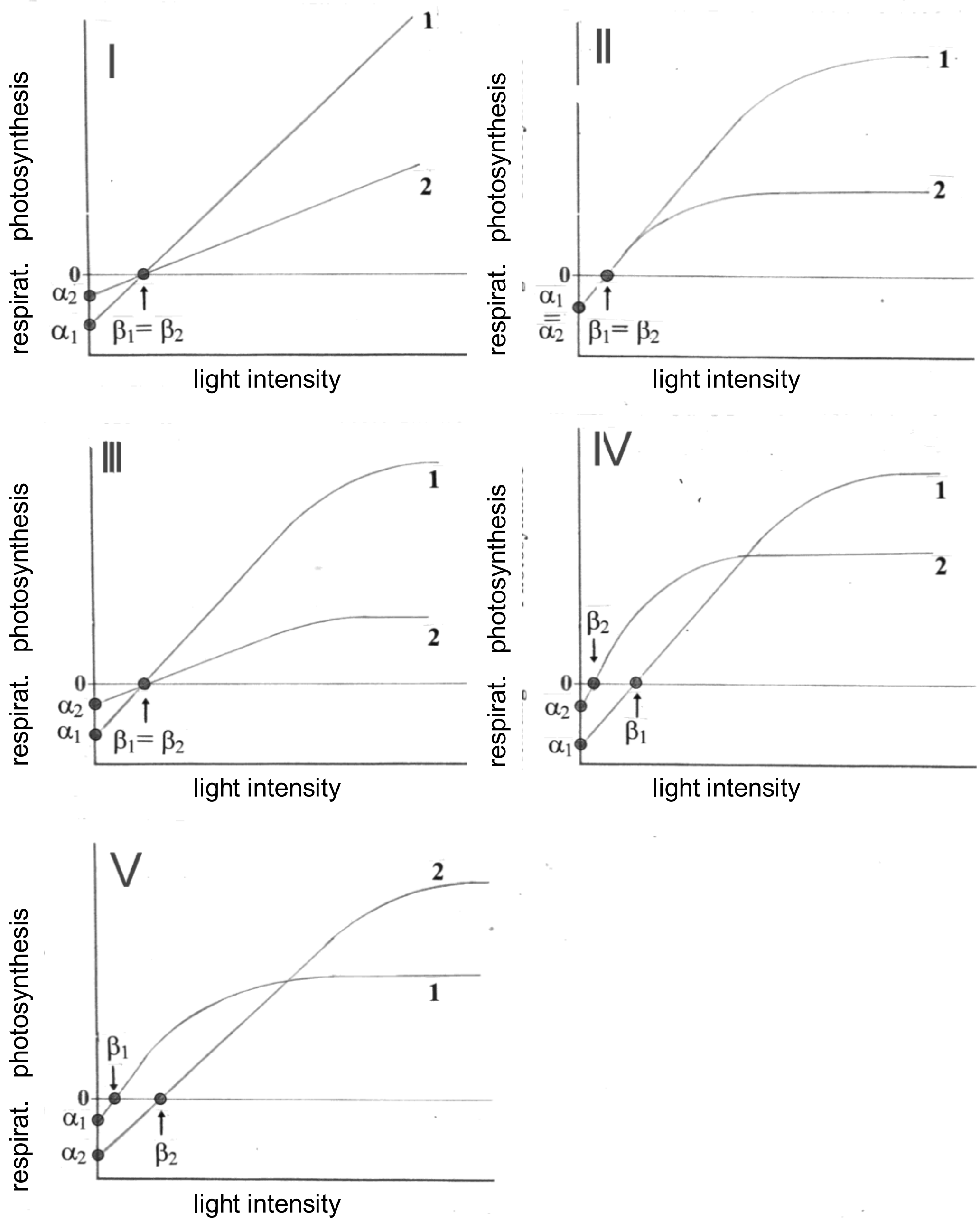
D: Plasmolysis occurs.

E: The cell bursts.

A 23: **By examining the dependence of photosynthesis on photon**
(1 pt) **supply you get so-called light curves (curves I to V).**

Legend: 1: typical sun plant; 2: typical shade-loving plant;

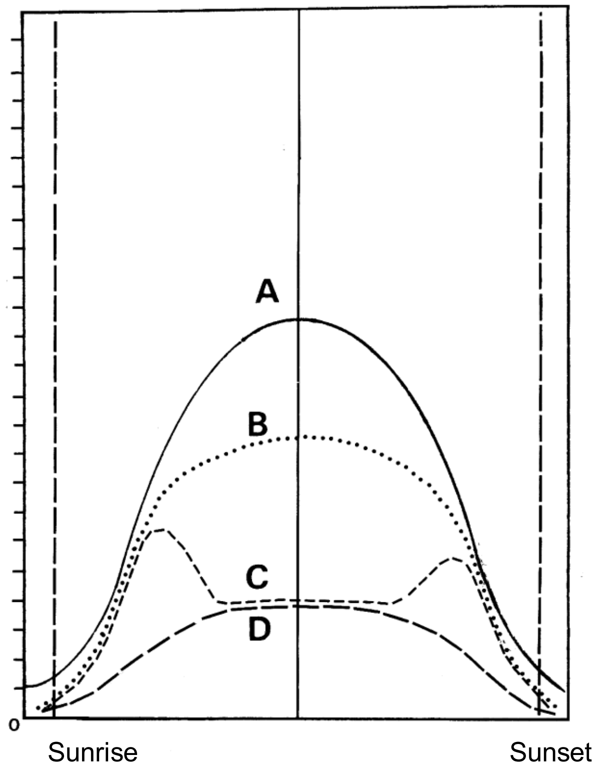
α: respiration in darkness; β: light compensation point



Which of the preceding curves including the inscription is correct?

A: I B: II C: III D: IV E: V

A 24: (1 pt) **The figure shows - besides evaporation the daily curves for the process of transpiration of a plant underlying deterioration of water supply. Which of the curves expresses the daily course of the transpiration in the cuticule?**



A: curve A

B: curve B

C: curve C

D: curve D

A 25: (1 pt) **If a respiratory quotient > 1 is measured in an experiment, that means:**

A: In the measured respiration process carbohydrates are used as substrates.

B: In the measured respiration process fats are used as substrates.

C: In the measured respiration process organic acids are used as substrates.

D: In the measured respiration process proteins are used as substrates.

A 26: (1 pt) **The following figure shows a germ which was grown in hydroponics in a glass vessel and which was exposed to light only from the right-hand side. The growth curvatures you can observe in the stem axis are called:**

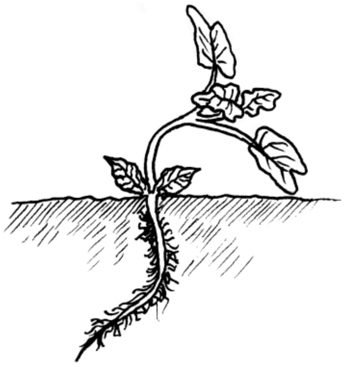
A: photonasty

B: phototropism

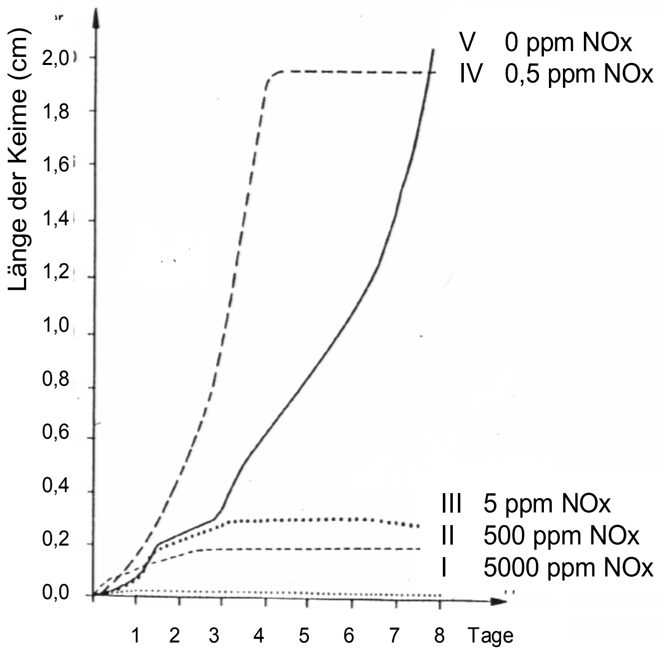
C: phototaxis

D: photomorphosis

E: photoperiodism



A 27: (1 pt) **Germs were grown in closed chambers (I-IV) with different nitrogen oxide NO_x-concentrations in the air. The following figure demonstrates the average length of the germs depending on time. The nitrogen oxide concentration (kept constant) is given in ppm together with the corresponding chamber number.**



A: The lower the NO_x-concentration the larger the germs can grow on average within 8 days.

B: In an atmosphere free of NO_x germs grow faster from day 5 to 8 than in the first four days.

C: For achieving an average germ length of 1.5 cm half of the time that would be needed without NO_x is sufficient in a concentration of 0.5 ppm NO_x.

D: At a concentration of 5000 ppm there is nearly no germ growth, but 1/10 of this concentration promotes growth during the fourth day.

E: After 4 days in chambers with air containing at least 0.5 ppm NO_x, no germ growth can be found any more.

A 28: Which function does the glyoxylate cycle have during
(1 pt) **germination?**

A: reduction of fatty acids

B: synthesis of ATP

C: decarboxylation of glyoxylate from photorespiration

D: linking the β-oxidation to gluconeogenesis

E: synthesis of glycine by transamination

A 29: Which three sensory systems regulate light-depending develop-
(1 pt) **ment and differentiation of angiosperms?**

I. phytochrome

II. cryptochrome

III. protochlorohyllid

IV. chlorophy

V. anthocyan

A: I, III and V

B: I, II and IV

C: II, III and V

D: I, II and III

E: II, IV and V

ANATOMY AND PHYSIOLOGY OF ANIMALS AND MEN

A 30: (1 pt) **The eyes of squids are highly efficient, those of snails are poorly efficient. Consider whether efficiency of organs may be coupled with the intensity of their metabolism. If squids were provided with poorly efficient eyes and snails with highly efficient eyes whereas the further body organisation remained unchanged in both cases, this would be:**

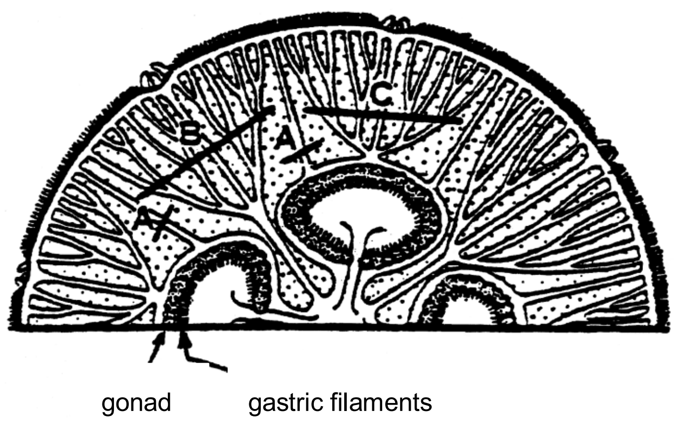
A: a disadvantage to squids and an advantage to snails

B: an advantage to squids and a disadvantage to snails

<u>C:</u> a disadvantage to both squids and snails

D: an advantage to both squids and snails

A 31: (1 pt) **A medusa metabolizes most energy at the rim of its umbrella. Energy is extracted from small particles which can be phagocy tizedon their whole way through the tubes of the gastrovascular system. How do the small particles have to be transported through the gastrovascular system of the moon jelly (see figure below) in order to provide the rim of its umbrella with a maximum amount of food?**



<u>A:</u> through tubes marked by A towards the rim of the umbrella

B: through tubes marked by B towards the rim of the umbrella

C: through tubes marked by C towards the rim of the umbrella

D: no preference of particular tubes

A 32: **In a smooth muscle, the length difference between its relaxed and**
(1 pt) **its maximally contracted state is**

A: larger than in a striated muscle

B: smaller than in a striated muscle

C: as large as in a striated muscle

D: null, because smooth muscles cannot contract themselves but, rather, prevent tissues from becoming stretched.

A 33: **Let striated skeletal muscles be replaced by smooth ones, and,**
(1 pt) **reversely smooth muscles of the intestinal wall by striated ones. The effect would be:**

A: Both locomotion and intestinal peristaltic would be improved.

B: Both locomotion and intestinal peristaltic would be impaired.

C: Both locomotion and intestinal peristaltic would be as before.

D: Locomotion would be impaired, but intestinal peristaltic would be improved.

E: Locomotion would be improved, but intestinal peristaltic would be impaired.

A 34: **Many species of *Rotatoria* (rotifers; up to 3 mm length) in**
(2 pts) **freshwater have a reproductive cycle called heterogony: Reproduction occurs temporarily only in females and temporarily in males and females. If this is an advantage to these species of *Rotatoria*, which of the following statements is correct?**

A: Several generations of females and males are followed by one with only females.

B: Several generations of only females are followed by one with females and males.

C: Every generation of only females is followed by one with females and males, and vice versa.

D: Several generations of only females are followed by several with females and males, and vice versa.

A 35: (1 pt) **Stamina training leads to many effects in man. Which of the following effects does not apply to stamina training?**

A: enlargement of the heart

B: increase of the number of capillaries in muscles

C: increase of the number of mitochondria within muscle cells

<u>D:</u> increased pulse rate during rest

E: increase of the lung volume

A 36: (1 pt) **Manual work increases the CO_2 concentration in the blood. What is the result of this?**

I. The affinity of hemoglobin to oxygen decreases.

II. Elimination of CO_2 through the lungs decreases.

III. Loss of mineral salts through the air breathed out increases.

IV: The brain suffers from oxygen deficiency.

V: The body warms up.

<u>A:</u> only I   B: only IV   C: I, V   D: II, III   E: II, IV

A 37: (1 pt) **What short-term effects may occur in the human cardiovascular system at a sudden transition from lying to standing?**

I. The pulse rate is increased.

II. The total peripheral resistance is increased.

III. More blood flows through the kidneys.

IV. More blood flows through the upper and lower limbs.

V. The blood pressure is decreased.

A: I, III, IV

B: III, IV, V

<u>C:</u> I, II, V

D: only II, III

E: only IV, V

A 38: (1 pt) **If a fish species from fresh water developed into a marine fish species, which problems of osmoregulation would have to be solved?**

I Excess of salts would have to be excreted.

II. Water would have to be reabsorbed from the initial ultrafiltrate of kidneys.

III. The salt concentration of the blood would have to be adjusted to that of the sea.

IV. Drinking of sea water would have to be avoided.

V. Permeability of the skin would have to be reduced.

A: only I, II C: all answers

B: only II, IV D: only V E: only II, IV

A 39: (2 pts) **In an everse eye (the opposite of inverse), the light-sensitive region of retinal cells is directed towards the incoming light. The figure below taken from a text book illustrates how an everse median eye of a spider could have developed by invagination. Why should this suggested eye structure be considered incorrect?**

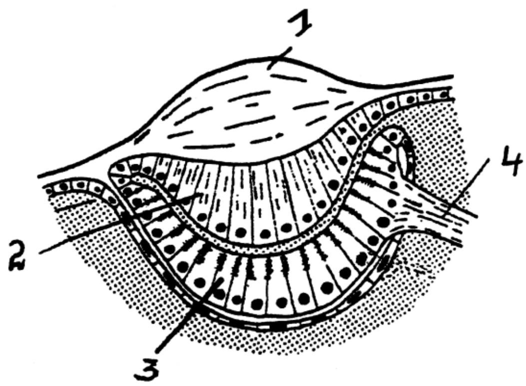
Legend:

1: lens

2: vitreous body

3: retinal cell, the sensory area is opposite to nucleus

4: optic nerve



A: In the development of eyes, invagination never plays a role.

B: The figure really shows an inverse eye.

C: Generally, sensory cells perceive the stimulus distally and conduct the impulses proximally.

D: Generally, sensory cells perceive the stimulus proximally and conduct the impulses distally.

E: The cells of the vitreous body and the cells of the retina are mixed up.

A 40: (1 pt) **Bones are dynamic rather than static structures. How may this be realized?**

A: Those who sit crookedly will soon get a crooked back.

B: In case of being bedridden, the internal structure of bones adapts to the altered stress.

C: Bones do not break as readily as static structures of equal strength.

D: A tooth crown freshly implanted, which initially does not fit well, can do so after a couple of weeks without intervention of the dentist.

A 41: (2 pts) **If a man of 70 kg weight ingests 40 g alcohol, the alcohol level in his blood will raise one part per thousand. About 1 g alcohol is eliminated per hour and 10 kg body weight. The man of 70 kg body weight has been involved in a traffic accident and has run away. A blood sample has been taken from him after 2 ½ hours. It contained 0.5 parts per thousand of alcohol. Assuming he did not ingest any alcohol after the accident - how much alcohol did his blood contain at the time of the accident?**

A: 1.10 parts per thousand

B: 0.95 parts per thousand

C: 0.80 parts per thousand

D: 0.65 parts per thousand

E: 0.55 parts per thousand

ETHOLOGY

A 42: The mobbing reaction of house swallows (*Hirundo rustica*).(1 pt)

House swallows mostly breed in colonies. They live on flying insects. Predators spotted during flights for prey or near the nest are noisily attacked in nose-dives. This mobbing reaction communicates itself to the other swallows and supports the defence against enemies. The table shows the ethological status of the swallows and their share in the mobbing reaction and in the population, respectively.

birds' status	share in the population in per cent	share in the mobbing reaction in per cent
adult animals, not mated	6	2
adult animals, before breeding	9	11
adult animals, breeding	14	10
adult animals with young animals	51	77
young animals	20	0
total	100	100

Which of the following hypothesis have to be assumed to be correct according to the results?

I: The mobbing reaction is an intra-specific signal.
II: The mobbing reaction is an element of self-defence.
III: The mobbing reaction is an element of choice of mates.
IV: The mobbing reaction is a kind of maternal care.
V: The mobbing reaction is a form of commensalism.
VI The mobbing reaction is an altruistic mode of behaviour.

A: IV, V, VI B: III, IV, V C: II, IV, VI D: I, IV, VI

A 43: The rank of macaques (*Macaca sylvanus*).
(2 pts)

Macaques are related to rhesus macaques; they live in Morocco and Algeria. Adult males, females and their young animals form groups in which ranks are set up by superorder or suborder.

The table below shows the frequencies of aggression within a group of nine females (A to I):

being attacked

attacking

	A	B	C	D	E	F	G	H	I	total
A	-	16	6	6	16	-	4		5	53
B	-	-	4	14	10	-	2	1	2	33
C	-	-	-	7	8	1	2	-	5	23
D	-	-	-	-	18	2	-	1	8	29
E	-	-	-	-	-	7	5	10	11	33
F	-	-	-	-	-	-	2	14	8	24
G	-	-	-	-	-	-	-	10	-	10
H	-	-	-	-	-	-	-	-	6	6
I	-	-	-	-	-	-	13	-	-	13
	0	16	10	27	52	10	28	36	45	224

Read the matrix and choose which one of the females is the lowest in the rank order.

How do you call the individual loosing conflicts within the group?

I.	female A	II	female I	III.	female E
IV.	female F	V.	female H	VI.	female G
VII.	omega animal	VIII.	alpha animal	IX.	subdominant

Which of the following combinations is the correct one?

A: I, III, IV
B: II, V, VII
C: III, VII, IX
D: IV, VI, IX
E: V, VII, IX

GENETICS/EVOLUTION

A 44: Which of the following statements on introns is correct? (1 pt)

A: They are non-transcribed sequences (spacers) between two genes.

B: They are transcribed spacers between two genes.

C: They are located between the coding regions of a gene.

D: They are located between the coding regions of a mature mRNA.

E: They are non-coding regions of a polycistronic mRNA.

A 45: Which statements on sex chromosomes (gonosomes) are cor rect?
(1 pt)

I. They are always heterochromatic.

II. They may occur in a euchromatic or heterochromatic form.

III. They occur in human beings and in all animals.

IV. They occur in yeast (*Saccharomyces cerevisiae)*.

V. They occur in some mosses.

VI. They occur in some flowering plants.

VII. Their homozygosis always leads to female sex.

A: I, II, III C: I, IV, VI

B: I, III, V D: II, V, VI E: II, V, VII

A 46: The protoplast fusion in dicotyledons is well suited for the following objectives A-D. What can also be achieved by cross hybridization?
(1 pt)

A: combination of the genetic material of different plant families

B: studies on the fate of plastids during the development from cells with mixed plastide populations

C: studies on the fate of mitochondria during the development from cells with mixed mitrochondria populations

D: transfer of resistance genes from wild species into cultivated species

A 47: (2 pts) **Did Gregor Mendel know some of the phenomena (I- VII)? Under which capital letter do you only find such phenomena?**

I. decrease of the degree of homozygous-recessives in the gen eration sequence

II. extrakaryotic inheritance

III. break of coupling

IV. polyploidy

V. hybrid character of the endosperm (albumens)

VI. cleistogamy in pea

VII. homogeneity of the F1 of homozygous parents differing in two pairs of alleles

A: I, II

B: I, III

C: V, VI

D: III, VI

E: IV, VII

A 48: (1 pt) **Which of the following statements characterizes a 'substitution hybrid'?**

A: The hybrid of two auxotrophic mutants is prototrophic

B: The deficiency caused by a recessive allele is repaired by another gene

C: A pair of chromosomes is replaced by a pair of chromosomes of an-other species.

D: The hybrid competes one of the parents out of the population

E: The plastids of one species are displaced by those of another species (after back-crossing).

A 49: (1 pt) **Which process does not lead to a change in the chromosome number?**

A: poisoning of the nuclear spindle

B: non disjunction

C: endomitosis

D: centromere fracture

E: duplication

A 50: (1 pt) **The bacteria strains A and B and a certain bacteriophage which is infectious for both strains grow in one culture. After one day some bacteria which are equivalent to type A have originated, but show characteristics based on five alleles in B.**

Which processes might have caused this phenomenon?

I.	transformation	IV.	sexduction
II.	transposition	V.	mutation
III.	transduction	VI.	transfection

A: I, II, III C: I, V, VI E: , III, IV

<u>B:</u> I, III, IV D: II, IV, VI

A 51: (1 pt) **The table sums up characteristics which are original (plesiomorphic) or deduced (apomorphic) within the group of angiosperms.**

	characteristics
1	vascular bundle collateral closed, herb
2	vascular bundle collateral open, woody plant
3	blossom polysymmetric, actinomorphic
4	blossom monosymmetric, zygomorphic
5	monospermous indehiscent fruit (e.g. nut)
6	polyspermous dehiscent fruit (e.g. capsula)
7	tracheal segments, long
8	tracheal segments, short
9	blossoms without nectar
10	blossoms with nectar
11	ovary superior
12	ovary inferior

Which of the following combinations shows deduced (apomorphic) characters only?

A: 1, 3, 5, 7, 10, 11 C:2, 4, 6, 8, 9, 12

<u>B:</u> 1, 4, 5, 8, 10, 12 D:2, 3, 5, 8, 9, 12 E: 1, 4, 6, 7, 10, 12

A 52: (1 pt) **I - V lists names of plants and 1 - 5 lists some characteristics referring to the reproduction of cormophytes.**

I. *Lycopodium (Lycopodiophyta)*
II. *Gingko (Pinophyta)*
III. *Pinus (Pinophyta)*
IV. *Cycas (Pinophyta vel Cycadophyta)*
V. *Magnolia (Magnoliophyta)*

1. aggregations of sprophylls (strobili) or blossoms unisexual
2. aggregations of sprophylls (strobili) or blossoms bisexual
3. aggregations of sprophylls (strobili) or blossoms sexually not differentiated
4. fertilization by spermatozoids
5. fertilization by immobile sperms

Which assignments are correct?

A:	I: 1, 4	II: 3, 4	III: 3, 4	IV: 1, 5	V: 3, 4
B:	I: 1, 5	II: 2, 5	III: 1, 4	IV: 2, 5	V: 2, 5
C:	I: 3, 4	II: 1, 4	III: 1, 5	IV: 2, 5	V: 2, 5
<u>D:</u>	I: 3, 4	II: 1, 4	III: 1, 5	IV: 1,4	V: 2, 5

A 53: (1 pt) **Which advantage do angiosperms (with double fertilisation and formation of a secondary endosperm) have in comparison to gymnosperms (single fertilisation and formation of a primary endosperm)?**

1. The neotenic development of a female prothallium (macrogametophyte) requires less energy.
2. The triploid endosperm of angiosperms can store more nutrients.
3. Regarding the investment of energy and reserve material, the formation of a secondary endosperm after double fertilization is more economic.
4. Double fertilization is an additional prevention against hybridization.
5. Double fertilization accelerates the embryonic development.

A: 1, 2, 3
B: only 2, 4
<u>C:</u> only 1, 3
D: 2, 4, 5
E: 1, 3, 4

A 54: (2 pts) **Lamarck and Darwin each proposed a theory on the origin of species diversity. According to Lamarck's theory of species transformation, 'infusories' may originate and have to originate by abiogenesis up to the present and give rise to the development of higher organisms. A single origin of organisms is sufficient for Darwin's theory of natural selection. Which of the following statements is correct?**

A: Lamarck has to be considered as the author of the descent theory which, however, was first founded by Darwin.

B: Different contemporary species may be related to each other according to Darwin's theory, but not according to Lamarck's theory.

C: Long-term evolving of species depends on improvement in performance of organisms according to Darwin's theory and on increasing success of organisms according to Lamarck's theory.

D: Lamarck considered inheritance of acquired characteristics as possible, whereas Darwin did not.

A 55: (2 pts) **The well known evolutionary geneticist Maynard Smith stated in 1989: 'We need some measure of the survival and reproduction of the different genotypes. This measure is fitness.' Which of the following statements is correct?**

A: While organisms are mortal, genes are potentially immortal. Therefore, the statement cited is correct.

B: Indeed, fitness is a condition to achieve various kinds of success. Fitness can only be measured by measuring the latter. Therefore, the statement cited is correct.

C: According to the statement cited, the success of survival and reproduction is a measure of fitness. However, fitness is a condition to achieve success. Therefore, the statement cited is wrong.

D: Fitness of genotypes can only be measured by the survival and reproductive success of the corresponding organisms. Therefore, the statement cited is correct.

E: The suggested measure of fitness works well. Therefore, it does not matter whether the statement cited is right or wrong.

ECOLOGY

A 56: (1 pt) **Why do some columnar cacti in their natural habitat turn their longitudinal axis to the point where the sun is at its zenith in summer-time? Evaluate the explanations I - III.**

I. to attain as much light as possible

II. to heat the apically arranged reproductive organs in the morning and in the evening

III. to minimize the increase in temperature of the columnar body

Which of this / these explanation(s) is (are) correct?

A: None of the explanations is correct.

B: Only explanation I is correct.

C: Only explanations I and II are correct.

<u>D:</u> Only explanation III is correct.

E: All three explanations are correct.

A 57: (1 pt) **Which plant life form of the soil flora in a deciduous forest is developing and fruiting most quickly in spring?**

A: therophyts, because they have seeds that already germinate at low temperatures

B: therophyts, because their subterranean storage organs allow a quick start of growth

C: geophyts, because their seeds quickly germinate on the soil in spring

<u>D:</u> geophyts, because they can quickly form a shoot from their subterranean storage organs

E: None of the explanation above is correct.

A 58: (1 pt) **In which way does a cormophytic plant protect itself against freezing ($<$ 10 ^{o} C)?**

A: Plants develop a dense branching to prevent the loss of heat.

B: Plants protect themselves against freezing by a thick cuticle and thick hair on the leaves.

C: Plants concentrate salts in their cells (osmotic effect).

<u>D:</u> Plants have to tolerate cellular dehydration as a consequence of ice-formation.

E: Freezing is avoided by metabolic heat production.

A 59: **Why do you often find cyanobacteria and red algae in places with**
(1 pt) **low irradiance?**

I. All of them are small and are outcompeted by fast-growing species.
II. They are strongly photosensitive.
III. They can efficiently utilise light with the help of additional an tenna pigments

A: All three explanations are correct.
B: Only I is correct.
C: Only II is correct.
D: Only III is correct.
E: Only II and III are correct.

A 60: **Why is a high-moor bog an extreme habitat?**
(1 pt)

I. Because it is oligotrophic and permanently cold.
II. Because it allows extreme situations on the surface concerning climate.
III. Because it is oligotrophic and has a low pH value.

A: I, II and III
B: Only I
C: I and II
D: II and III
E: Only III

A 61: **Which one of the desert plants I and II has to tolerate more heat in**
(1 pt) **a habitat with the same solar radiation and why?**

I. a desert plant with large leaves and water-storing bulbs
II. a desert plant with small but succulent leaves

A: I heats up more intensively than II, because the leaves possess a large surface.
B: I and II heat up at the same range and have to be equally heat toler-ant.
C: II heats up more intensively, because its heat capacity is low.
D: II heats up more intensively than I, because the leaves contain a lot of water.
E: II heats up more intensively than I, because the leaves of I transpire more intensively.

A 62. **Rips are an advantage to columnar cacti and globular cacti:**
(1 pt)
I. because they are in agreement with the concept of xerophytes by increasing the surface.

II. because predators are irritated.

III. because they decrease the irradiation by partial shading

A: Only I   C: I and II   E: I, II and III

B: Only II   D: Only III

A 63: **The ovary needs a lot of heat energy for maturation. In cold climates this may be a problem. By which means is the perianth capable of increasing the energy input in a particularly effective way?**
(1 pt)

A: by a bell shaped perianth preventing the nightly emission

B: by paraboloid flowers reflecting the solar radiation to the ovary

C: by dark-coloured flowers absorbing a particularly high amount of heat

D: by the symmetry of zygomorphic flowers causing an evenly warming up of the ovary

E: by an ovary which is bigger than the perianth

A 64: **R-strategists (r-selectionists) are inhabitants of fast originating and vanishing habitats. They are selected for quick colonisation, for fast and complete utilisation of these habitats and for fast search for new favourable places. Which of the following characteristics apply to r-strategists?**
(2 pts)

I. They have a slow development.

II. They have a relatively large number of offspring.

III. They have a short life span.

IV. Their mortality is independent of the population density.

V. Their population size is relatively constant.

A: I, II and III   C: II, III and V   E: I, III and V

B: I, II and IV   D: II, III and IV

A 65: (2 pts) **The ecosystems shown in the table differ in the amount of their net primary production.**

selected ecosystems

number	ecosystem
1	tropical rain forest
2	savannah
3	subtropical sand desert
4	temperate deciduous forest
5	boreal deciduous forest
6	tundra

Name the correct order (increasing net primary production) of the eco-sytems shown in the table.

A: 3, 6, 2, 5, 4, 1

<u>B:</u> 3, 6, 5, 2, 4, 1

C: 6, 3, 5, 2, 4, 1

D: 6, 3, 2, 5, 1, 4

A 66: (1 pt) **Which possible effects does the smoke from the vast forest fires in tropical rain forest have on the plants in neighbouring areas?**

I. decrease of the photosynthetic rate

II. increase in the respiration rate

III. decrease of the plant growth

IV. increase in the transpiration rate

A: I and II

B: II and III

<u>C:</u> I and III

D: III and IV

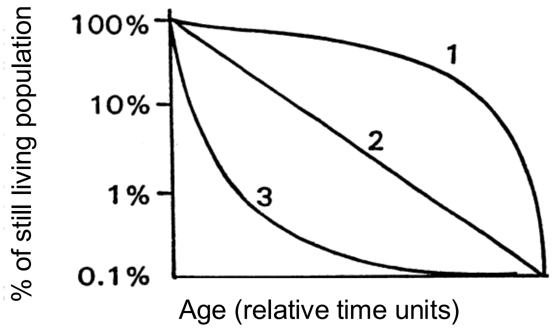
E: II and IV

A 67: (1 pt) **The following figure shows survivorship curves. Inspect the curves showing the percentage of individuals of populations of three different species which are still alive at any particular age.**

I. elephant

II. frog

III. rabbit



Inspect the survivorship curves. Which of the following combinations is correct?

A: I (2), II (3)

B: I (1), II (3)

C: II (3), III (1)

D: I (1), II (2)

E: II (2), III (3)

SYSTEMATICS

A 68: Which characteristics are typical for wind-pollinated (anemophi lous) plants?
(1 pt)

A: smooth stigma, viscous pollen and polyspermous dehiscent fruit

B: smooth stigma, non-viscous pollen and polyspermous indehiscent fruit

<u>C:</u> papillate stigma, non-viscous pollen and monospermous indehiscent fruit

D: papillate stigma, viscous pollen and monospermous dehiscent fruit

E: papillate stigma, viscous pollen and polyspermous indehiscent

A 69: Where do beans (*Fabacae*, e.g. soybean *Glycine max*, syn. *Soja hispida*) store reserve material for germination?
(1 pt)

A: in the pericarp

<u>B:</u> in the cotyledons of the embryo

C: in the triploid nutritive tissue (endosperm) of the seed

D: in the diploid nutritive tissue (perisperm) of the seed

A 70: Which storage organ does not exist in monocotyledons? (1 pt)

A: onion C: tuber <u>B:</u> turnip D: rhizome

A 71: I - V lists plant species and 1 - 5 lists morphological and taxonomic characteristics.
(2 pts)

I. onion (*Allium*)	1. monocotyledons
II. peach (*Prunus*)	2. dicotyledons
III. coconut palm (*Cocos*)	3. stone fruit
IV. oak (*Quercus*)	4. capsula
V. corn (*Zea*)	5. nut or caryopsis

Which assignments are correct?

A:	I: 1, 3	II: 1, 4	III: 1, 4	IV: 2, 4	V: 1, 5
B:	I: 1, 4	II: 2, 5	III: 1, 5	IV: 2, 3	V: 1, 3
C:	I: 1, 4	II: 2, 5	III: 1, 3	IV: 2, 5	V: 1, 3
<u>D:</u>	I: 1, 4	II: 2, 3	III: 1, 3	IV: 2, 5	V: 1, 5
E:	I: 1, 4	II: 2, 3	III: 1, 4	IV: 2, 5	V: 1, 3

A 72: In which family do symbiotic nitrogen-fixing bacteria in the root
(1 pt) occur?

A: *Rosaceae* C: *Fabaceae* (*Leguminosae*)

B: *Brassicaceae* (*Cruciferae*) D: *Asteraceae* E: *Fagaceae*

A 73: What is correct concerning penguins?

(1 pt)
I. Penguins are an intermediate form between birds and mammals.
II. Penguins are densely covered with feathers.
III. Penguins are densely covered with hair.
IV. Penguins are densely covered with chitin fibres.

A: I, II C: only II

B: I, III D: only III E: only IV

A 74: Which of the following animal taxa only occur in the sea?

(2 pts)
I. starfish and sea urchins (*Stellaroidea, Echinoidea*)
II. jellyfish (*Cnidaria*)
III. sponges (*Porifera*)
IV. squids (*Cephalopoda*)
V. higher developed crustacea (*Malacostraca - Crustacea, Astacus*)

A: I, IV C: only V

B: only II, III D: I, II, III E: II, IV, V

A 75: In which animals does heterogony occur like in rotifers?

(1 pt)

I. in water fleas (*Cladocera - Daphnia*)
II. in plant-lice (*Aphidina - Homoptera*)
III. in dragon flies (*Odonata*)
IV. in bivalves (*Bivalvia - Lamellibranchiata*)
V. in sea stars (*Asteroida - Stellaroidea*)

A: only I, II C: only V

B: only III, IV D: I, II, III E: III, IV, V

MICROBIOLOGY / BIOTECHNOLOGY

A 76: (1 pt) **A broth culture of *Escherichia coli* (50 ml inoculated with 0.5 ml of an overnight culture), grown at 37° C for 18 hours, contains:**

A: cells of *E. coli* which all divide at the same rate

B: mostly endospores

<u>C:</u> cells of *E. coli* which are all in the stationary growth phase

D: cells of *E. coli* which are in all possible growth phases

A 77: (1 pt) **Clear plaques in a bacterial lawn that do not increase in size are caused by**

A: the parasitic bacterium *Bdellovibrio bacteriovorus.*

<u>B:</u> bacteriophages.

C: bacteria producing antibiotics.

D: bacteriocin-producing bacteria.

A 78: (2 pts) **In a wastewater treatment plant flocks of activated sludge swim on the surface of the settling tank. Which physiological process causes this problem?**

A: nitrification

B: sulphate reduction

<u>C:</u> denitrification

D: alcoholic fermentation

A 79: (2 pts) **It is well known that heterologous DNA which is genetically stable can be established in a bacterial cell. Which of the following processes can be used to achieved this?**

I. conjugation

II. transformation of plasmid DNA

III. transformation of chromosomal DNA

IV. general transducti

V. special transduction

A: I, III, V

B: I, II, III

C: I, III, IV

D: II, IV, V

<u>E:</u> I, II, V

A 80: (1 pt) **Which of the following organisms is used to transfer genes into higher plants?**

A: *Escherichia coli*

B: *Rhizobium trifolii*

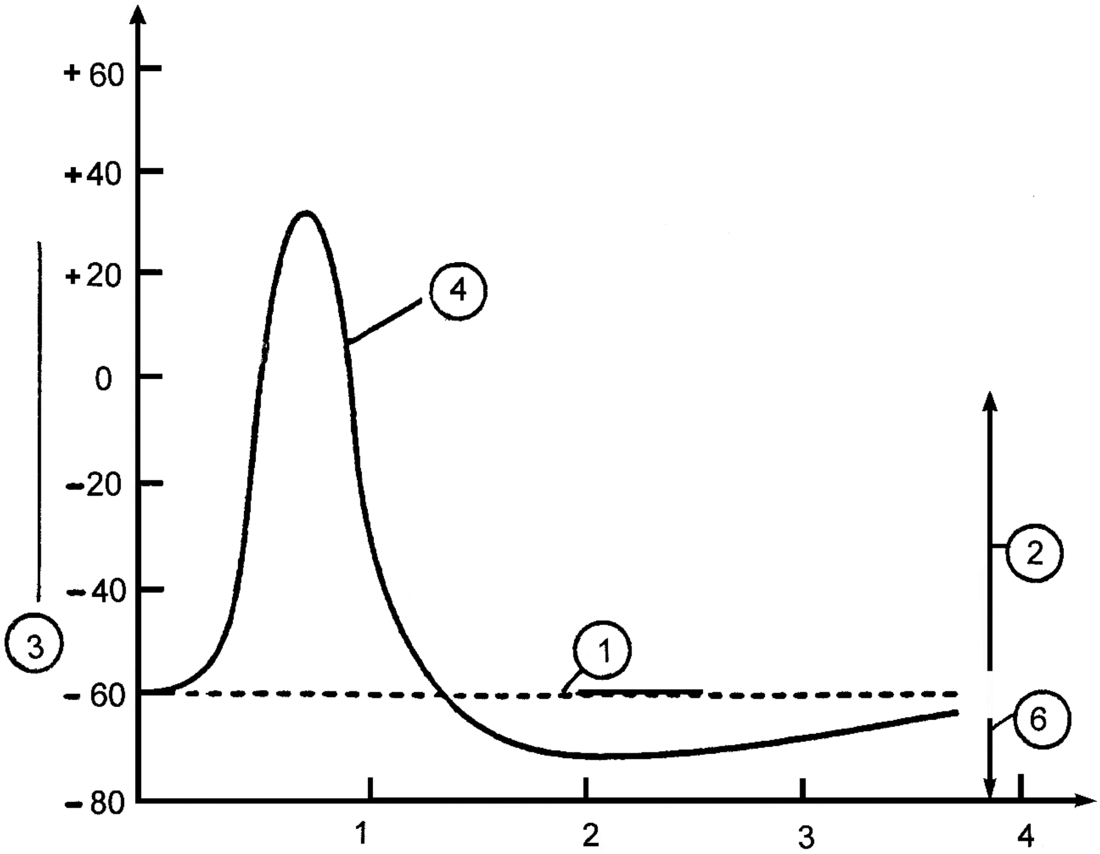
<u>C:</u> *Agrobacterium tumefaciens*

D: *Salmonella typhimurium*

5.2.2 Theoretical Test - Part B

CELL BIOLOGY

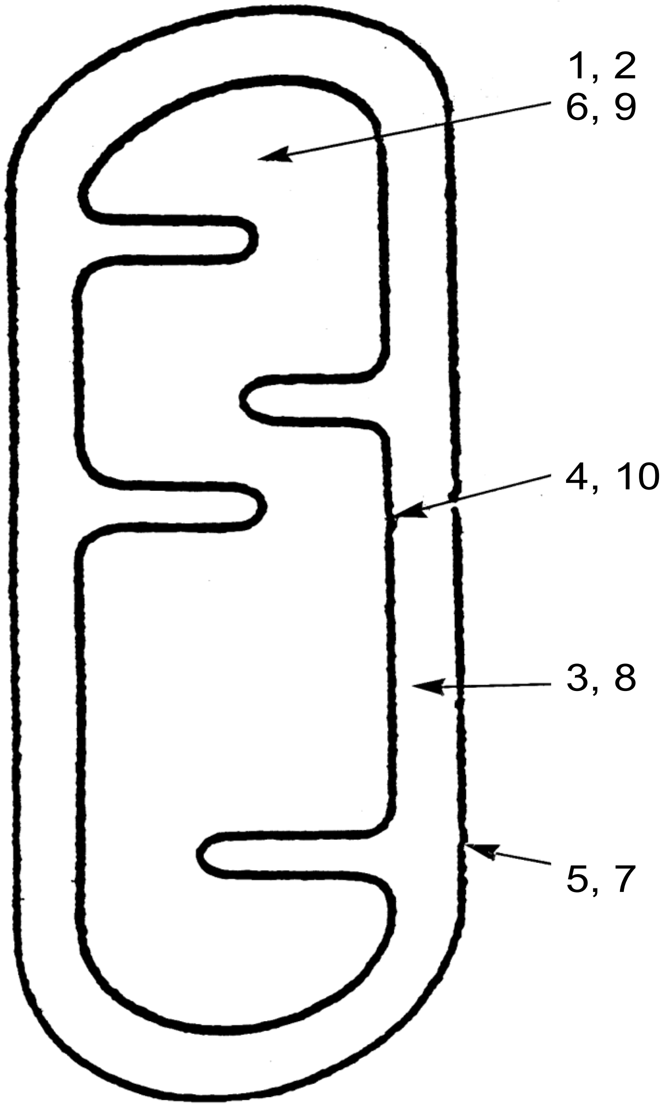
B 1: (1 pt) **Stimulating a giant axon of a squid at the time = 0 leads to a change in the membrane potential, which is measured with a microelectrode. The results are shown in the figure below. Label the figure using the adequate code numbers.**



Code numbers:

1. resting potential
2. depolarisation
3. membrane potential (mV)
4. action potential
5. osmotic potential
6. hyperpolarisation

B 2: **Match the molecules or proteins listed below with the various**
(2 pts) **sub-compartments of mitochondria.**



1. pyruvate ehydrogenase
2. DNA polymerase
3. cytochrome c
4. ATP synthase
5. porin
6. aconitase
7. protein import receptor
8. cytochrome b_2
9. enzyme of β-oxidation of fatty acids
10. succinic acid dehydro-genase

B 3: S K I P P E D .

(3 pts) **Bacterial ribosomes are distinguished from ribosomes coded by the nucleus because of their sedimentation (Svedberg-constant S) and their composition of rRNA. Name the ribosomes and their subunits according to the Svedberg constant and their rRNA composition. Fill in the correct code number in the corresponding space in the following table.**

Code numbers:

1. 5S rRNA	3. 16S rRNA	5. 23S rRNA
2. 5.8S rRNA	4. 18S rRNA	6. 28S rRNA

bacterial ribosomes	ribosomes coded by the nucleus
......70.......S	.......80.............S
large subunit	large subunit
......50.....S	........60............S
composition of rRNA	rRNA composition
.... .1.........	.... .1.............
.........5.........	..........2............
....	..........1............
small subunit	small subunit
.....30...S	..........40..........S
composition of rRNA	composition of rRNA
..........3.........	...........4.............
....	....
....	....

B 4: (2 pts) **The average time of duplication of mammalian cells in cultures is 24 hours. Just divided cells growing on a cover-slip were treated with radioactively labelled (tritium) thymine for 10 minutes and immediately fixed. Figure I shows a typical microscopic section. Figure II shows the autoradiography with the dispersion of the silver grains of the section in figure I using the same magnification. Calculate the average duration of the S-phase in these cells with a maximum error of 30 minutes.**

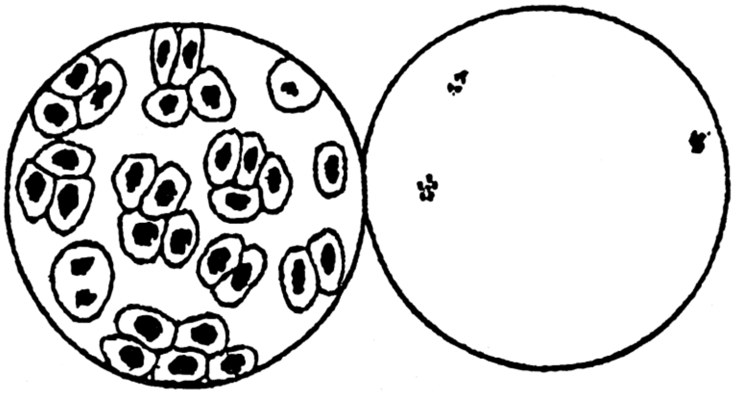


figure 1 figure 2

Average duration of S-phase: .....2,5 h..........

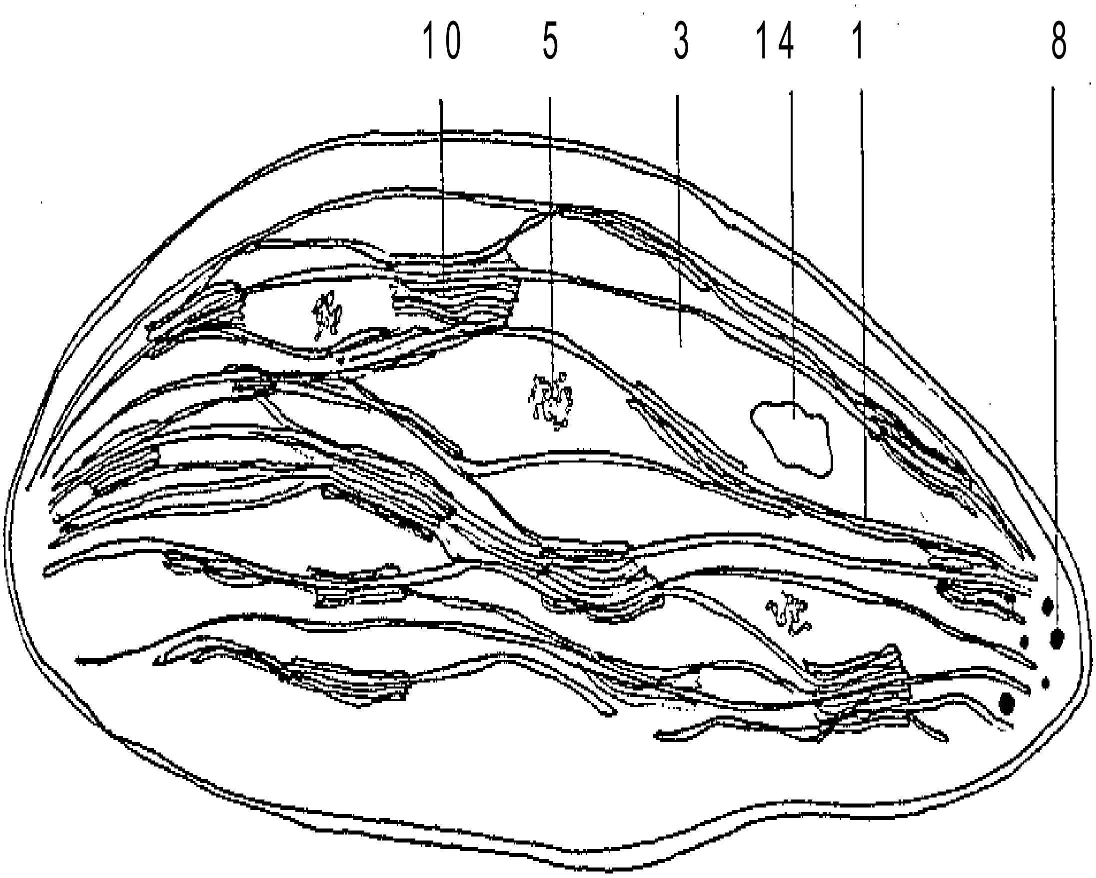
B 5: (2 pts) **The following table shows structures of eukaryotic and prokaryotic cells as well as various membranes ('types of membrane'). Which cell structures possess which type of membrane ('types of membrane')? Mark the correct answer with a cross.**

	presence or types of membranes		
cell structures	no membrane	monolayer membrane	double membrane
1. nucleus			**X**
2. lysosomes		**X**	
3. mitochondria			**X**
4. Golgi apparatus		**X**	
5. peroxisomes		**X**	
6. rough endoplasmic reticulum		**X**	
7. chloroplasts			**X**
8. vacuoles		**X**	
9. ribosomes	**X**		
10. centrioles	**X**		
11. nucleolus	**X**		
12. flagella of eukaryotes		**X**	
13. flagella of prokaryotes	**X**		

B 6: (2pts) **Label the marked structures of the chloroplast in the following figure. Use the corresponding code numbers.**

Code numbers:

1. thylakoid	5. nucleoid	9. plastidome (collection of plastids)	13. pyrenoid
2. cristae	6. nucleolus	10. granum	14. grain of starch
3. stroma	7. amyloplast	11. elaiosplast	
4. nucleosome	8. lipid droplets	12. prolamella body	



B 7: (2 pts) **The following table shows types of plastids and their specific characteristics. Match the characteristics to the types of plastids by marking with a cross.**

Types of plastids	characteristics			
	starch formation	photosynthesis	coloured	contains DNA
Chloroplast	X	X	X	X
Chromoplast			X	X
Rhodoplast			X	X
Proplastid				X
Leuko-amyloplast	X			X

B 8: (1 pt) **A cell produces and secretes a certain protein. Select from the list only those structures which are involved in these processes, to our present knowledge - and list the code numbers in the correct order of the processes.**

1. peroxisome
2. free ribosome
3. Golgi apparatus
4. secretory vesicle
5. plasma membrane
6. vacuole
7. rough endoplasmic reticulum
8. lysosome

correct order of compartments: 2, 7, 3, 4, 5

ANATOMY AND PHYSIOLOGY OF PLANTS

B 9: (2 pts) **The following figure shows a simplified schematic drawing of the most important photochemical complexes and their localisation in the thylakoid membrane of chloroplasts. Label the spots marked with ☐ with the four integral membrane protein complexes.**

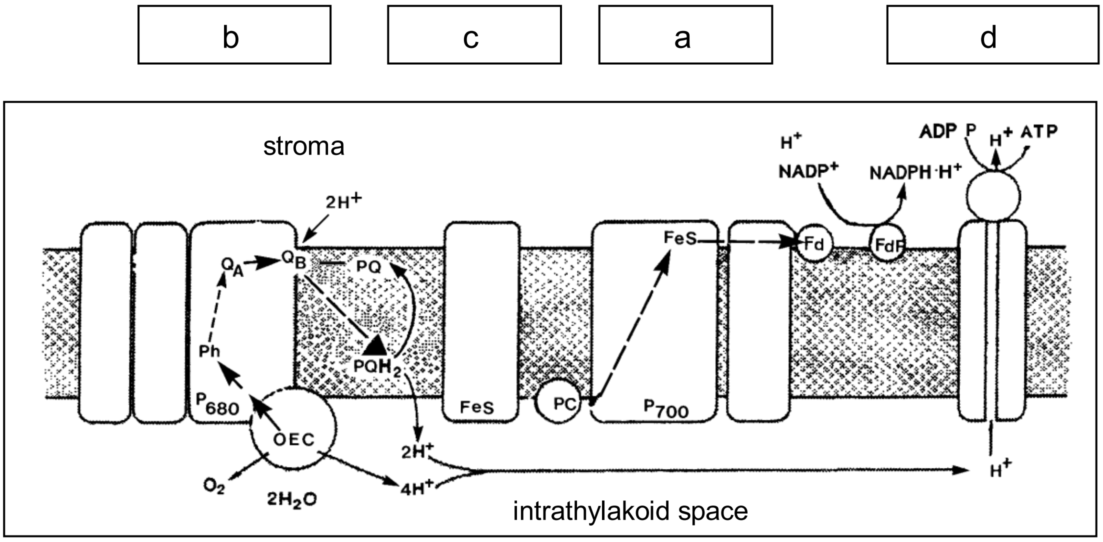
a- photosystem I

b- photosystem II

c- cytochrome b_6 / f

d- ATP synthase

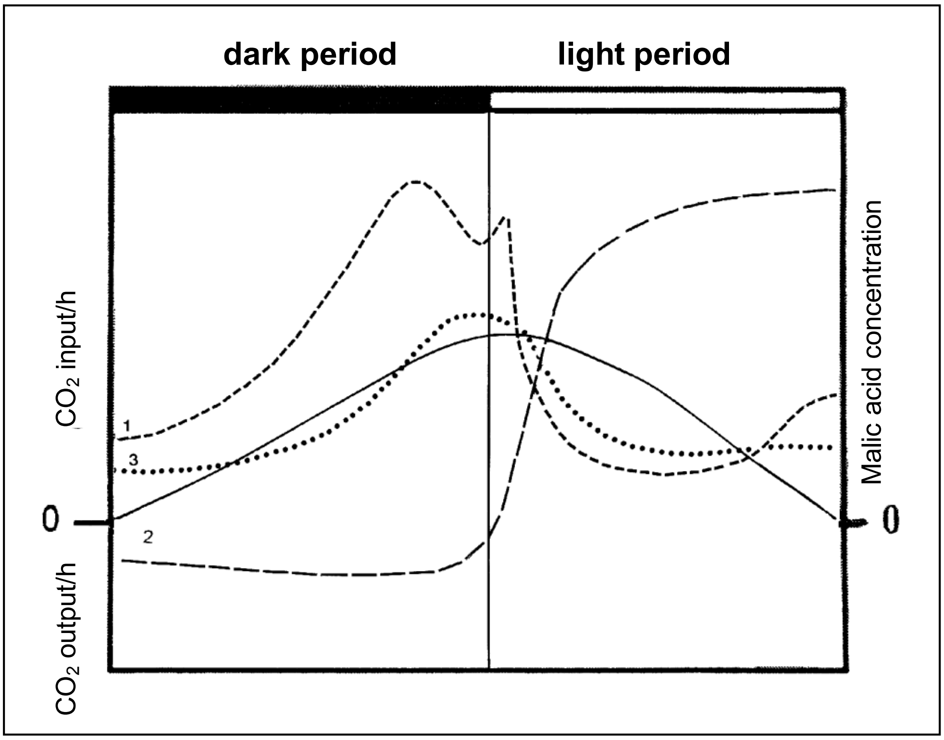
Mark with arrows (using a <u>yellow pen</u>) the electron flow from water as the e^-- donator to $NADP^+$ as the e^- terminal acceptor.



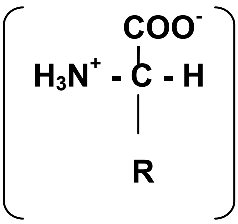
legend: FdR = Ferredoxin-$NADP^+$-Reductase; Fd = Ferredoxin; FeS = Iron-sulphur-centre; P_{700}, P_{680} = chlorophylls of the reaction centres; PC = Plastocyanin; PQ = Plastoquinone; Q = Quinon; Ph = Pheophytine; OEC = water splitting complex .

B 10: **Plot with a <u>yellow pen</u> (1) the course of gas exchange of a typical**
(3 pts) **CAM plant and with <u>a pencil</u> (2) the course of gas exchange of a C_3-plant using the figure.**

The malic acid concentrations in the CAM plant vacuoles should be plotted in <u>blue (3)</u>.



B 11: **S K I P P E D .**
(2 pts)



Amino acids can be divided in various classes according to the polarity of their R-groups. Classify the following amino acids due to the polarity of their R-groups by arranging the following code numbers in the table.

1: serine (Ser)
2: alanine (Ala)
3: valine (Val)
4: phenylalanine (Phe)
5: tyrosine (Tyr)
6: glutamine (Gln)
7: arginine (Arg)
8: glutamic acid (Glu)
9: aspartic acid (Asp)

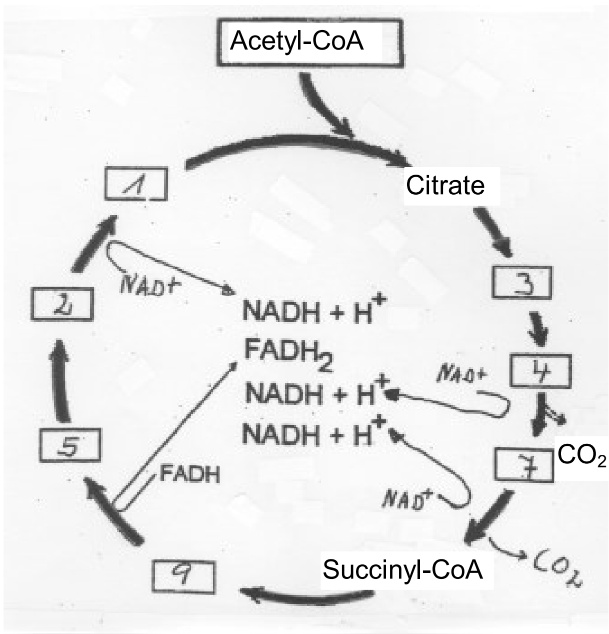
classification of amino acids according to the polarity of their R-group (at pH 7)

nonpolar (hydrophobic) R-groups	2, 3, 4
polar, but uncharged R-groups	1, 5, 6
negatively charged (acidic) R-groups	8, 9
positively charged (alkaline) R-groups	7

B 12: **The figure below is a simplified scheme of the citric acid cycle.**
(2 pts) **Fill in the missing intermediates in the correct order by writing down the corresponding code number in the space provided.**

1: oxaloacetate	4: isocitrate	7: 2-oxoglutarate
2: malate	5: fumarate	8: malonate
3: cis-aconitate	6: glyoxylate	9: succinate

Indicate by an arrow - like in the given example - the missing release of CO_2 as well as the three missing dehydrogenations in which the hydrogen is transferred to the NAD$^+$.



B 13: (2 pts) **Compare figure A and B. Indicate in the table, which structures in figure B correspond to those in figure A.**

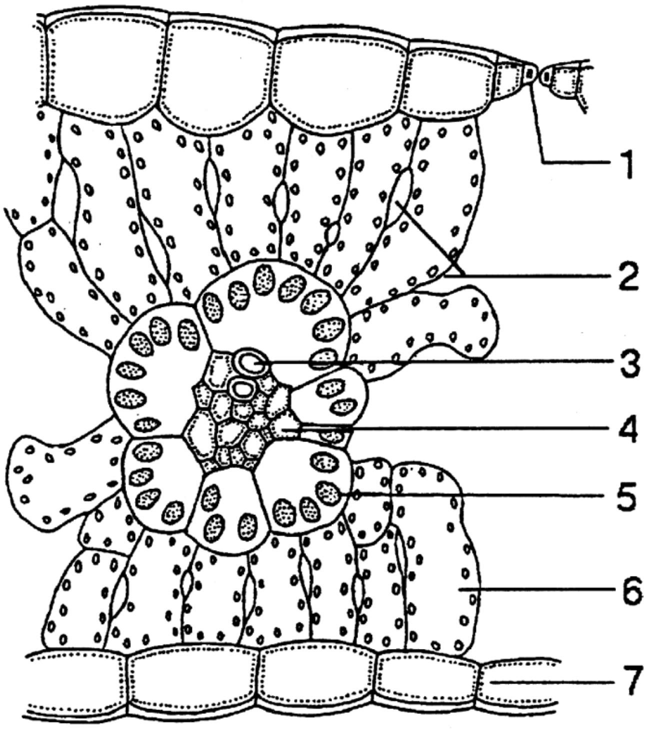


figure **A**

figure A	figure B
1	5
2	9
3	1
4	2
5	7
6	6
7	4

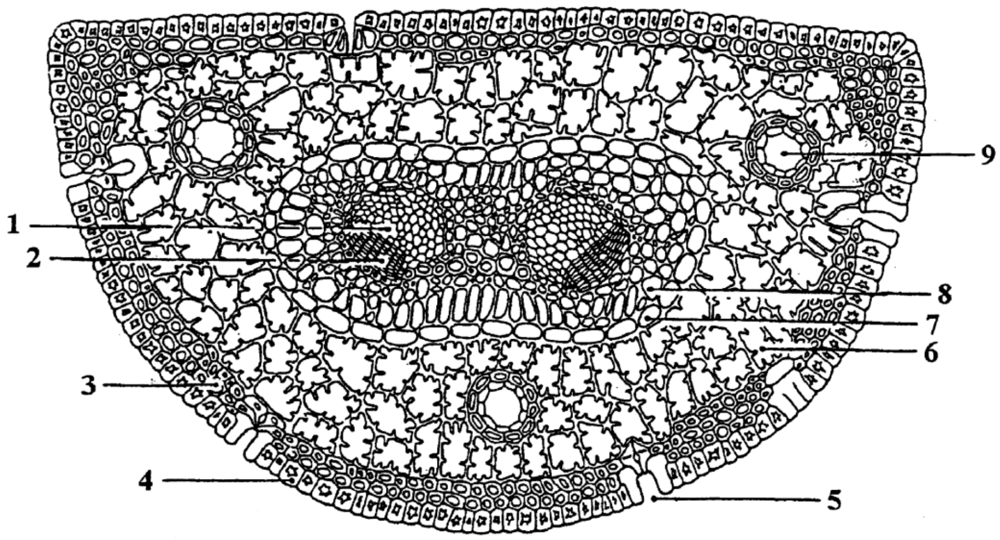
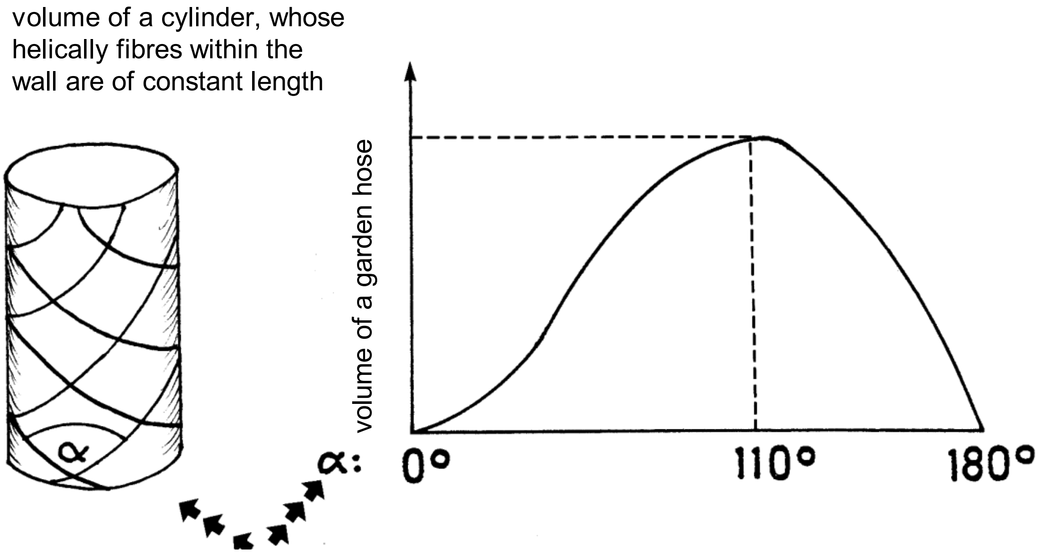


figure **B**

ANATOMY AND PHYSIOLOGY OF ANIMALS AND PLANTS

B 14: (2 pts) **Within the wall of a garden hose, flexible fibres which can hardly be stretched run in crosswise helices enclosing an angle of $\alpha = 110^0$. Only at this angle, the water pressure within the hose cannot alter he length of the hose, its diameter, or its volume (see the maximum indicated in the curve presented).**



angle α enclosed by the helically running fibres of the wall

In flat- and roundworms, flexible but inelastic fibres run crosswise helically within the body wall. The cross section of the body is flat in flatworms and circular in roundworms. The body volume is frequently changed by ingestion of food and defecation.

Therefore, which of the following statements is correct? Mark with a cross.

( ) $\alpha = 110^0$ in flatworms and $\alpha = 110^0$ in roundworms

(X) $\alpha = 110^0$ in flatworms and $\alpha = 150^0$ in roundworms

( ) $\alpha = 150^0$ in flatworms and $\alpha = 110^0$ in roundworms

( ) $\alpha = 150^0$ in flatworms and $\alpha = 150^0$ in roundworms

B 15: (1 pt) **Microscopically small marine annelid worms differ in various aspects from their macroscopically large relatives. Mark the correct statement with a cross.**

- ◯ In the former, the relation of body surface to body volume is smaller than in the latter.
- ◯ In the former, the brain volume occupies a smaller part of the body volume than in the latter.
- ◯ A heart is often absent in the former, but always present in the latter.
- ◯ External fertilization is widespread among the former and does not occur among the latter.
- ◯ Planctic larvae are widespread among the former and do not occur among the latter.

B 16: (2 pts) **The main waste product of protein and purine metabolism is urea in mammals and uric acid in birds. The solubility of these products in water is different. If mammals produced uric acid and birds urea (with an otherwise unchanged body organisation) why would this be disadvantageous to both? Mark the correct answer.**

- ◯ In both cases, the embryos would have substantial problems with excretion.
- ◯ In both cases, the adults would have substantial problems with excretion.
- ◯ The organs of mammals are unsuitable for excreting uric acid.
- ◯ The organs of birds are unsuitable for excreting urea.
- ◯ In the case of urea formation, birds would lack important raw materials for feather formation.
- ◯ In the case of uric acid formation, mammals would lack important raw materials for hair formation.

B 17: **Which one of the following statements related to the neuronal basis of learning is correct?**
(2 pts)

- ◯ Learning immediately induces the formation of specific memory molecules.
- ◯ Learning immediately induces the formation of specific memory synapses.
- ◯ Learning immediately induces the formation of specific memory neurons.
- ◯ Permanently, too many memory molecules are formed. Learning improves the fitness of a few of them which survive, while the less fit ones are decomposed.
- ◯ Too many synapses are formed constantly. Learning improves the fitness of a few of them which survive, while the less fit ones are decomposed.
- ◯ Too many neurons are formed constantly. Learning improves the fitness of a few of them which survive, while the less fit ones are broken down.
- ◯ Selection due to differences in fitness does not occur in the brain. Neurons are activated by learning and otherwise rest.

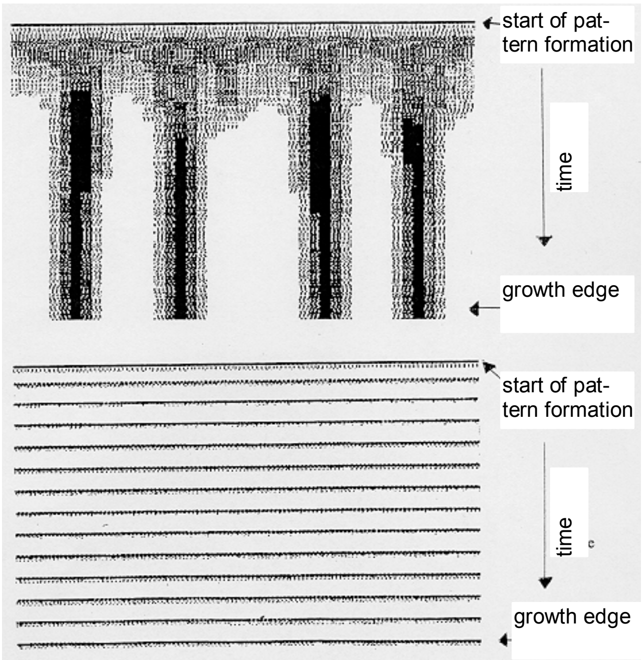
B 18: S K I P P E D .

(3 pts) **Inspired by nature, the presented patterns I and II were generated by a computer. Pattern formation takes place only at the growth edge (at the bottom in the figures). An activator stimulates pigmentation (responsible for black parts of the patterns), while this process is inhibited by an inhibitor (responsible for white parts of the patterns). Patterns form, because the concentrations of activator and inhibitor vary in time and space. The activator promotes its own production by autocatalysis and, additionally, promotes production of the inhibitor by catalysis. Both activator and inhibitor can diffuse and can be broken down. The example shows, the laws of pattern formation differ only by their rates of diffusion D and the rate of decomposition R of activator and inhibitor.**

In order of increasing size the values are (A stands for activator, I for inhibitor):

D_A = 0.005 and 0.1 D_I = 0.4 in both cases

R_A = 0.01 and 0.06 R_I = 0.003 and 0.015



Write down which values correspond to pattern I and which to pattern II.

- **v**alues of pattern I**:** **0,005** D_A = 0,005 R_A = 0,01 R_I = 0,015
- **v**alues of pattern II**:** **0,1** D_A = 0,1 R_A = 0,06 R_I = 0,003

ETHOLOGY

B 19: Sexual selection of swallows (*Hirundo rustica*)

(4 pts) Reproduction and parental care cause costs and yield benefits. The right mate selection can optimize the cost-benefit-ratio (e.g. measured by the number of eggs per nest or by the number of the hatched and fledgling offspring). Male and female swallows differ in their behaviour and in the length of their outer tail feathers (see table below).

Characteristics of swallows

swallow	Body length	weight	feathers other than mil feathers	tail feather	arrival from Africa
male	19 cm	18-26 g	identical E E to females	106 mm (100%)	before E E (females)
female	19 cm	18-26 g	identical Γ Γ to males	91 mm (84% of 106 mm)	after Γ Γ (males)

Courting male swallows change their flight path in the presence of a female and show two long feathers in the spread tail fan. These feathers might indicate certain features of males as a secondary sexual characteristic. If that is correct, experiments with modified ordinary tail feather lengths should yield various results. In the picture males are shown with ordinary and experimentally modified tail feathers.

The next table shows the results of three groups of males (A, B, C), which had different feather lengths.

Results of an ethological experiment

male tail feathers	A: 106 mm (ordinary)	B: 85 mm (shortened)	C: 127 mm (lengthened)
time of courting	6.8 days	12.3 days	3.4 days
offspring / season	5.0 young	3.3 young	8.4 young
aggression Γ Γ (males) against Γ Γ (males)	as B, C	as A, C	as A, B

Analyse these results and answer the following questions:

(1) What is the time-saving of a pair (in %) with the duration of incubation of 14 to 16 days, if the female does not mate with male A but with male C?
........21,3.............to ....24,3....... %
(incubation of 14 to 16 days)

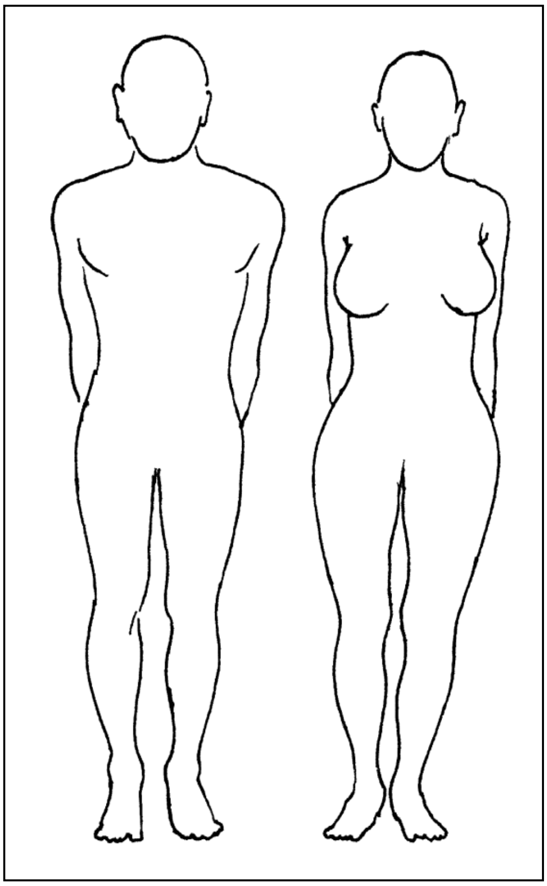
(2) How many offspring on average does a female have with a male C (long tail feathers) compared to an ordinary male A (result in %)? .....68...... %

(3) According to the results, what determines the most successful reproduction of breeding pairs? Mark with a cross.

- ◯ the condition and the behaviour of females in the choosing of a mate against males (female choice)
- ◯ the condition and the successful competition of males against each other (male-male competition)
- ◯ the condition and the successful competition of females against each other (female-female competition)
- ◯ the condition and the behaviour of males in the choosing of a mate against females (male choice)

B 20: **Preference of male and female body proportions in selective**
(4 pts) **model experiments.**

In a very extensive investigation (n = 10,000 people) children, youths and adults were each shown two outline pictures of the male and female body (models).



After the comparison each person stated their preferred model. The following table (next page) shows the results for 4 - 20- year-olds, divided by

I. age of the experimental subject
II. sex of the experimental subject
III. sex of the preferred model

Selective behaviour of males and females (body outline in double selection)

age (years)	Ε choice by (males) ΓΓ %	Γ choice by (males) ΓΓ %	Γ choice by (females) ΕΕ %	Ε choice by (females) ΕΕ %
4	45	55	43	57
5	43	57	44	56
6	39	61	44	56
7	35	65	42	58
8	33	67	39	61
9	32	68	37	63
10	28	72	36	64
11	26	74	36	64
12	26	74	37	63
13	28	72	42	58
14	34	65	50	50
15	42	57	57	43
16	50	50	63	37
17	57	43	66	34
18	63	37	67	33
19	67	33	63	34
20	68	32	58	42

Evaluate the table and mark the correct answer with a cross.

(1) Which models do younger females prefer?

○ male models

○ female models

(2) Which models do older males prefer?

○ male models

○ female models

(3) Between which ages do females change from non-preference (< 50%) to preference (> 50%) of male models?

○ at 14

○ at 15

○ at 16

p.t.o.

(4) Between which ages do males change from no-preference (< 50%) to preference (> 50%) of female models?

◯ at 14

◯ at 15

◯ at 16

(5) Which hypotheses correspond to the data?

Mark the correct statements with a cross.

◯ **Hypothesis 1:** Secretion of growth hormones from the tissue of the thyroid gland causes the orientation for mates of the opposite sex. The hormonal effect starts at a different time in boys and in girls.

◯ **Hypothesis 2:** Sexual learning optimises the preference of the opposite sex. The hormonal effect starts at a different time in boys and in girls.

◯ **Hypothesis 3:** The neurophysiological maturation of the preference concerning the opposite sex is promoted by the increasing amount of oestrogen (Ε Ε) and testosterone (Γ Γ) during puberty. It develops at different times during maturation in boys and girls.

B 21: Mate selection in grasshoppers (*Tettigoniidae*, crickets)

(2 pts) In the population of one species A males which are ready to reproduce sing on fixed locations. The females are orientated towards the songs, approach the males and get on them (inversion of the sexual role com-pared to other grasshoppers). The males produce <u>one</u> spermatophore during their lifetime, and it can only be given to one female. Nevertheless, a female can produce <u>more</u> than one clutch of eggs and mate with several males in succession. Contrary to the otherwise rare fema-le reproduction products (compared to the number of male gametes) in this case the females should have a measurably higher success rate in reproduction. An investigation showed the following results:

	average weight of females before eggs are laid	average number of eggs per female
Rejected by males	3.23 g	30
Accepted by males	3.71 g	48

Answer the following questions according to the results:

(1) What is the average weight of a female without eggs?

- ◯ 2.43 g
- ◯ 2.24 g
- ◯ 2.32 g

(2) How many eggs can each of four males fertilize, when it mates with a female that produces four clutches of eggs in succession and weighs 3.87 g, 3.74 g, 3.52 g and 3.74 g, respectively when copulating?

male 1 with female 1 .....54...... eggs

male 2 with female 1 .....49...... eggs

male 3 with female 1 .....41...... eggs

male 4 with female 1 .....49...... eggs

B 22: Spectrum of prey and food selection of the oyster catcher
(2 pts) **(*Haematopus ostralegus*)**

Oyster catchers are birds that look for prey in the shallow water of sea coasts, e.g. bivalve. The shells in a habitat are of different sizes and these sizes correlate with the amount of energy in the shell meat:

- Small shells can be opened fast and easily (costs) but provide less food energy (benefit).
- Big shells provide more energy (benefit), but they are more difficult and time-consuming to open (costs).

The following table shows

I. the total amount of energy of big shells of different size

II. the frequency of distribution of all shells present

III. the frequency of distribution of the shells selected

Number and energy content (relative units) in shells living in a feeding territory that were selected by birds

total amount of energy per shell (E)	shells present (n)	energy present (E)	shells selected (n)	energy consumed (E)
1	1	1	0	0
2	17	34	0	0
3	11	33	1	3
4	9	36	3	12
5	6	30	6	30
6	7	42	7	42
7	20	140	11	77
8	22	176	10	80
9	19	171	14	126
10	13	130	13	130
11	6	66	6	66
12	2	24	2	24
13	1	13	1	13
1 to 13	134	sum 896	74	sum 603

Analyse and evaluate the table and answer the following questions:

(1) What total amount of energy could be expected from 74 shells that were randomly selected from 134 shells?

.......495...... energy units E (propotional)

(2) What is the absolute total amount of energy and the total amount of energy in percentage, that can additionally be consumed from 74 shells that were selected by birds.

........108........ energy units R (real) ....21,8....... % benefit

GENETICS/EVOLUTION

B 23: (2 pts) **Which characteristics does an interspecific hybrid from crossing diploid flowering plants have? From the list below, select and write down the code numbers of the correct reasons or explanations in the circles below.**

<u>properties of the hybrid</u>

- (3) amphihaploid (haploid form of amphihaploid)
- ( ) amphidiploid (alloplyploid with double the normal chromosome number)
- ( ) fertile, but its offspring are sterile
- ( ) usually fertile, if the parents belong to the same genus
- ( ) sterile and therefore not suited for plant breeding
- (6) It can be made fertile by the toxin colchicin.
- ( ) It can be made fertile by the phytohormone β-indolelacetic acid (IAA).

Code numbers for <u>reasons and definitions</u>:

1. The interspecific infertility is a significant feature of the species.
2. The embryonic development is impaired.
3. Each type of chromosomes is present only once.
4. Two chromosome sets are present.
5. The formation of fertile gametes is impaired.
6. The treatment facilitates the meiotic chromosome pairing to take place.
7. The treatment facilitates fruit maturation.
8. The treatment does not lead to the mentioned result.

B 24: (2 pts) **In DNA replication the 3'-end priming problem is known (end replication problem). From the list below, write in the circles in the corresponding genophores (chromosomes DNA) the numbers of the phenomena by which the problem is solved or avoided.**

genophores

- (1) main genophores of eubacteria
- (1) plasmids of eubacteria
- (1) main genophores of archaea bacteria
- (1) mitochondrial DNA
- (1) plastid DNA
- (4) chromosomes of nuclei
- (2) DNA of lambda-phages
- (3) DNA of adenovirus
- (6) DNA of retrovirus

code numbers for phenomena:

1. circular nature of DNA
2. pre-replicative circularization of the DNA
3. replication jumps from the 5'-end of the leading, to the 3'-end of the lagging strand
4. telomerase activity
5. specific primer-independent DNA replicase
6. transcription / reverse transcription
7. polyadenylization

B 25: (2 pts) **Isolated protoplasts of two albino mutants of potatoes were fused. A variegated plant was obtained. Where are the mutant genes, which have caused the chlorophyll deficiency, located? A new mutation, plastid communication and plastid DNA recombination should be excluded.**

Mark the correct answer with a cross.

- (X) in the nucleus of one mutant, in the plastids of the other one
- ( ) in the nucleus of both mutants
- ( ) in the plastids of both mutants

B 26: **Compare the following types of anaphase.**

(2 pts) **Which of the following statements are correct for anaphase I of meiosis? Which statements are correct for the anaphase of mitosis? Write the correct code numbers from the list below, in the spaces beside the anaphase types. Pay attention to the fact that chromatides are subunits of chromosomes.**

1. phase I of meiosis: ....1, 3, 4, 5..........
2. anaphase of mitosis: ..1.............5..........

code numbers:

1.Chromosomes move to the poles.

2.Single chromatids move to the poles.

3.The moving chromosomes consist of two chromatides.

4.The chromosomes can carry two alleles of a gene.

5.One haploid set of chromosomes can move to each pole.

6.There are four spindle poles per cell.

B 27: **In the course of the evolution of plants the haploid life phase,**
(2 pts) **i.e. the gametophyte, has been more and more reduced and the diploid life phase, i.e. the sporophyte, has become the dominant generation. Write the number of the following taxa in the correct order according to the increasing dominance of the diploid life phase.**

I. *Ulothrix (Chlorophyta)*

II. *Chlorella (Chlorophyta)*

III. *Pinus (Pinophyta)*

IV. *Polytrichum (Bryophyta)*

V. *Rosa (Magnoliophyta)*

VI. *Navicula (Phaeophyta, Diatomeae)*

.... II, I, IV, III, V, VI.................

B 28: **S K I P P E D .**

(1 pt) **The principle of natural selection is essentially important to Darwin's theory of natural selection, and this is essentially important to our understanding of evolution. According to the principle of natural selection, exponential growth of populations forces selection to occur again and again.**

Which of the following statements is correct? Mark with a cross.

◯ The principle of natural selection is a rule, as it dominates the evolution of many, but not all species of organisms.

◯ The principle of natural selection is a law which dominates evolution of all species of organisms only.

◯ The principle of natural selection is a natural law which is only valid within the biotic world where it dominates the phylogenesis of all species and the ontogenesis of all organisms.

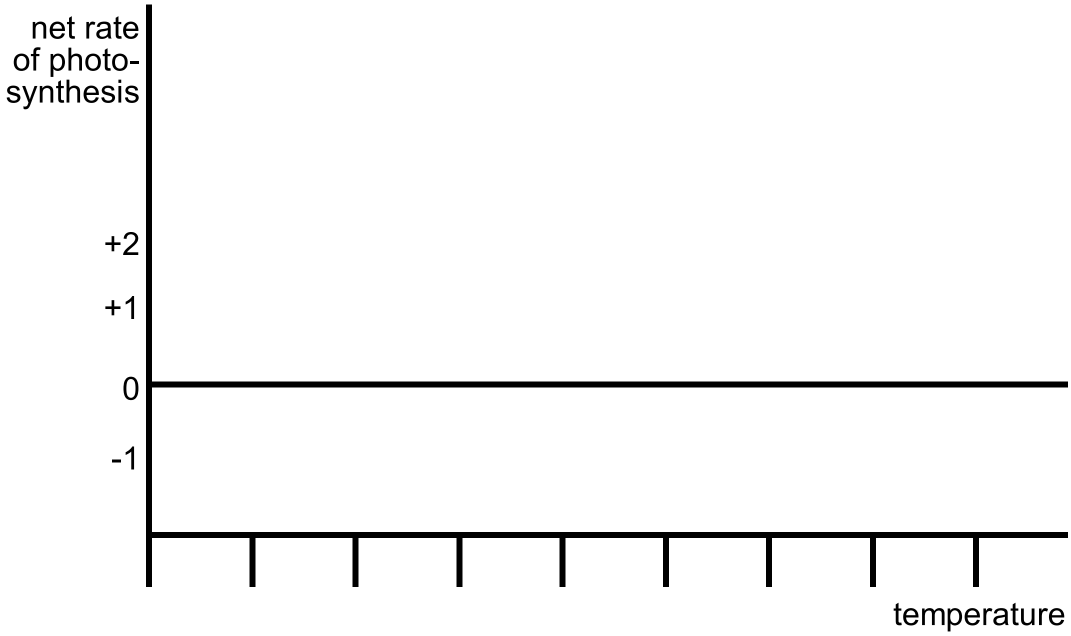
◯ The principle of natural selection is a natural law which in both the biotic and abiotic world dominates all processes in which self-replication of basic entries occurs.

◯ The principle of natural selection is only seemingly valid in evolution. In reality, it dominates nothing else than self-organization of dynamic order in abiotic systems.

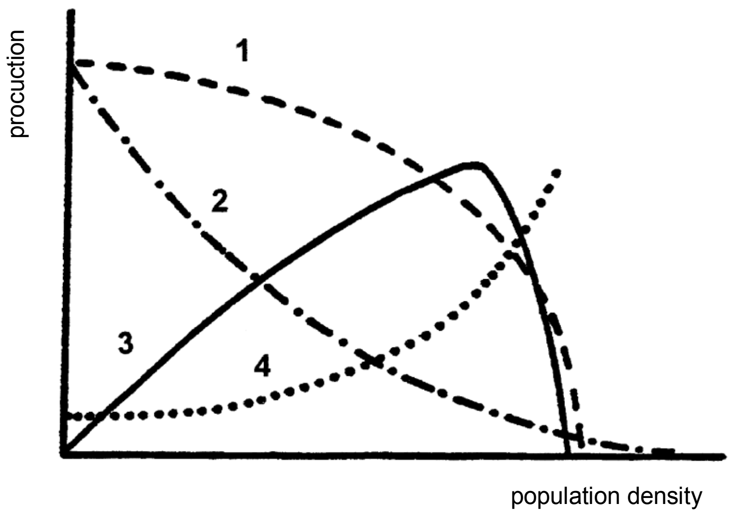
◯ The principle of natural selection is not a natural law but, rather, a tautology: The fittest are the most successful in survival and reproduction and, hence, they are the fittest.

ECOLOGY

B 29: (1 pt) **The dependence of the net photosynthesis on temperature follows a mathematical function. Show the dependence of the net photosynthesis on temperature ising the axes below, of a C_3 plant at light saturation.**



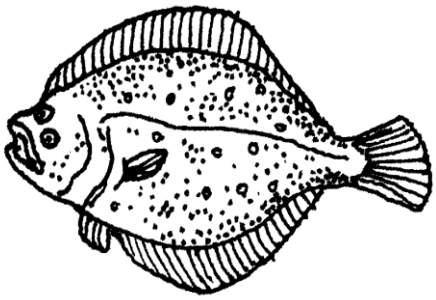
B 30: (2 pts) **The following graph shows the changes in values of various biological factors/parameters in relation to increasing density of fish.**



Match the curves 1, 2, 3 and 4 from the graph to the terms in the table. Match each curve only once.

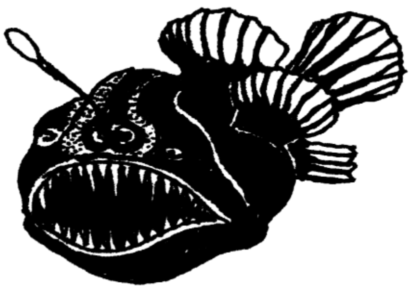
	curve from the graph
total fish production	3
individual growth	2
food potential not used	1
expenditure of energy of each fish in the search for food	4

B 31: The following pictures show fish from various locations.
(2 pts)

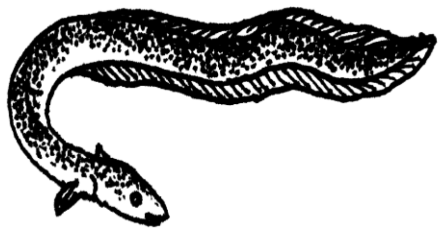


A. flat fish
at the bottom of shallow sea

B: tuna
in the open water in sea



C: angler-fish
at the bottom of deep sea



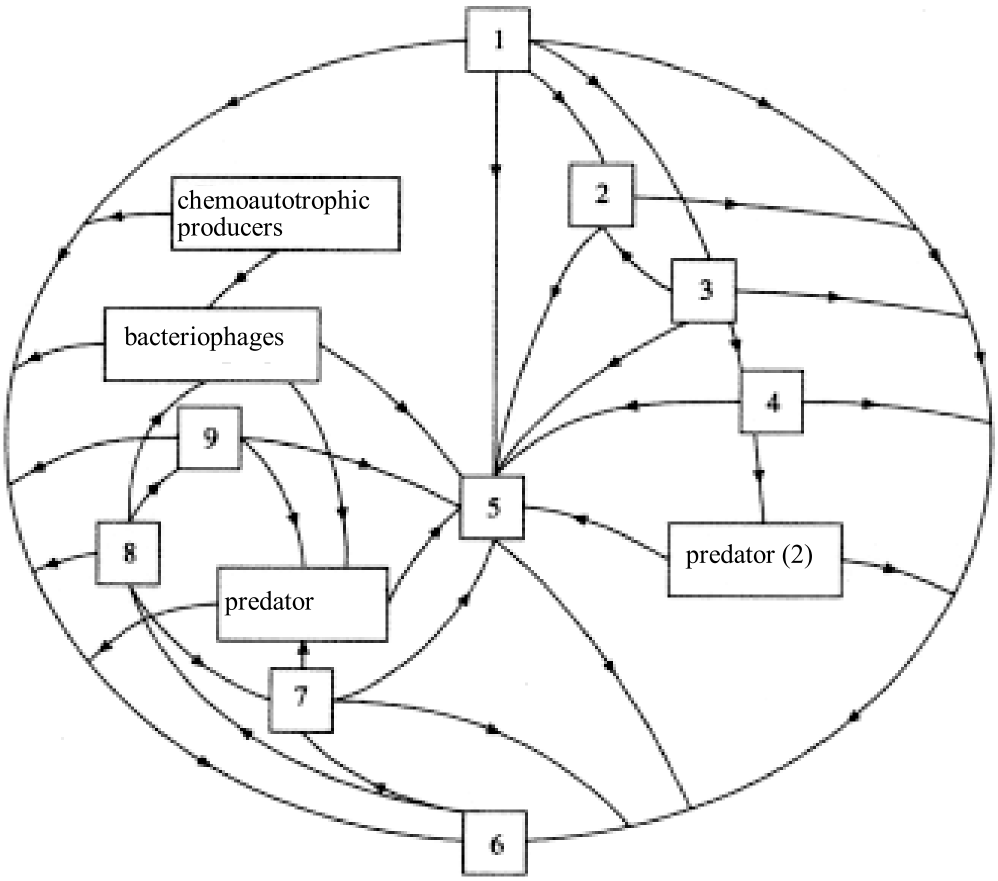
D: eel
predominantly at the bottom of fresh water

Match the fish A, B, C and D from the picture to the gill surfaces in the table.

Gill surface per gramm body weight (in arbitrary units) of fish of various locations.

gill surfaces	fish
2551	B
902	D
462	A
51	C

B 32: **The following figure shows a section of a food web in an ecosys-**
(3 pts) **tem.**



Write down the numbers from the figure at the appropriate place in the following table.

Parts from a food net in an ecosystem

part from the food web	assigned number from the picture
organic waste	6
pantophage (omnivore)	2
saprophage (delritivores)	7
photoautotrophic organisms (producer)	1
phytophage (herbivore)	3
decomposers	8
mycophages	9
parasitic animals	5
zoophage (predator I)	4

B 33: (2 pts) **Genetically identical seedlings of the sunflower *(Helianthus, Asteraceae)* were planted in two neighbouring gardens A and B. After three months the plant height was measured with the following results:**

garden	number of plants	average height (in mm)	standard deviation
A	12	1.6	0.3
B	16	1.4	0.2

How can the differences be evaluated regarding the growth?

(1) The differences are accidental. The growth conditions in both gardens are the same (null hypothesis).

(2) The differences do not occur by coincidence. The growth conditions in garden A and B are significantly different (null hypothesis is rejected). You have to check the question with the help of the t-test.

The following t-values should be used.

probability	critical t-value
90 %	1.32
95 %	1.71
97 %	2.06
99 %	2.48
99.5 %	2.78

<u>Exercises:</u>

(1) Calculate the standard deviation of each difference between the average values for garden A and B for this t-test. Use the following formula:

$$S = \sqrt{\left\{\left(S_A^2 / n_A\right) + \left(S_B^2 / n_B\right)\right\}}$$

Result: .... S = 0,10 ....

(2) Calculate the t-value and determine by which probability the null hypothesis can be <u>rejected</u> (the differences are significant). Mark with a cross.

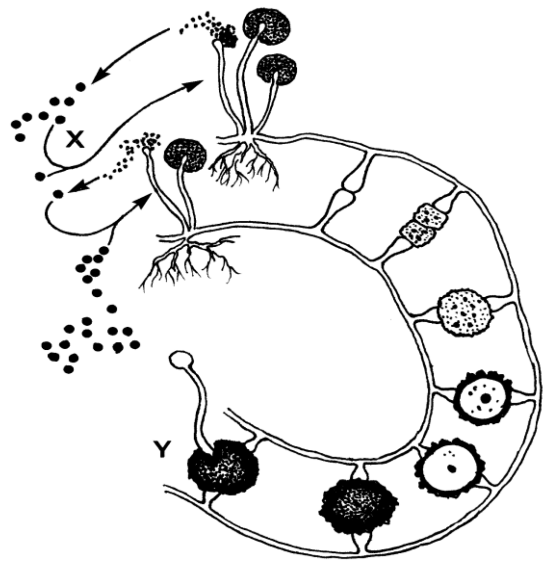
<u>probability</u> ◯ < 90 % (X) 95 to 97.5 % ◯ 99 to 99.5 %

◯ 90 to 95 % ◯ 97.5 to 99.0 % ◯ > 99 %

SYSTEMATICS/TAXONOMY

B 34: The following illustration shows the life cycle of a fungus.

(2 pts)



(1) Which fungus group does the fungus whose life cycle is shown belong to? Mark the correct answer with a cross.

◯ *Ascomycota*
◯ *Basidiomycota*
(X) *Zygomycota*

(2) Which kind of spores are spread at X?

◯ haploid meiotic spores
(X) haploid mitotic spores
◯ diploid spores

(3) Which way of life is typical for this fungus?

(X) This fungus is a saprophyte.
◯ This fungus is a parasite.

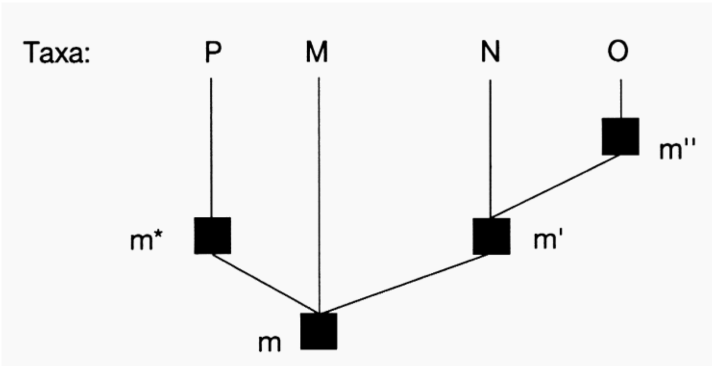
(4) Where does the meiosis take place?

◯ The meiosis takes place at X.
◯

X The meiosis takes place at Y.

B 35: (3 pts) **A synapomorphy is a homologous characteristic of *various* species (therefore *Syn-*), that has evolved/is derived (apomorphic) compared with the primary absence or previous state of that characteristic in other species. The original characteristic m evolves into m' and m'' on the one hand and to m* on the other (see figure).**

Note that m' is apomorphic compared with m, but not compared with m''. M, N, O and P could be the taxa in which the characteristics occur.



Mark the statements which are compatible with the definition of synapomorphy.

- ◯ m' is a synapomorphy of N compared with m in M
- ◯ m' is a synapomorphy of N
- ◯ m' is a synapomorphy of NO (N plus O) compared with m in M
- ◯ m'' is a synapomorphy of O compared with m in M
- ◯ m'' is a synapomorphy of O
- ◯ m'' is a synapomorphy of O compared with m* in P
- ◯ m'' is a synapomorphy of O compared with the primary absence of m'' in P
- ◯ m'' is a synapomorphy of N compared with the primary absence of m' in M

◯ the secondary lack of m’ in O is a synapomorphy of O compared with m’ in N

B 36: (1 pt) **A set of species is called monophyletic if it contains exactly all known species which are decendants from one well characterized but nevertheless hypothetical stem species.**

For calling a studied set of species monophyletic the proof of at least one synapomorphy of this set is

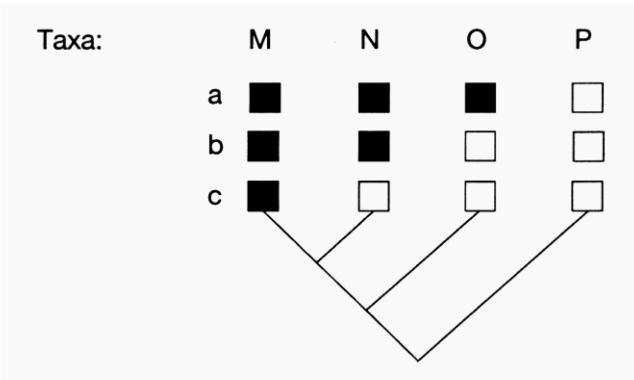
◯ necessary and sufficient

(X) necessary, but not sufficient

◯ not necessary, but sufficient

◯ not necessary and not sufficient

B 37: (2 pts) **In cladistics (a method of systemactics) the outgroup comparison plays an important role. It works as follows: The states of the characteristics a, b and c marked black and white, are present in the taxa M, N, O as shown in the figure. Suppose MNO (M plus N plus O) are monophyletic. P is then its outgroup. As the states marked black occur only within MNO they are apomorphic compared with the states marked white which occur both in MNO and the outgroup P.**



What is correct? Mark with a cross.

◯ 1. The states of the characteristics m, n and o marked black are not only apomorphies but even synapomorphies of MNO, MN and M compared with the states marked white.

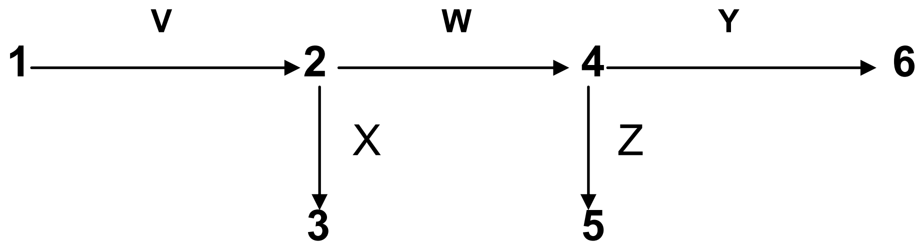
◯ 2. Because of the evidence of synapomorphy, the states of m, n and o marked black are even homologies of MNO, MN and M, respectively.

◯ 3. If the states of a, b and c marked black do not occur outside of MNO, MN and M, respectively, these sets of species are monophyletic.

◯ 4. The outgroup comparison method has led to a circular argument.

MICROBIOLOGY/BIOTECHNOLOGY

B 38: (2 pts.) **The diagram represents a sequence of reactions taking place in a bacterium, in which amino acids are produced from one another by the action of specific enzymes. Numbers 1 to 6 represent different amino acids; letter V to Z represent different enzymes. All the amino acids are essential for survival. The original strain of the bacterium required only amino acid 1. A mutant strain of the bacterium could only survive when provided with amino acids 1,2 and 5 in its culture medium. Which enzymes were missing in the mutant strain?**



In the mutant the following enzymes were missing: ..... V, Z .....

B 39: Mark the correct answers with a cross. (2 pts)

◯ 1. Yeast cells used for wine production tolerate up to 14 % ethanol.

◯ 2. Citric acid is produced industrially with the help of *Aspergillus niger* in an anaerobic process.

◯ 3. By mutagenesis and strain selection bacterial and fungal production of antibiotics is increased on a higher level than by gene amplification.

◯ 4. Cephalosporins are produced by bacteria.

◯ 5. The flock of activated sewage sludge is the active microbiological aggregate in anaerobic waste water treatment.

◯ 6. It was found in practice that microorganisms modified by gene tech nology for in situ remidiation of organic contaminations in the soil or ground water are inferior to the adapted, natural microbial community with regard to their cleaning performance.

B 40: What is correct? Mark with a cross. (1 pt)

(X) H_2 can be used as an electron donor by chemolithoautotrophic bacteria.

- ◯ Sulphate reducing bacteria are inferior to methanogenics bacteria when competing for hydrogen.
- Ⓧ H_2 is used for the denitrification of drinking water.

5.2 Practical Tests

5.2.1 Laboratory 1: Systematically-anatomically orientated

Introducing remarks:

In laboratory 1 you have to solve both of the following tasks:

Task 1: Anatomical examination of a plant leaf

Task 2: Examination and systematic classification of four different plant species.

Read the questions for both tasks and then decide in which order you would like to work.

Please, do not forget to write down your personal data (Surname, First name, Country, Code Number) in the space provided.

Task 1: Examination of a plant leaf

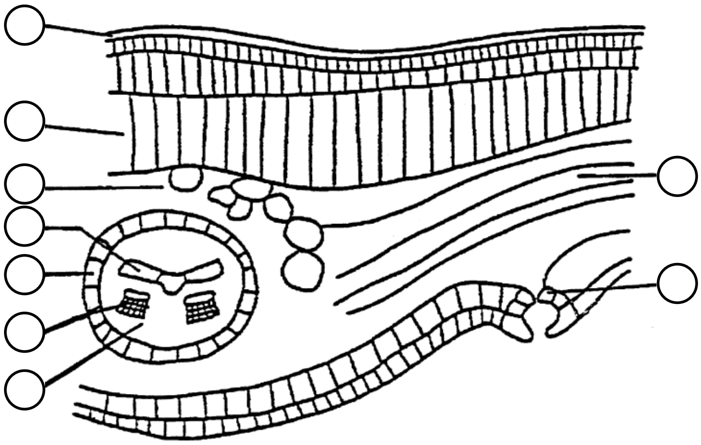
(14 pts)

Introducing remarks:

The required equipment and chemicals for the examination are at your bench. Use the equipment and chemicals suitable for you examinations. Make several cross sections through the penne of the leaf (figure 1). Stain these cross sections with the aqueous solutions of the dyes Astra-blue (stains cellulose) and Auramin (stains lignin) and analyse the anatomic structures under the microscope. As supplementation you can make longitudinal and surface sections.

1 (1.1) (9 pts) **Label the given schematic drawing (figure 1). Write down the code numbers of the given anatomical structures next to the correct reference lines.**

Code numbers:
1. Cuticula
2. Epidermis
3. Hypodermis
4. Spongy parenchyma
5. Palisade parenchyma
6. Vascular bundle sheath
7. Xylem with lignin
8. Phloem with sieve cells and parenchyma
9. Transfusion tissue
10. Accessory transfusion tissue
11. Stomatic cells



1 (1.2) Which of the following systematical groups does the object refer
(2 pts) **to? Mark with a cross.**

◯ Fern (*Polypodiophyta, Pteridophyta*)

◯ Gymnosperms

◯ Angiosperms

1 (1.3) Evaluate the object from the ecological point of view.
(3 pts) **Mark with a cross.**

◯ Hydrophyte (swamp or water plant)

◯ Hygrophyte (plant with adaptions to damp locations)

◯ Mesophyte (plant with adaptions to balanced locations)

◯ Xerophyte (plant with adaptions to dry locations)

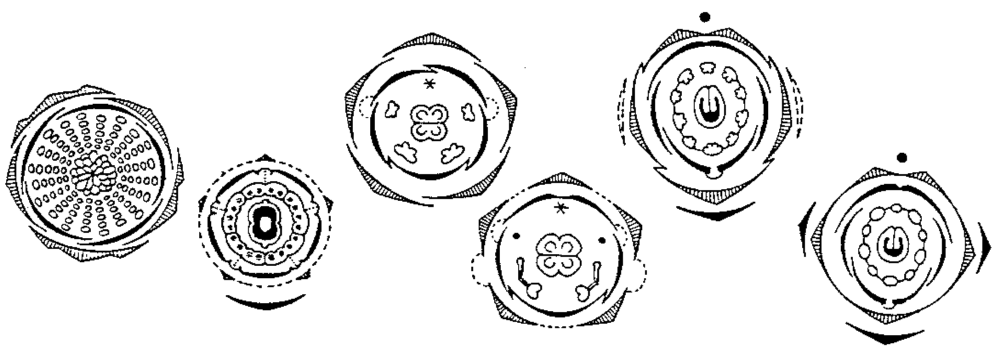
Task 2: **Examination and systematic classification of four different**
(24 pts) **plant species.**

Introducing remarks:

On your bench there are four vessels. In each vessel there is a flowering shoot of a plant species. The species are labelled A, B, C and D. The required equipment and a magnifying glass microscope are on your bench as well.

Analyse the given objects A, B, C and D morphologically. Answer the following questions with the help of the answer code and fill in the corresponding code numbers in the table below.

1 (2.1) **Which floral diagram (D 1 - D 6) belongs to which species? Fill in**
(4 pts) **your decision (code number) in the table at the end of this task.**



use **D1** **D2** **D3** **D4** **D5** **D6**
as code numbers

1 (2.2) **Which family name belongs to which species? Fill in the corre-**
(8 pts) **sponding code number in the table.**

Code numbers:

1. *Asteraceae* 4.	4. *Lamiaceae*	7. *Rosaceae*
2. *Brassicaceae*	5. *Oleaceae*	
3. *Fabaceae*	6. *Ranunculaceae*	

1 (2.3) (4 pts) **Which species have which kind of fruit (F 1 - F 7)? Fill in the corresponding code number in the table.**

Code numbers:

F 1. Achene
F 2. Follicular fruit
F 3. Pulse
F 4. Fruit composed of four one-seed nutlets
F 5. Aggregate of nutlets
F 6. Stone fruit, Drupe
F 7. Berry

1 (2.4) (4 pts) **Which species have which inflorescence (B 1 - B 7)? Fill in the corresponding code number in the table.**

B 1. Spike
B 2. Capitulum
B 3. Panicle
B 4. Thyrsus
B 5. Bunch, Raseme
B 6. Solitary flower
B 7. Volute

1 (2.5) (4 pts) **Which species have which leaf arrangement? Fill in the corres-ponding code number in the table.**

Code numbers:

P 1. alternating
P 2. decussate
P 3. distichous

Table

	A	B	C	D
Diagram				
Family				
Fruit				
Inflorescence				
Leaf arrange-ment				

5.2.2 Laboratory 2: Physiologically - orientated

Task 1: Model experiment referring to the respiratory chain

(23 pts)

Introducing remarks:

Electron transfer through several redox systems to the terminal acceptor as it happens for instance in the endoxidation of the respiratory chain can be simulated in a model experiment in a test tube, following the so-called BAUMANN experiment.

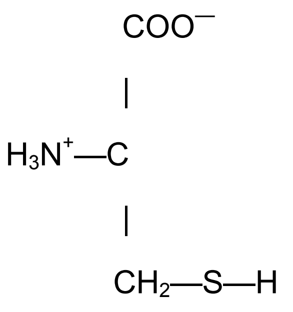
Add Fe^{2+} to a solution of sodium acetate containing the amino acid cysteine, shake it for a short time and write down the colour immediately and after some minutes. Shake the mixture again and write down the colour immediately and after some minutes etc.

Information: Cysteine forms a coloured compound with Fe^{3+}, whereas Fe^{2+} does not.

I: Preparation of the experiment

The following solution is necessary for the experiment:
10 ml of aqueous 0,1 M sodium acetate solution containing the amino acid cysteine in the concentration of 41 mM (=solution a).

It should be produced by mixing 0,2 M sodium acetate solution (solution b) with 82 mM cysteine solution (solution c).



CYSTEINE

2 (1.1) How many mg sodium acetate (waterless) have to be weighed for
(3 pts) **00 ml of the 0,2 M sodium acetate solution? For calculation use the following**

atomic masses: H:1; O: 16; C: 12; Na: 23.

Result (no decimals)	**1640 mg**

2 (1.2) (3 pts) **How many g cysteine have to be weighed for 100 ml of the 82 mM cysteine solution? For calculation use the following atomic masses:**

H: 1; O: 16; C: 12; S: 32; N: 14.

Round off the result (no decimals): **1 g**

Obtain solution b (6 ml), solution c (6 ml) and the required Fe SO_4 from the assistant and start the experiment.

II: Procedure

2 (1.3) (2 pts) **Mix solution b and solution c in the correct volume ratio to get 10 ml of the required solution a.**

The use of a pipette aid is obligatory.

Present your experiment and the remaining solutions immediately for judgement (score credit) to the laboratory advisor. Leave your pipette aid with the laboratory advisor.

If you have made a mistake in the procedure you can get solution b and solution c again. In this case you cannot score in (3).

2 (1.4) (1 pt) **Add $FeSO_4$ to the solution a, plug the test tube with a stopper and shake it strongly. Which colour does the solution have after shaking? Mark with a cross.**

- ◯ red
- ◯ white
- ◯ green
- ◯ <u>blue-violet</u>

2 (1.5) (1 pt) **Leave the test tube open (without stopper) for 1-2 minutes. Which colour does the solution have after this time? Mark with a cross.**

- ◯ red
- ◯ <u>white</u>
- ◯ green
- ◯ blue-violet

2 (1.6) **How often can the colour change be achieved by shaking?**
(1 pt) **Mark with a cross.**

- ◯ once
- ◯ up to 5 times
- ◯ <u>more than 6 times</u>
- ◯ not repeatable

III: Evaluation of the experiment:

2 (1.7) **Which component(s) is (are) used up in the experiment?**
(1 pt) **Mark with a cross**

- ◯ iron and oxygen
- ◯ <u>cysteine and oxygen</u>
- ◯ sodium acetate
- ◯ oxygen
- ◯ cysteine
- ◯ none

2 (1.8) **The redox potential Eo of the system Fe^{3+} / Fe^{2+} is + 0,77 Volt.**
(1 pt) **Which redox potential does an e^- donator of this system have? Mark with a cross.**

- ◯ greater than + 0,77 V   ◯ <u>less than + 0,77 V</u>
- ◯ equal to + 0,77 V

2 (1.9) **Which value does the redox potential Eo of the e^- terminal**
(1 pt) **acceptor have in the performed experiment? Mark with a cross.**

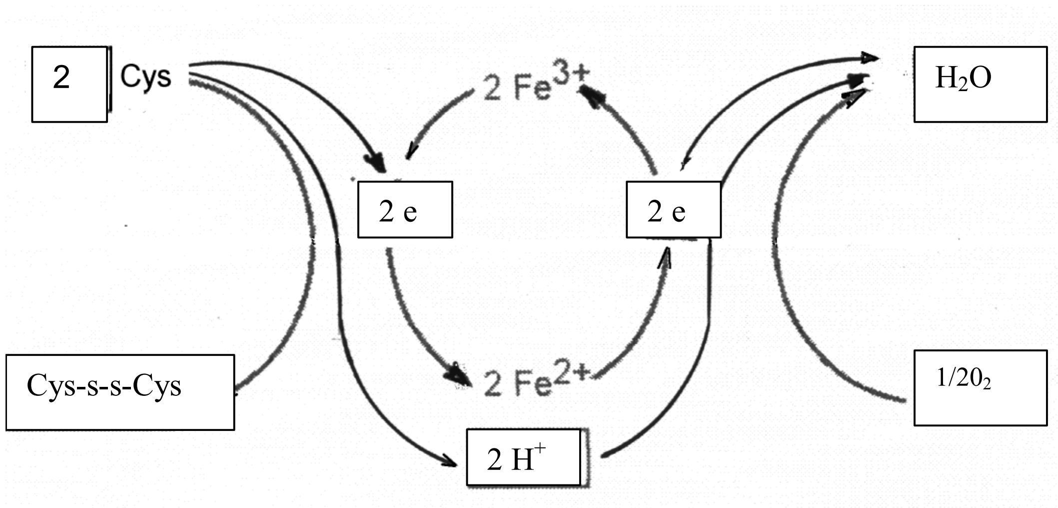
- ◯ greater than + 0,77 V
- ◯ less than + 0,77 V
- ◯ equal to + 0,77 V

2 (1.10) Which enzyme in the respiratory chain is analogous to the Fe-system in the BAUMANN experiment? Mark with a cross.
(1 pt)

- ◯ NADH ubiquinone reductase
- ◯ cytochrome oxidase
- ◯ ATP synthase
- ◯ ubiquinone cytochrome c reductase

2 (1.11) Complete the incomplete schematic drawing of the electron transfer in the BAUMANN experiment.
(8 pt)

You can score 1 or 2 points per correct item in ☐ .



Task 2: Imbibition movements of the awns in *Avena sterilis*

(17 pts)

Introducing remarks:

The basis for each imbibition movement is the swelling capability of wall substances. If imbibition occurs in all directions equally, it is called isotropic; if one direction is preferred, the imbibition is called anisotropic. Curvatures can be the result of a substantially different wall structure as well as a different texture – even in homogeneous material. Texture is the arrangement of fibrils in the wall layers. The movements to be observed in the proposed experiment are caused by different textures. Your object is distinguished by two conspicuous awns. You have to examine their movements. A magnifying glass (direct light and transmitted light) is available.

I. Procedure*:*

2 (2.1) Observe the movement of the awns after moistening.

(2 pts) **Put the air-dry spikelets together with the awns on a piece of paper and sprinkle the awns with water (use the sprayer) and observe (with the help of the magnifying glass as well) your object. Which reactions can you observe? Mark with a cross.**

- ◯ No reaction
- ◯ Both of the awns show a synergic rotation based on decoiling.
- ◯ The awns do not touch each other.
- ◯ Both of the awns show a synergic rotation based on spiralisation. Occasionally they hook together and sometimes start 'saltatory movements'.
- ◯ <u>Both of the awns show a synergic rotation based on decoiling. Occasionally they hook together and sometimes start 'saltatory movements'</u>.
- ◯ The movement of one awn is based on decoiling, the movement of the other one on spiralisation.

2 (2.2) Observe the awn movement when drying.

(2 pts) **Let the awns dry after the experiment (switch both lamps on full power and use them for heating). It can take 10 to 15 minutes until you can see a reaction. Observe your object. Which of the following statements is correct? Mark with a cross.**

◯ Both awns show a synergic rotation, which is based on spiralisation, occasionally they hook together, and sometimes start 'saltatory movements'.

◯ Both awns show a synergic rotation, which is based on decoiling. The awns do not touch each other.

◯ <u>Both awns show a synergic rotation, which is based on spiralisation.</u>

◯ <u>The awns do not hook together.</u>

◯ Both awns show a synergic rotation, which is based on decoiling, occasionally they hook together, and sometimes start 'saltatory movements'.

◯ The movement of one awn is based on decoiling, the movement of the other awn is based on spiralisation.

II. Evaluation

2 (2.3) Texture and imbibition of cellulose

(3 pts) **On your bench there are two pieces of typing paper. According to the manufacturing process the cellulose fibres are essentially longitudinally orientated.**

2 (2.3a) Give the paper a good spray of water from both sides and decide
(1 pt) **after about 5 minutes whether the paper preferably extents in the longitude of the fibre (A), cross to the fibre direction (B) or in both directions equally (C). Mark with a cross.**

◯ A

◯ <u>B</u>

◯ C

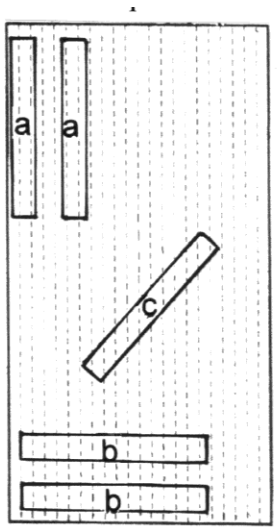
2 (2.3.b)What is the maximum extention given in percent?

(2 pts) **Fill in the result:** 2,3 %

2 (2.4) Perform a mental experiment.

(8 pts) **In figure 1 the fibre direction of a piece of paper is given in dotted longitudinal lines. Stripes of paper are labelled a, b and c. Imagine: The stripes given in figure 1 are cut out, moistened and clued together identically as shown in column 1 of the table 1. For drying the stripes are hung up at the upper end (*).**

Draw the expected form modifications as a side view in column 2 (table 1).



	Column 1	Column 2	
A	a + a	*	1P
B	b + b	*	1P
C	b + a	*	1P
D	a + b	*	1P
E	a + c	*	1P

2 (2.5) Link the observations regarding the awn movement to the result

(2 pts) **of the (4) pilot experiment (mental experiment).**

Which texture are the movements of the awns based on?
Mark with a cross.

- ◯ (aa)
- ◯ (bb)
- ◯ (ba)
- ◯ (ab)
- ◯ (ac)

5.2.3 Laboratory 3: Genetically - microbiologically orientated

Task 1: Isolation of bacterial DNA

(12 pts)

Introducing remarks:

DNA should be isolated from cells of a 5-day-old liquid culture of the bacterium *Escherichia coli* K 12. Various biochemical steps have to be done in a certain order under different temperatures and incubation times. The tasks are: (1) to determine the correct order of these steps, (2) to assign a specific temperature and incubation time to these steps and (4,5,6) to select the correct substances or solutions for the relevant steps.

3 (1.1) (4 pts) **Determine the correct order of the steps. Write down the code letters of the following steps in the correct order.**

A winding up the DNA

B disruption of the cytoplasmic membrane

C precipitation of the uncleaned DNA

D disruption of the bacterial cell wall

Order: D, B, C. A...

3 (1.2) (3 pts) **Assign one of the temperatures (T) and incubation times (I) given below to each of the following steps.**

- Disruption of the cytoplasmic membran T: .+ 60^0 C I: 2 min..
- Precipitation of the uncleaned DNA: T: . 0^0 C I: 30 sec
- Disruption of the bacterial cell wall: T: . +37^0 C. I: 10 min.

Incubation time: 30 sec, 2 min, 10 min, 15 min, 30 min

Temperature: 0^0 C, room temperature, +37^0 C, +60^0 C, +100^0 C

Realize the following steps in the order you have determined.

3 (1.3) STEP A: Winding up the DNA

(2 pts) **Try to wind up the precipitated DNA strands with a wooden rod.**

Ask the laboratory advisor to score the result.

(The laboratory advisor is going to sign.)

- ◯ <u>DNA could be wind up</u>
- ◯ DNA could not be wind up

3 (1.4) STEP B: Disruption of the cytoplasmic membrane.

(1 pt) **To disrupt the cytoplasmic membrane you have to add 0.2 ml of one of the following solutions.**

Mark the correct answer with a cross.

- ◯ HCl (1 M)
- ◯ acetone (pure)
- ◯ glycerine
- ◯ <u>sodiumdodecylsulphate solution (25 %)</u>
- ◯ NaOH (1 M)

3 (1.5) STEP C: Precipitation of the uncleaned Dann

(1 pt) **For the precipitation of the uncleaned DNA the lysate has to be overlayed with a liquid. Select the correct one from the following liquids and mark it with a cross.**

Realize the overlaying in the following way: Let the fluid from a beaker slowly run down the wall of the test tube. The well-perceptible whitish strands which separate slowly from the aqueous phase after overlaying predominately consist of chromosomal DNA.

- ◯ <u>ethanol (96%, denatured)</u>
- ◯ double distilled water (aqua bidest.)
- ◯ HCl (1 M)
- ◯ NaOH (1 M)
- ◯ glycerine

3 (1.6) STEP D: Disruption of the bacterial cell wall

(1 pt) **To disrupt the bacterial cell wall a tip of a spatula of one of the following substances has to be added to a culture of *Escherichia coli* K12 (in a test tube).**

Mark the correct substance with a cross.

- ◯ penicillin
- ◯ lysozyme
- ◯ urea
- ◯ $CaCl_2$
- ◯ trypsine

Task 2: Investigation of the mitosis in the root meristem of a specimen of the *Magnoliopsida* (*Dicotyledoneae*)

(25 pts)

Introducing remarks:

Young roots were harvested from plants grown in sand and differently treated:

Treatment (1): Incubation (for 4 hours) in the aqueous solution of a substance that inhibits chromosome movement

Treatment (2): Incubation (for 24 hours) in ethanol/glacial acetic acid (3:1)

Treatment (3): Incubation (for 24 hours) in a saturated solution of car mine in 45 % acetic acid

Treatment (4): Heating in a boiling water bath for 5 minutes

On your bench you can find two different samples.

Sample I: Root tips only submitted to treatments (2) - (4)

Sample II: Root tips submitted to treatments (1) - (4)

3 (2.1) Compression preparations

(2 pts) **Make compression preparations of the samples I and II in which as many cells as possible are in the cell cycle, lying in a monolayer and flattened in such a way that the chromosome arms are pushed into a focus layer but are not squash-damaged.**

Apply a technique you are familiar with or follow the procedure given below.

- Separate the apical meristem of a root in a droplet of 45 % acetic acid on the slide.
- Fragmentate the tip by distearing and slight squashing.
- Cover it with a cover glass.
- Disrupt the tissue clumps by gentle hints with the blunt end of a pair of forceps held upright down on the cover glass.
- Adjust the amount of liquid so that the cells glide but do not float.

In case of insufficient spreading add 45 % acetic acid; slightly lift the cover glass with a needle and avoid shifting of the cover glass by a pair of forceps.

When spreading is sufficient the preparate is covered with a tissue and a gentle pressure by a finger is applied in order to flatten the cells. Attention! The danger of squash-damaging is particularly high when the cells are well spread.

Present your preparates (under the microscope) to the laboratory advisor for quality control and scoring at any time.

3 (2.2) Scetches of different cell stages

(8 pts) **Prepare scetches of the stages of the cell cycle using sample I (a), (b), (c), (e), and (f) and a metaphase-like figure of sample II (d) on the following blank page. Note the list of the stages of the cell cycle below. Draw a chromatide and a daughter chromosome only with a line but otherwise corresponding to your preparate; unclear regions may be circled with dotted lines.**

Stages of the cell cyle:

(a) interphase (1 pt)

(b) middle prophase (1 pt)

(c) metaphase plate in side view (3 pts)

(d) metaphase-like figure of sample II seen from above (1 pt)

(e) late anaphase or early telophase (1 pt)

(f) late telophase (1 pt)

Blank piece of paper (task 2). Scetches of cell stages.

3 (2.3) **Detailed drawings of chromosomes**

(10 pts) **Draw two metaphase chromosomes from sample I, true to nature, and label the drawing.**

3 (2.3a) **Draw two significantly different chromosomes.**
(2 pts)

3 (2.3b) **Characterize the drawn chromosomes by using capital letters according to the following terms.**
(3 pts)

A: metacentric
B: acrocentric
C: dicentric
D: acentric
E: satellite chromosome

3 (2.3c) **Label the parts of the larger chromosome using the code numbers of the following terms.**
(5 pts)

1. chromosome arm
2. chromatide arm
3. daughter chromosome
4. centromere
5. centrosome
6. satellite
7. nucleolus organisator region
8. nucleosome

Labelled drawings (task 3):

3 (2.4) **Chromosome number**

(1 pt) **Indicate the chromosome number of sample I. ......12........**

3 (2.5) **Ploidy level**

(1 pt) **Indicate the ploidy level of sample I. Consider that a distinctive chromosome type occurs only once in the haploid chromosome set. Mark with a cross.**

◯ haploid (1 n)
◯ <u>diploid (2 n)</u>
◯ triploid (3 n)
◯ tetraploid (4 n)

3 (2.6) **Effects of the treatments (1) - (4) (see introducing remarks p.7)**
(1 pt) **Match the treatments (1) - (4) to the effects you achieved. Write down the numbers of the treatment in the corresponding circles.**

- ◯ inhibition of the centromere fission
- ◯ inhibition of tubuline association
- ◯ fixation of protoplasmic structures
- ◯ shortening of the chromosomes
- ◯ staining of the chromatine
- ◯ staining of the nucleus spindle
- ◯ destruction of the middle lamella
- ◯ destruction of the primary walls

3 (2.7) **Treatment (1)**
(1 pt) **Which substance was used in the treatment (1)?**
Mark with a cross.

- ◯ <u>colchicine</u>
- ◯ bromouracile
- ◯ α- amanitin
- ◯ actinomycine
- ◯ mitomycine

3 (2.8) **Which aim was followed by J.H. Taylor (1958) when he applied**
(1 pt) **the same substance? Mark with a cross.**

- ◯ production of polyploid plants
- ◯ <u>verification of the hypothesis of semiconservative replication in eukaryotes</u>
- ◯ inhibition of mRNA synthesis
- ◯ inhibition of translation
- ◯ investigation of the cytomorphogenesis in *Desmidiacea*

5.2.4 Laboratory 4: Ethologically orientated

Task: (35 pts) **Experimental investigation of triad grasp, forceps grasp and tool (grasp of man as functions of primate hands).**

Introducing remarks:

During the evolution of primates the grasping hand has developed in a way that it can be used for locomotion as well as for manipulation of objects. Therefore a differentiated co-operation of hand, eye and brain is necessary.

For grasping or splitting tiny food items the ability to manipulate is particularly important (fine tuned motor function) to get sufficient food energy per unit of time and without foreign bodies.

The required equipment and objects are situated on your bench: 2 Petri dishes, a pair of angle forceps, sea sand (sieved), 20 sunflower seeds and a stopwatch. Precision scales are available for the weighing procedure.

Task:

4 (1) (2 pts) **Move your thumb and index finger of one hand without any optical control against each other. In which area do they touch each other? Mark with a cross.**

- ◯ inner side of the thumb and outer side of the finger
- ◯ outer side of the thumb and inner side of the finger
- ◯ outer side of the thumb and outer side of the finger
- ◯ inner side of the thumb and inner side of the finger

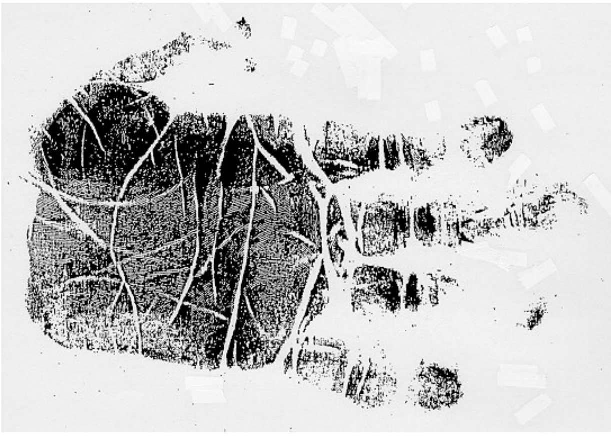
4 (2) How is this co-ordination possible? Mark with a cross.
(2 pts)

- ◯ by learning
- ◯ by ontogenetic maturing
- ◯ by the construction of the skeleton
- ◯ by neuronal decisions
- ◯ by flexor and extensor muscles

4 (3) (2 pts) **Figure 1 shows the print of a man's hand (Dr. Lucius), figure 2 shows the print of a chimpanzee's hand. How are the recognizable structures on the surface of the inner hand of man and chimpanzee called? S K I P P E D.**

- ◯ capillary ridges in both
- ◯ tactile fields in both
- ◯ prehensile relief of chimpanzees, papillary ridges of man
- ◯ papillary ridges in both

Print of a chimpanzee's hand (figure 1).



Print of a Dr. Eckhard R.Lucius's hand (figure 1).

4 (4) **Investigation of triad grasp, forceps grasp and tool grasp of**
(29 pts) **man: Arrange 20 sunflower seeds in the sand-filled Petri dish I in such a way that they lie flat, istributed over the whole dish, and do not touch each other.**

4 (4a) **Grasp each seed one after the other with your thumb, index**
(5 pts) **finger and middle finger at the same time (triad grasp). All 20 seeds are put individually one after the other in the empty Petri dish II. Measure the required time in minutes and seconds (e.g. 0:49 minutes) with the help of a stop-watch. Smoothen the sand in dish I, transport all the seeds with the help of a pair of forceps from dish II to dish I and weigh the sand (on a filter paper, in mg) that has been transported from dish II when grasping. Repeat the experiment 10 times, write down all data and fill in the results in the table on page 11.**

4 (4b) **Grasp each seed from the smoothened sand with your**
(5 pts) **thumb and index finger only (forceps grasp). Repeat the procedure from task (4.1).**

Determine the time and the transported amount of sand in 10 experiments and fill in the data in the table on page 11.

4 (4c) **Prepare the following experiment as described under (4.1).**
(5 pts) **However, <u>this time a pair of forceps</u> should be used for picking up the seeds (tool grasp). Repeat the experiment 10 times, measure the time and amount of sand and fill in the results in the table on page 11.**

4 (4d) **Decide in which of the experiments the smallest amount of sand**
(4 pts) **(on average) was transported together with the seeds. Mark with a cross.**

◯ smallest amount of sand in (4.1) (triad grasp)

◯ smallest amount of sand in (4.2) (forceps grasp)

◯ smallest amount of sand in (4.3) (tool grasp)

4 (4e) (10 pts) **Calculate the mean and the standard deviation (x ± s) of n = 10 values for the transported amount of sand and the required time in the experiments (4.1) to (4.3). Fill in the results in the table on page 11 and evaluate the significance of the transported sand with the help of the t-test. Mark below which of the differences is (are) significant and which is (are) insignificant.**

experiment 1 versus experiment 2 ◯ significant ◯ insignificant difference

experiment 1 versus experiment 3 ◯ significant ◯ insignificant difference

experiment 2 versus experiment 3 ◯ significant ◯ insignificant difference

Table

	experiment 1		**experiment 2**		**experiment 3**	
exp. no.	time (sec)	sand (mg)	time (sec)	sand (mg)	time (sec)	sand (mg)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
sum						
mean						
standard deviation						

Evaluation:

(1.) experiment 1: experiment 2 (sand)

t =________________; p

(2.) experiment 1: experiment 3 (sand)

t = ________________; p

(3.) experiment 2: experiment 3 (sand)

t = ________________; p

Appendix to the practical test - ethologically orientated

Test for differences in mean between two measuring series.
It has to be tested whether the difference between the results of the three experiments (amount of sand in mg) is statistically significant.

$n_1 =$ $n_2 =$ $n_3 =$

$\overline{x_1} \pm s_1 =$ $\overline{x_2} \pm s_2 =$ $\overline{x_3} \pm s_3 =$

Degrees of freedom

$m_1 = n_1 + n_2 - 2$ $m_2 = n_1 + n_3 - 2$ $m_3 = n_2 + n_3 - 2$

(1.) experiment 1: experiment 2

$$s_D = \sqrt{s_1^{\ 2} + s_2^{\ 2}} = \qquad t = \frac{\left|\overline{x_1} - \overline{x_2}\right|}{s_D} =$$

(2.) experiment 1 : experiment 3

$$s_D = \sqrt{s_1^{\ 2} + s_3^{\ 2}} = \qquad t = \frac{\left|\overline{x_1} - \overline{x_3}\right|}{s_D} =$$

(3.) experiment 2 : experiment 3

$$s_D = \sqrt{s_2^{\ 2} + s_3^{\ 2}} = \qquad t = \frac{\left|\overline{x_2} - \overline{x_3}\right|}{s_D} =$$

t- table (acc. to STUDENT)

	probability p for t		
m	0,05	0,01	0,001
18	2,10	2,88	3,92

6 Individual results and medals awarded

Rank	Score	Name	Country
Gold Medals			
1	200	JING	CHINA
2	198,5	CAHYNA	CZECH REPUBLIC
3	196,5	MASLOV	BELARUS
4	195	CHAKORN	THAILAND
5	191,5	RATNER	AUSTRALIA
6	190,5	DREYER	GERMANY
7	188	SONG	REPUBLIC OF KOREA
8	187,5	CHEN	CHINA
9,5	185,5	FRANZ	GERMANY
9,5	185,5	DONNELLY	UNITED KINGDOM
11,5	183,5	TREBILCO	AUSTRALIA
11,5	183,5	JIANSEN	CHINA
Silver Medals			
13	180,5	PARK	REPUBLIC OF KOREA
14	180	MALOSH	AUSTRALIA
15	178	NABOON	THAILAND
16	176,5	SEN	UNITED KINGDOM
17,5	176	DIMING	CHINA
17,5	176	SHIN	REPUBLIC OF KOREA
19,5	175,5	HEINZE	GERMANY
19,5	175,5	TSCHIPIGA	RUSSIAN FED:
21,5	175	FALT	CZECH REPUBLIC
21,5	175	VISSER	NETHERLANDS
23	174	SJÖÖ	SWEDEN
24	173,5	PIOTROWSKY	GERMANY
25,5	173	BEZRUTSCHKO	BELARUS
25,5	173	SAKALAR	TURKEY
27,5	172,5	OVCHINNIKOWA	BELARUS
27,5	172,5	SCHOLMA	NETHERLANDS
29	172	LEE	REPUBLIC OF KOREA
30	171	ANCHALEE	THAILAND
31	170,5	KAJZAR	POLAND
33	169,5	KUHAR	ARGENTINA

33	169,5	LJUBETSKI	BELARUS
33	169,5	GONCHARENKO	UKRAINE
35	169	NIKANORKIN	RUSSIAN FED:
36	168	RUDOLFOVA	CZECH REPUBLIC
37,5	167	ISAACS	AUSTRALIA
37,5	167	MCGEE	UNITED KINGDOM
39,5	166,5	ZABALOY	ARGENTINA
39,5	166,5	RYBNIKOV	UKRAINE
41	165	DANAI	THAILAND
Bronze Medals			
42	163,5	POLACEK	SLOVAK REPUBLIC
43	163	TODOROVA, TATINA	BULGARIA
44	161,5	WISE	UNITED KINGDOM
45	161	ÖZDEMIR	TURKEY
46	159,5	SEWOSTJANOWA	RUSSIAN FED:
47	159	RACHMATULINA	RUSSIAN FED:
48	158	STOICA	ROMANIA
49	157,5	DUNA	ROMANIA
50	156,5	BOGUSCH	CZECH REPUBLIC
51	155,5	KHYZHNIAK	UKRAINE
52,5	154,5	ROUMENINA	BULGARIA
52,5	154,5	UYANIK	TURKEY
54	154	LILIAN	MOLDOVA
55	151	DZIAN	SLOVAK REPUBLIC
56,5	148	PAULUS	BELGIUM
56,5	148	KOOL	NETHERLANDS
58,5	145,5	KIRJANOVA	LATVIA
58,5	145,5	KNAAP	NETHERLANDS
60	144	TODOROVA, IOVANA	BULGARIA
61	143,5	RADECKA	LATVIA
62	140	NYSSEN	BELGIUM
64	139	SADYKOW	KAZACHSTAN
64	139	JIGANOW	KAZACHSTAN
64	139	ÖZSOLAK	TURKEY
66	138	DE ANGELO	ARGENTINA
67	136,5	LAHDENPERÄ	FINLAND
68	135,5	LIEPINS	LATVIA
69,5	134,5	PIETRULEWICZ	POLAND
69,5	134,5	SKORUPKA	POLAND

71	134	SOLTES	SLOVAK REPUBLIC
72,5	133	WALKER	IRELAND
72,5	133	DAHLBERG	SWEDEN
74	129,5	BRIDGHAM	IRELAND
75,5	129	DIACONU	ROMANIA
75,5	129	KASIMOV	UZBEKISTAN
77	128	HUDAYBERDIYEN	UZBEKISTAN
79	127,5	RINALDI	ARGENTINA
79	127,5	DARIBAEW	KAZACHSTAN
79	127,5	KOVALIOVA	UKRAINE
81,5	126,5	AVI	ESTONIA
81,5	126,5	CHU	VIETNAM
83	126	PEURALINNA	FINLAND
84	125,5	MIHANIUC	MOLDOVA
85	124,5	DEFERME	BELGIUM
Other participants			
86	122	McCARTHY	IRELAND
87,5	121	STOKSIK	POLAND
87,5	121	CARLSSON	SWEDEN
89	119	MAMMADOV	AZERBAIJAN
90	118,5	LAHT	ESTONIA
91	117	HÄTINEN	FINLAND
92	116,5	MAMEDOV	TURKMENISTAN
93	116	FISCHER	ESTONIA
94	115,5	BAGIROV	AZERBAIJAN
95	115	SOSKA	SLOVAK REPUBLIC
96,5	114,5	YAHYAYEV	AZERBAIJAN
96,5	114,5	TASDEMIROV	UZBEKISTAN
98,5	113,5	ONODE	ROMANIA
98,5	113,5	VU	VIETNAM
100,5	112,5	GUTU	MOLDOVA
100,5	112,5	ZULHUU	MONGOLIA
102	112	OJANEN	FINLAND
103	111	SLUCKA	LATVIA
104	110	NIDHUBHGAILL	IRELAND
105	108,5	NGUYEN THI THU HUONG	VIETNAM
106	108	DEVLETOV	UZBEKISTAN
107	107,5	ATAYEV	TURKMENISTAN

108	107	NGUYEN VAN DUY	VIETNAM
109	106,5	ZUSUPOW	KIRGIZISTAN
110	105	CIALIC	MOLDOVA
111	104	MURADOV	TURKMENISTAN
112	100	ZAMANOV	AZERBAIJAN
113	99,5	GUINEFORT	BELGIUM
114	99	BATCHVAROVA	BULGARIA
115	98,5	HJERPE	SWEDEN
116	95,5	ESMAEEL	KUWAIT
117	95	ACHMEDOV	TAJIKISTAN
118	92	IBRAHIMOV	TAJIKISTAN
119	88,5	IMANAKUNOWA	KIRGIZISTAN
120,5	88	MONOLDOROW	KIRGIZISTAN
120,5	88	SUKHRAGCHAA	MONGOLIA
122	86,5	OYDUVSAMBUU	MONGOLIA
123	86	MOHAMMAD	KUWAIT
124	85	URBLA	ESTONIA
126	82	ALGASCHEW	KAZACHSTAN
126	82	MIRZOYEV	TAJIKISTAN
126	82	JALILOV	TAJIKISTAN
128	78,5	TOMURBAT	MONGOLIA
129	70,5	AJDARALIJEWA	KIRGIZISTAN
130	60	DAHDARI	KUWAIT
131	59,5	ALRAJHI	KUWAIT

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