Fermentation Technology

UNIT 5

European Initiative for Biotechnology Education

Contributors to this Unit

Ognian Serafimov (Unit Co-ordinator), Gérard Coutouly, Jan Frings, Guido Matthée, John Schollar, Paul E.O. Wymer

The European Initiative for Biotechnology Education (EIBE) seeks to promote skills, enhance understanding and facilitate informed public debate through improved biotechnology education in schools and colleges throughout the European Union (EU).

EIBE Contacts

AUSTRIA

Rainhart Berner, Höhere Bundeslehr- und Versuchsanstalt für Chemische Industrie Wein, Abt. für Biochemie, Biotechnologie und Gentechnik, Rosensteingasse 79, A-1170 WEIN.

BELGIUM

Vic Damen / Marleen van Strydonck, Afd. Didaktiek en Kritiek, Universiteit van Antwerpen, Universiteitsplein 1, B-2610 WILRIJK.

DENMARK

Dorte Hammelev, Biotechnology Education Group, Foreningen af Danske Biologer, Sønderengen 20, DK-2860 SØBORG.
Lisbet Marcussen, Biotechnology Education Group, Foreningen af Danske Biologer, Lindevej 21, DK-5800 NYBORG.

EIRE

Catherine Adley / Cecily Leonard, University of Limerick, Plassey, LIMERICK.

FRANCE

Gérard Coutouly, LEGPT Jean Rostand, 18 Boulevard de la Victorie, F-67084 STRASBOURG Cedex.
Laurence Simonneaux, Ecole Nationale de Formation Agronomique, Toulouse-Auzeville, Boîte Postale 87, F-31326 CASTANET TOLOSAN Cedex.

GERMANY

Horst Bayrhuber / Eckhard R. Lucius / Regina Rojek / Ute Harms / Angela Kroß, Institut für die Pädagogik der Naturwissenschaften, Universität Kiel, Olshausenstraße 62, D-24098 KIEL 1.
Ognian Serafimov, UNESCO-INCS, c/o Jörg-Zürn-Gewerbeschule, Rauensteinstraße 17, D-88662 ÜBERLINGEN.
Eberhard Todt, Fachbereich Psychologie, Universität Gießen, Otto-Behaghel-Straße 10, D-35394 GIEßEN.

LUXEMBOURG

John Watson, Ecole Européenne de Luxembourg, Département de Biologie, 23 Boulevard Konrad Adenauer, L-1115 LUXEMBOURG.

ITALY

Toni Bargellesi / Stefania Uccelli / Alessandra Mannino, Centro di Biotechnologie Avanzate, Largo Rosanna Benzi 10 , I-16132 GENOVA.

THE NETHERLANDS

David Bennett, Cambridge Biomedical Consultants, Schuystraat 12, NL-2517 XE DEN HAAG.
Fred Brinkman,Vrije Universiteit Amsterdam, De Boelelaan 115, NL-1081 HV AMSTERDAM.
Guido Matthée, Hogeschool Gelderland, Technische Faculteit, HLO, Heijendaalseweg 45, NL-6524 SE NIJMEGEN.
Liesbeth van de Grint / Jan Frings, Hogeschool van Utrecht, Vakgroep Biologie, Postbus 14007, NL-3508 SB UTRECHT.

SPAIN

Maria Saez Brezmes / Angela Gomez Niño, Facultad de Educación, Universidad de Valladolid, Geologo Hernández Pacheco 1, ES-47014 VALLADOLID.

SWEDEN

Margareta Johanssen, Föreningen Gensyn, S-26800 SVALÖV.
Elisabeth Strömberg, Ostrabo Gymnasium, PO Box 276, Kaempegatan 36, S-451 17 UDDEVALLA.

THE UNITED KINGDOM

Wilbert Garvin, Northern Ireland Centre for School Biosciences, NIESU, School of Education, The Queen's University of Belfast, BELFAST, BT7 1NN.
John Grainger / John Schollar / Caroline Shearer, National Centre for Biotechnology Education, The University of Reading, PO Box 228, Whiteknights, READING, RG6 6AJ.
Jill Turner, Department of History, Philosophy and Communication of Science, University College London (UCL), 22 Gordon Square, LONDON, WC1E 6BT.
Paul Wymer, The Wellcome Centre for Medical Science, The Wellcome Trust, 210 Euston Road, LONDON, NW1 2BE.

EIBE Co-ordinator

Horst Bayrhuber, Institut für die Pädagogik der Naturwissenschaften an der Universität Kiel, Olshausenstraße 62, D-24098 Kiel 1, Germany.
Telephone: + 49 (0) 431 880 3137 (EIBE Secretary: Regina Rojek). Facsimile: + 49 (0) 431 880 3132.

Fermentation Technology

UNIT 5

European Initiative for Biotechnology Education

CONTENTS

Contents

World Wide Web

Few areas are developing as rapidly as biotechnology. So that they can be revised and kept up-to-date then distributed at minimum cost, the EIBE Units are published electronically.

These pages (and the other EIBE Units) are available throughout Europe and the rest of the world on the World Wide Web. They can be found at:

http://www.reading.ac.uk/NCBE

All of the EIBE Units on the World Wide Web are Portable Document Format (PDF) files. This means that the high-quality illustrations, colour, typefaces and layout of these documents will be maintained, whatever computer you have (Macintosh - including Power PC, Windows, DOS or Unix platforms).

PDF files are also smaller than the files from which they were created, so that it will take less time to download documents. However, to view the EIBE Units you will need a suitable copy of the *Adobe Acrobat*® Reader programme.

The *Acrobat*® Reader 3.0 programme is available free-of-charge. It can be downloaded from:

http://www.adobe.com/

With this software, you can view or print the EIBE Units. In addition, you will be able to 'navigate' around and search the documents with ease.

PLEASE NOTE: *Adobe* and *Acrobat* are trademarks of Adobe Systems Incorporated, which may be registered in certain jurisdictions. *Macintosh* is a registered trademark of Apple Computer Incorporated.

EIBE contributors

- **Ognian Serafimov (Unit Co-ordinator)**
  Assoc. Centre to UNESCO's INCS,
  c/o Jörg-Zürn-Gewerbeschule,
  Überlingen, Deutschland

- **Gérard Coutouly**
  LEGTP Jean Rostand,
  Strasbourg, France

- **Jan Frings**
  Hogeschool van Arnhem en Nijmegen,
  Nijmegen, Nederland

- **Guido Matthée**
  Hogeschool van Arnhem en Nijmegen,
  Nijmegen, Nederland

- **John Schollar**
  NCBE, The University of Reading,
  Reading, The United Kingdom

- **Paul E. O. Wymer**
  The Wellcome Centre for Medical Science
  London, The United Kingdom

Design, illustration and typesetting:
Caroline Shearer, NCBE, The University of Reading, The United Kingdom.

Acknowledgements

We are grateful to Madeleine and David Spears from Science Pictures Ltd. in Hitchin, UK, for the fruitful co-operation during the developmental process of the CD-ROM Fermentation.

Many thanks for the support by the Headmaster of Jörg Zürn Technical High School in Überlingen, Mr. Kurt Boch, as well as by the colleagues of the College for biological-technical assistants.

We also thank the Laboratory School of the Hogeschool van Arnhem en Nijmegen for using equipment and facilities and Herman Stevens for help and advice during development of this Unit.

Jan Frings, Wilbert Garvin (Northern Ireland Centre for School Biosciences, The Queen's University of Belfast, The United Kingdom), Dorte Hammelev (Educational Biotechnology Group, Frederiksberg, Denmark), Guido Matthée, John Schollar and Ognian Serafimov arranged and ran a multinational workshop in Konstanz and Überlingen in which materials in this Unit were tested. EIBE would like to thank them and the teachers from Germany, England, Italy, The Netherlands and Northern Ireland who took part and gave many helpful comments on the draft materials. The workshop participants were:

from Germany: Alfred Kemper and Matthias Scholliers
from England: Gill Slater and John Roelich
from Italy: Gabriella Foggi and Lucy Higgins
from The Netherlands: Winus van der Helden and Mieke Welschen
from Northern Ireland: Denmour Boyd and Barbara Gray.

These materials have been devised by practising teachers and educationalists from several European countries, brought together with financial support and encouragement from DGXII of the European Commission, under the auspices of EIBE, the *European Initiative for Biotechnology Education*.

The EIBE materials have been extensively tested in workshops involving teachers from across Europe.

The views expressed in this Unit and the activities suggested herein are those of the authors and not of the European Commission.

Particular attention should be paid to the general safety guidelines given inthe introduction to this Unit, and to the specific safety guidelines throughout the text.

© Copyright

This EIBE Unit is copyright. The contributors to this Unit have asserted their moral right to be identified as copyright holders under Section 77 of the Copyright, Designs and Patents Act, UK (1988).

Educational use. Electronic or paper copies of this EIBE Unit, or individual pages from it may be made for classroom use, provided that the copies are distributed free-of-charge or at the cost of reproduction, and the contributors to the unit are credited and identified as the copyright holders.

Other uses. The Unit may be distributed by individuals to individuals for *non-commercial* purposes, but not by means of electronic distribution lists, mailing (listserv) lists, newsgroups, bulletin board or unauthorised World Wide Web postings, or other bulk distribution, access or reproduction mechanisms that substitute for a susbscription or authorised individual access, or in any manner that is not an attempt in good faith to comply with these restrictions.

Commercial use. Should you wish to use this material in whole or in part for commercial purposes, or to republish it in any form, you should contact:

EIBE Secretariat
c/o Institut für die Pädagogik
der Naturwissenschaften
Universität Kiel
Olshausenstraße 62
D-24098 Kiel
Germany

Telephone: + 49 431 880 3137
Facsimile: + 49 431 880 3132
E-Mail: rojek@ipn.uni-kiel.de

⚠ Safety

In all of the EIBE Units, we have tried to check that all recognized hazards have been identified and that suitable precautions are suggested.

Where possible, the proposed procedures are in accordance with commonly-adopted general risk assessments. If a special risk assessment may be necessary, this has been indicated.

However, users should be aware that errors and omissions can be made, and that different employers and educational authorities adopt different standards. Therefore, before doing any activity, users should *always* carry out their own risk assessment. In particular, any local rules issued by employers or educational authorities MUST be obeyed, whatever is suggested in the EIBE Unit.

Unless the context dictates otherwise, it is assumed that:

- practical work is carried out in a properly equipped and maintained science laboratory;
- any mains-operated equipment is properly maintained;
- care is taken with normal laboratory operations such as heating substances;
- good laboratory practice is observed when chemicals or living organisms are used;
- eye protection is worn whenever there is any recognised risk to the eyes;
- pupils and/or students are taught safe techniques for activities such as handling chemicals and microorganisms.

INTRODUCTION

About this Unit

★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★

The aim of this unit is to convey knowledge about the role of fermenter technology in the large scale production of food, beverages and pharmaceuticals using micro-organisms (yeast, fungi and bacteria), about some historical aspects of biotechnology and also about laboratory research and development.

This unit, which is produced on a CD-ROM, has a modular structure in order to give teachers the opportunity to make the best choice for a particular situation. Of course it is recommended that the topic is introduced with a local and topical background, to awake the interest of the students.

The CD-ROM is a not only a source of illustrations, animations and video sequences for teachers, it can also be used by students directly as a powerful tool for learning. Self assessment questions and the corresponding answers are attached to each topic. A commentary gives additional information to the corresponding text.

Hints for the user

A PC with Windows and a CD drive which has to be assigned the letter D are necessary. Soundblaster with loudspeakers is needed for listening to the commentary. A system which will support a 16 or 32 bit image is necessary. Sometimes the file d:\windows\mmplayer.dll will need to be copied to c:\windows.

To operate with Windows 3.11 click "file" in the program manager, click "run" and "browse". Choose d:\ferm\ferm.exe and press return. With Windows 95 click "execute" and "browse", choose ferm and start with d:\ferm.exe.

A contents list of the topics in the CD-ROM follows for reference, with details of the images and video clips available at each topic point.

CD-ROM MENU

What is Fermentation?

Image: The "Peaky Head" of yeast during beer fermentation

- **Fermentation**
  Image: Traditional fermentation products
  - **Fermentation technology**
    Image: A full scale industrial fermenter

- **The microbes**
  Image: Fungi and Bacteria
  - **Bacteria**
    Image: Scanning electron micrograph of bacteria
    - Archaebacteria
      Image: Bacteria growing in hot springs at Yellowstone National Park
    - Eubacteria
      Image: Scanning electron micrograph of dividing bacteria.
  - **Fungi**
    Image: Scanning electron micrograph of Penicillium
    Video: Demonstration of fungi
    - Deuteromycota
      Image: Penicillium *colony on nutrient agar*

- **Microbial growth and respiration**
  Image: Petri dish growing micrococcus flavus *colonies*
  - **Microbial growth**
    Image: Aspergillus niger *colonies growing on agar*
    Video: Demonstration of microbial growth
    - Phases of microbial growth
      Image: Microbial growth curve (with a video animation of the growth phase of bacteria)
      - Primary metabolites
        Image: Important primary metabolites
        Video: Fermented alcohol is filled into barrels
      - Secondary metabolites
        Image: Important secondary metabolites

- Reproduction
  Image: Developing fungal hyphae (with a graphic of a counting chamber on the video click)

- **The basic metabolic pathway**
  Image: Some of the many metabolic pathways and their products

  - Catabolic processes
    Image: Breakdown of glucose

    - Glycolysis
      Image: Glycolysis (Embden Meyerhof pathway)

    - Tricarboxylic acid (TCA) cycle
      Image: Krebs cycle
      Video: Development of CO_2 by micro-organisms as a result of the Krebs cycle.

    - Anabolic (biosynthetic) processes
      Image: Products of microbe anabolism useful to humans

- **Culturing micro-organisms**
  Image: Checking the culture bottle
  Video: Culturing of micro-organisms in a small fermenter

- **Design of fermenters**
  Image: Small scale fermenters, collection and holding vessels
  Video: Animation of a fermenter with auxiliary equipment

  - **Batch culture**
    Image: Collecting a sample from a batch culture of beer
    Video: Example of a batch fermenter

  - **Continuous culture**
    Image: Continuous culture vessel
    Video: Animation of the continuous fermenter above

  - **Feed-batch culture**
    Image: Adding further nutrient and anti-foam to a feed-batch culture

  - **Common features in design**
    Image: A one litre laboratory fermenter

    - Maintaining aseptic conditions
      Image: Preparing to inoculate in the clean room

    - Aeration and agitation
      Image: Air supply and filtration unit
      Video: Aeration of a fermenter

    - Other characteristic aspects
      Image: Foaming in a culture vessel

- Controlling the conditions
  Image: Gauges and control as the head of a feed-batch fermenter

  - Temperature
    Image: Temperature probe and gauges
  - Balance between substrate and products
    Image: The equation as a graphic
  - pH
    Image: Graph showing of pH range of the three different classes of micro-organism
  - Aeration
    Image: Aeration by means of a sparger
  - Suitable level of culture microbes
    Image: Culture being inoculated into a stock bottle

Historical Perspective

Image: Producing the brewer's mash

- **Bread**
  Image: Structure of bread showing the holes created by CO_2
- **Cheeses**
  Image: Various cheeses
- **Soy sauce**
  Image: Soy sauce used as food flavouring
- **Beer**
  Image: Yeast being skimmed from the surface of fermented beer
- **Penicillin**
  Image: Penicillin and other antibiotics
- **Sewage**
  Image: Flow diagram of sewage works
  Video: Aeration of sewage in a waste water plant

Scope of Fermentation Technology

Image: Flow diagram of the fermentation process

- **Range of organisms used**
  Image: Products of fermentation (a list)
- **Products**
  Image: Products of fermentation process
- **Culture media**
  Image: Carbon source for yeast growth
  Video: Filling a fermenter with media materials

Laboratory Research and Development

Image: Laboratory check of a culture for antibody production

- **Screening for suitable organisms**
  Image: Culture of Streptomyces
  Video: Practical activities in a microbiological laboratory.
- **Development of genetically modified organisms**
  Image: Gene splicing; E. coli *containing plasmids and foreign cells*
  Video: Animation of gene modification based on the image
- **Use of animal cells, hybridomas, enzymes**
  Image: Artificially coloured SEM of immobilised yeast
  - **Animal cells**
    Image: Animal cells
  - **Hybridomas**
    Image: Production of hybridoma cells in a laboratory
  - **Algae**
    Image: Algae
  - **Immobilised enzymes and cells**
    Image: Ways of immobilising enzymes
    - Advantages of using immobilised enzymes and cells as biocatalysts
      Image: Production of immobilised enzymes
    - Disadvantages of using immobilised enzymes and cells
      Image: Immobilising enzymes, immobilised enzymes

Industrial Processes

Image: Typical fermentation plant

- **Scale up from development to industrial process**
  Image: The starter culture
  Video: Pilot plant reactors

- **Monitoring and control of industrial processes**
  Image: Controlling an industrial fermentation

- **Product separation, recovery and disposal of spent broth**
  Image: Graphic showing a simplified version of the different recovery routes

- **Health and safety**
  Image: Biohazard sign

Other Information includes a book list, some useful web sites, a glossary, contact addresses of the EIBE production team and details about Science Pictures Ltd., the producers of the CD-ROM.