Basic Biology Course

4 Ecological Principles

BASIC BIOLOGY COURSE

UNIT 2

ORGANISMS AND THEIR ENVIRONMENT

BOOK 4

Ecological Principles

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University of Sussex

Basic Biology Course
Book 4. Ecological Principles: Errata

Page 58 (bottom line)
Conversion equation should read '1 kcal = 4.2 kJ'

Page 63 (diagram in frame 61)
Heat output from decomposer standing crop (on left) should read '19310 kJ'

Page 69 (five lines from bottom)
'thousand' should replace 'million' (twice)

Pages 113, 114
The top lines of text on these two pages were inadvertently transposed during printing

CAMBRIDGE UNIVERSITY PRESS

CAMBRIDGE
LONDON · NEW YORK · MELBOURNE

Published by the Syndics of the Cambridge University Press
The Pitt Building, Trumpington Street, Cambridge CB2 1RP
Bentley House, 200 Euston Road, London NW1 2DB
32 East 57th Street, New York, NY 10022, USA
296 Beaconsfield Parade, Middle Park, Melbourne 3206, Australia

Library of Congress catalogue card number: 75–6285

ISBNs:
0 521 20658 8 hard covers
0 521 20638 3 limp covers

First published 1975

Printed in Great Britain
at the University Printing House, Cambridge
(Euan Phillips, University Printer)

Foreword

This book is part of a Basic Biology Course for undergraduates written by the Inter University Biology Teaching Project Team at Sussex.

The main aim of the book is to provide you with an understanding of the structure of ecosystems. An ecosystem may be defined as a unit within the area in which life is possible on our planet, where living and non-living things interact, and where, with the aid of energy from sunlight, both living and non-living materials are continuously recycled – i.e. a 'self-contained' unit. We feel strongly that all people who call themselves 'educated' should know about the biological nature of the world in which they live. We hope that you will share our belief at the end of this book, because at no time in the history of man has it been so important for all of us to possess this understanding. Unless this and future generations can appreciate what actual and potential havoc the increasing population of man can create, and in turn take measures to avert it, we may well be heading on the road, not only to self-destruction, but also the destruction of other living organisms which are part of our environment.

You will see that the emphasis of the book is on the dynamic structure of ecosystems. There is virtually no mention of the genetic and evolutionary principles behind such concepts as selection pressure, adaptation and speciation. This has been quite intentional, as these concepts will form part of the subject matter of a separate course (the Joint Universities Genetics Course) in which the University of Sussex is working collaboratively with the Open University and the Universities of Birmingham and Hull. It is intended that this genetics course will be available to students in 1976.

Brighton, Sussex, 1974

M.A. Tribe
M.R. Eraut
R.K. Snook

Acknowledgements

This book was developed under the auspices of the Inter University Biology Teaching Project and is the responsibility of the Sussex University Project Team. However, it owes a great deal to the students who studied and criticized our earlier versions and to many colleagues both at Sussex and elsewhere who made constructive suggestions for its improvement.

In particular we would like to thank the following:

The Nuffield Foundation for financially supporting the project from 1969-72;

Cambridge University Press for the continued interest and support in publishing the materials;

Mrs P. Smith and Mrs S. Collier, the project secretaries;

Mr Colin Atherton for photographic assistance; and

Mr D. Streeter (University of Sussex) and Professor W.H. Dowdeswell (University of Bath) for their advice.

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4.0. Introduction

One of the effects of our highly technological, functionally specific society, has been to make us 'consumer minded'. That is to say, we buy a product such as meat or bread or a car, with little thought about who produces it, how it is produced, or what the side effects of its production are.

Unfortunately, the manufacture of cars involves the deposition of vast quantities of slag on otherwise useful agricultural land, the evolution of poisonous vapours into the atmosphere, and extensive urbanization of the countryside. With the indiscriminate spread of industries such as these, less and less land is available for the rearing of cattle and the cultivation of wheat. Intensive agricultural methods are therefore employed, involving the massive use of inorganic fertilizers, insecticides, deforestation, and the production of poor-quality foods. These man-made assaults on nature, if uncontrolled, will take from the industrial society, both its source of food, and the amenity of an unspoiled environment. It is only by understanding the patterns and balances of nature that we can intelligently organize our production activities, control our consumer demands, and avoid the prospect of being surrounded by a sterile, featureless wasteland.

Another effect of 'consumer mindedness' has been to insulate us from the 'Third World', where starvation and disease are the order of the day. Often such conditions obtain because of ignorance, and the consequent inability to co-operate with nature to the advantage of man. It therefore seems to be incumbent on the more fortunate societies to help the starving majority by giving them an understanding of the patterns and balances of nature, and by providing them with the technology to maximize their natural resources, reclaim marginal land, deserts and marshes, and, one day perhaps, farm the sea.

4.1. Interactions between organisms and their non-living environment

4.1.1. Discussion

One of the effects of pollution on the environment has been to change it to such a degree, and at such a rate, and in such a direction, that many living things are unable to adjust to the change. It follows that if we are to manage our impact on the environment, we must first of all have an understanding of the requirements which living things have of their surroundings.

We shall start therefore by looking at a geographically well defined area – a lake – and see how living things in the lake distribute themselves. We shall then try to discover what variables in the lake are the determining factors in this distribution.

4.1.2. Overview and objectives

In this section we shall look at the evidence for the dependence of cells and organisms on various inorganic substances and energy sources in the environment. The products of this interaction in the form of new living material will be considered.

At the end of this section you should be able to:

1. Formulate and explain the concept of limiting factors.
2. Formulate and explain the concept of production.
3. Demonstrate some skill in
   (*a*) formulating hypotheses;
   (*b*) designing experiments;
   (*c*) interpreting graphical data.
4. List and describe the basic requirements which plants have of their environment.

4.1.3. Preknowledge requirements

(i) The general structure of plant and animal cells as revealed by the light microscope, e.g. cell wall, nucleus, chloroplast, mitochondria, vacuole.
(ii) The chemical symbols for the following chemical elements of the periodic table, e.g. C, H, O, N, S, P, Fe, Mn, Mg, Mo, S.
(iii) SI units: metres (m), grammes (g), litres (l), seconds (s).
(iv) Elementary understanding of chemical isotopes.
(v) Some knowledge of the chemical properties of O_2, CO_2 and H_2O; oxidation and reduction.

4.1.4. Instructions on working through the programmed sections

In the programmed sections which follow, questions and answers are arranged sequentially down the page. You are provided with a masking card and a student response booklet. Cover each page of the book in turn (unless otherwise instructed) and move the masking card down to reveal two thin lines:

This marks the end of the first question on that page. Record your answer to the question under the appropriate section heading in the response booklet provided. Then *check* your answer with the answer given. If your answer is correct, move the masking card down the page to the next two thin lines and so on. If any of your answers are incorrect retrace your steps and try to find out why you answered incorrectly. If you are still unable to understand the point of a given question, make a note of it and consult your tutor. The single thick line

---

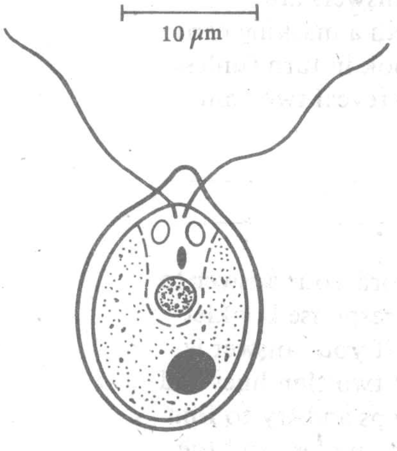
is a demarcation between one frame and the next.
Bold double lines signify convenient stopping points in the book.

4.1.5. Resource materials required

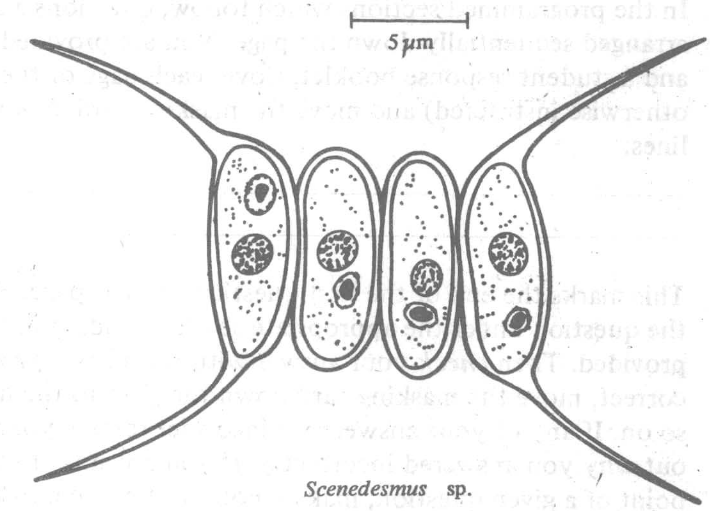
Before starting the section make sure you have the following materials:

- beaker of pond water
- 1 microscope
- microscope slides
- coverslips
- a needle
- test tubes
- dropping pipettes
- iodine solution
- petri dish
- bunsen burner
- test tube holder
- coarse forceps
- access to a variegated (green and white leaved) plant
- access to a slide projector and set of slides

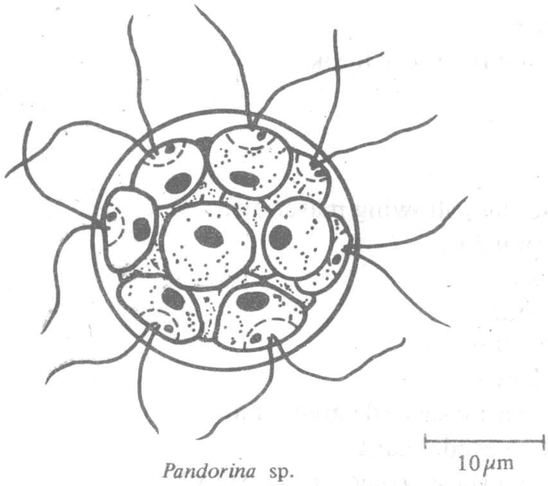
Examples of algae



Chlamydomonas sp.
(unicellular)

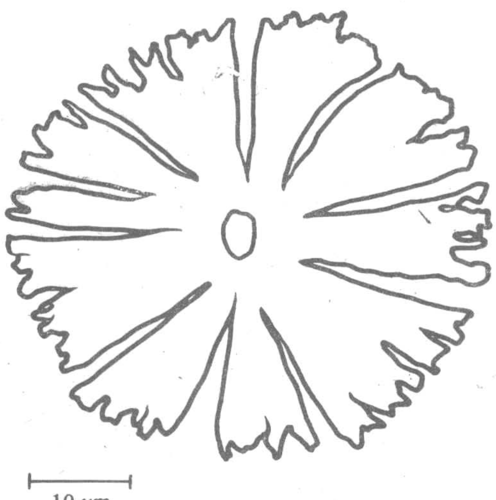


Scenedesmus sp.
(colonial groups of cells)

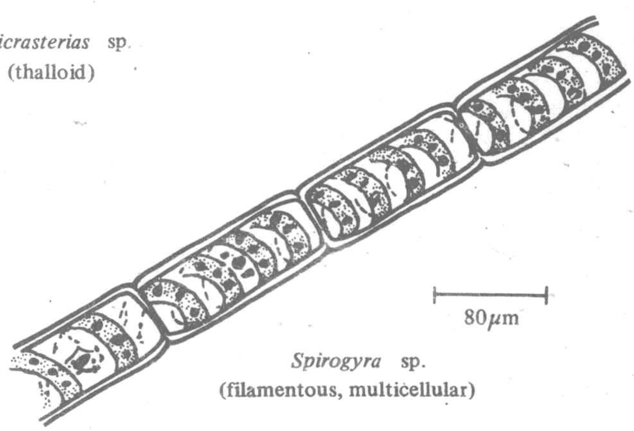


Pandorina sp.
(coenobial form – multicellular)

Ulothrix sp.
(filamentous)



Micrasterias sp.
(thalloid)



Spirogyra sp.
(filamentous, multicellular)

4.1.6. Looking into lakes and ponds

1 In the beaker marked A on the bench in front of you is a sample of water containing organisms taken from a pond. Using the dropping pipette provided, place a drop of this water in the depression of the cavity slide provided. Examine the drop under the microscope, using low- and high-power objectives. Give two reasons why you believe the objects you can see are living.

(*a*) They have a cellular organization.
(*b*) They show autonomous movement (some).

2 Can you suggest other criteria you would use to confirm your conclusion?

(*a*) Growth
(*b*) Reproduction

3 Are the organisms you can see uni- or multi-cellular?

Some are single-celled – uni-cellular (or acellular).
Some are long chains of cells – filamentous. } Multicellular
Some are sheets of cells – thalloid. }
(See diagrams opposite.)

4 What colour are the individual cells of these organisms?

Green or greenish yellow

5 Do the cells of these organisms have cell walls?

Yes

6 Would you say that these organisms are plants or animals? Give your reasons.

Plants, since they are green and have cell walls.

7 How many different types of unicellular plants can you see?

There may be many different types.

8 These minute plants are called *phytoplankton* (*phyto* = plant; *plankton* = floating or drifting life) and are found distributed in the main body of the lake water. If you wanted to find out which parts of a lake are most favourable to the phytoplankton population in early April – a time of rapid growth – what measurements would you make?

You probably suggested measuring the distribution of phytoplankton in samples of lake water; either samples from different points on the lake's surface, or samples from different depths, or both. In fact, depth is the critical factor for reasons which will emerge later.

9 Can you suggest why the distribution of phytoplankton should not be measured at a single point in time?

It would be impossible to distinguish the effects of past conditions in the lake from those of the present.

10 Bearing in mind your answer to frame 2, which of the following distributions would you use to ascertain the most favourable parts of the lake for phytoplankton? (Give your reasons.)

(*a*) Distribution of the increase in weight of living phytoplankton over a given period.
(*b*) Distribution of living phytoplankton.
(*c*) Distribution of the increase in the number of living phytoplankton over a given period.

a, which takes both growth and reproduction into consideration, would give the most accurate information. This quantity being a measure of the total increase in living material over a given period of time is given the name *production*.

b may be the result of conditions which no longer obtain.

c does not take growth into consideration.

---

11 All cells contain highly variable but relatively large quantities of water. Most of this water acts as a chemically inert medium supporting the chemical processes of life. So in what form would you weigh the phytoplankton?

Dehydrated. In this way one would measure the increase in dry weight, i.e. only the new *living* material. This quantity is called the *dry weight production*, though we often refer to it simply as the production.

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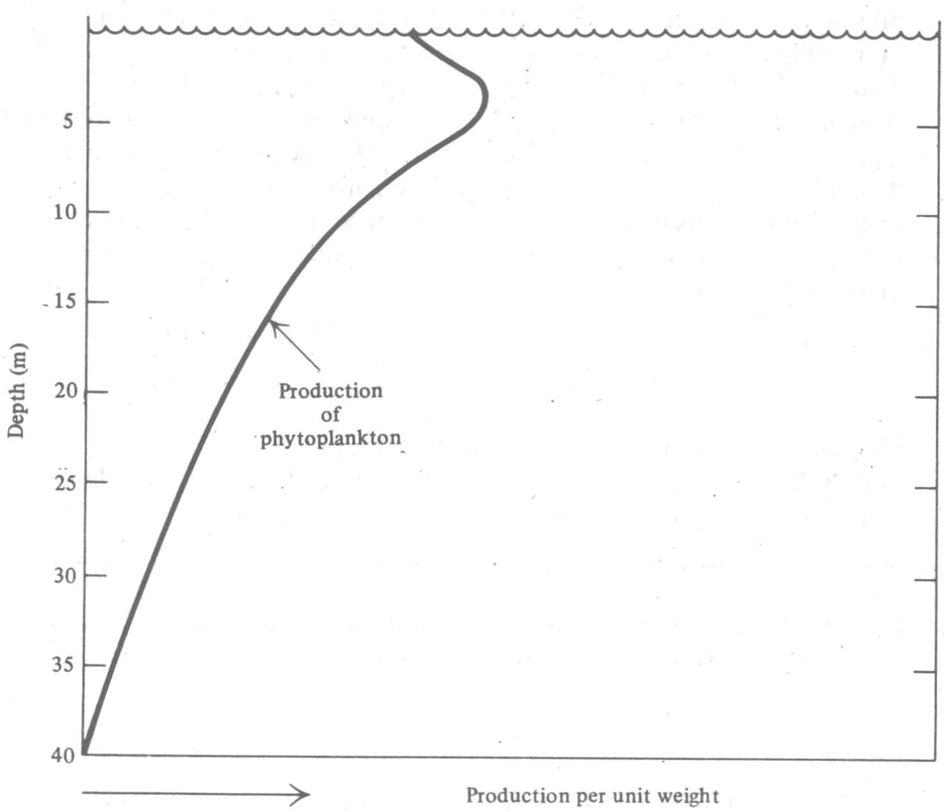
12 The distribution of phytoplankton dry weight production with respect to depth has been measured and is inserted on the graph below. Where would you say that conditions were most favourable for phytoplankton?



At a depth of about five metres

13 Why has production *per unit weight* been chosen for the horizontal axis?

Because it eliminates the concentration of phytoplankton as a variable; and this might depend on past as well as present conditions in the lake.

14 If W_1 and W_2 are the dry weights of phytoplankton in samples of equal volume taken at the same depth at the beginning and end of the experimental period, what is the production per unit weight at that depth?

$$\frac{W_2 - W_1}{W_1}$$

15 A chemical analysis of living things reveals that the elements generally found in greatest quantity are C, H, O, N, S and P. Other elements are present to a greater or lesser extent. Clearly, however, living things are more than a heap of chemicals. In fact, the characteristic which distinguishes living organisms from other non-living chemical systems is their supremely high level of complexity and sophisticated organization. Yet, as we have seen, in order to maintain themselves, living organisms depend on the presence of a favourable environment.
In the light of this discussion, what general environmental parameters, both physical and chemical, may have determined the distribution of production shown above?

Physical factors might be temperature, light, pressure.
Chemical factors might be the concentrations of various molecules containing C, H, O, N, S and P.

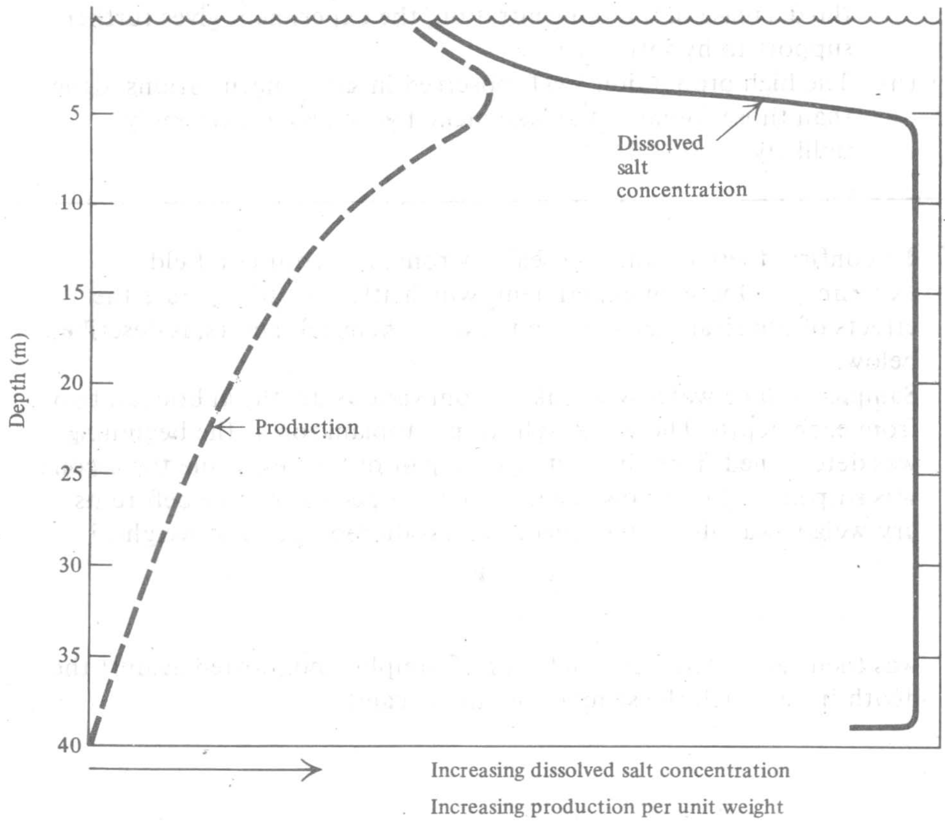
16 If several of the above factors influence production, which of them is likely to determine the shape of the production curve?

The one which is in too short or too great a supply. This is called the *limiting factor*.

17 Could there be more than one limiting factor responsible for our production distribution curve?

Yes

18 Let us first consider the possible effect on phytoplankton distribution of variations in the concentration of inorganic salts of nitrogen, sulphur and phosphorus. Examine the graph below.



In what ways might this inorganic salt distribution be responsible for aspects of the production curve (dashed line)? Suggest two hypotheses.

(*a*) Low salt concentration may reduce production at depths of less than five metres.
(*b*) High salt concentration may reduce production at depths of more than five metres.

19 **Slide 1** shows three beakers, one dark green (high production) containing x g/l of salts; the second medium green (medium production) containing $\frac{1}{2}x$ g/l of salts; and the third light green (low production) contains $\frac{1}{4}x$ g/l of salts. All three concentrations were higher than those found anywhere on the lake. The green colour results from the presence of phytoplankton grown for four weeks in the solutions. What information does the experiment give you with respect to the above hypotheses?

(i) Since production (as indicated by colour intensity) decreases with the decrease in salt concentration, the experiment gives further support to hypothesis *a*.

(ii) The high production levels observed in salt concentrations higher than those found in the lake make hypothesis *b* extremely unlikely.

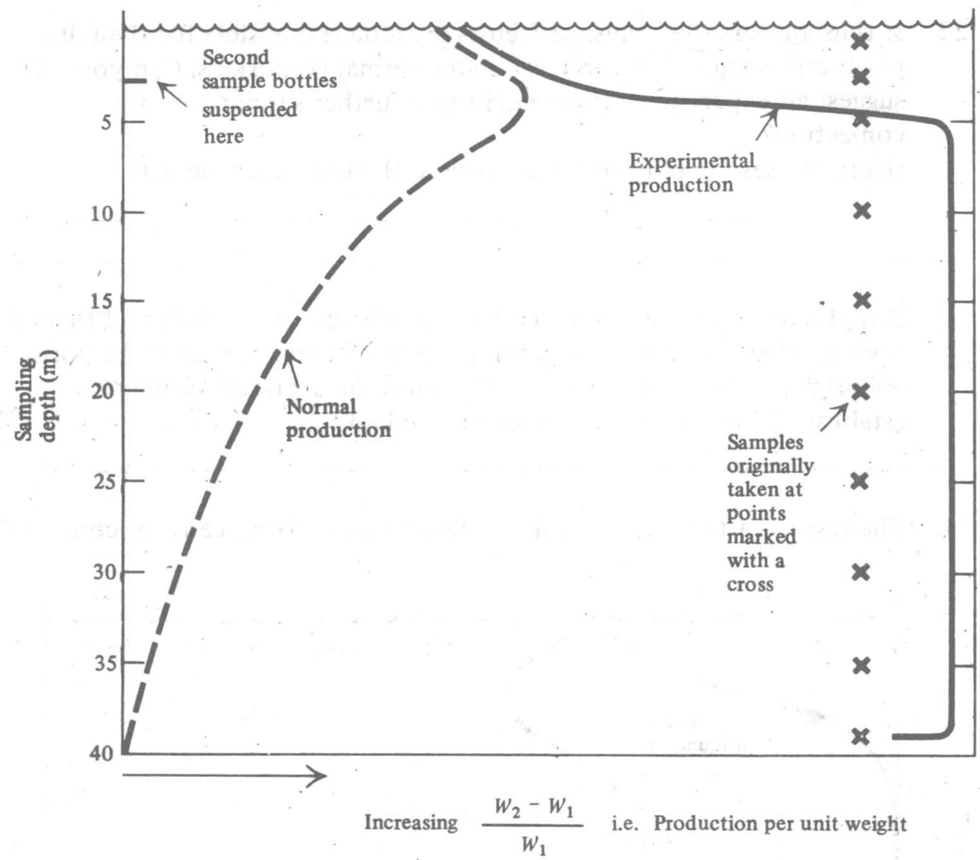
---

20 To confirm these results in a real environment requires a field experiment. One such experiment, which attempts to separate the effects of physical factors from those of chemical factors, is described below.

Samples of lake water were taken from various depths in bottles, two from each depth. The dry weight of phytoplankton at the beginning was determined from the first of each pair of bottles, while the second was suspended just below the surface for a period of time before its dry weight was also determined. The production per unit weight, i.e.

$$\frac{W_2 - W_1}{W_1}$$

was then calculated from each pair of samples and plotted against the depth from which the samples originally came.



For each sample bottle suspended just below the surface the factors corresponding to surface conditions were ________________________, and the factors corresponding to conditions at the sample depths were ________________________.

(Choose from temperature, light, pressure, and chemical factors.)

Surface conditions: *temperature, light*
Sample depth conditions: *pressure, chemical factors*

---

21 How do the results of this experiment affect the two hypotheses formulated in frame 18? Explain your answer.

There is some support for hypothesis *a*, as the drop in production in going from 5 m samples to surface samples can only be caused by chemical factors. (However, there could still be factors other than salt concentration, so hypothesis *a* is not definitely proved.) Hypothesis *b* is conclusively disproved as the chemical conditions in the samples from below 5 m clearly do not limit production.
