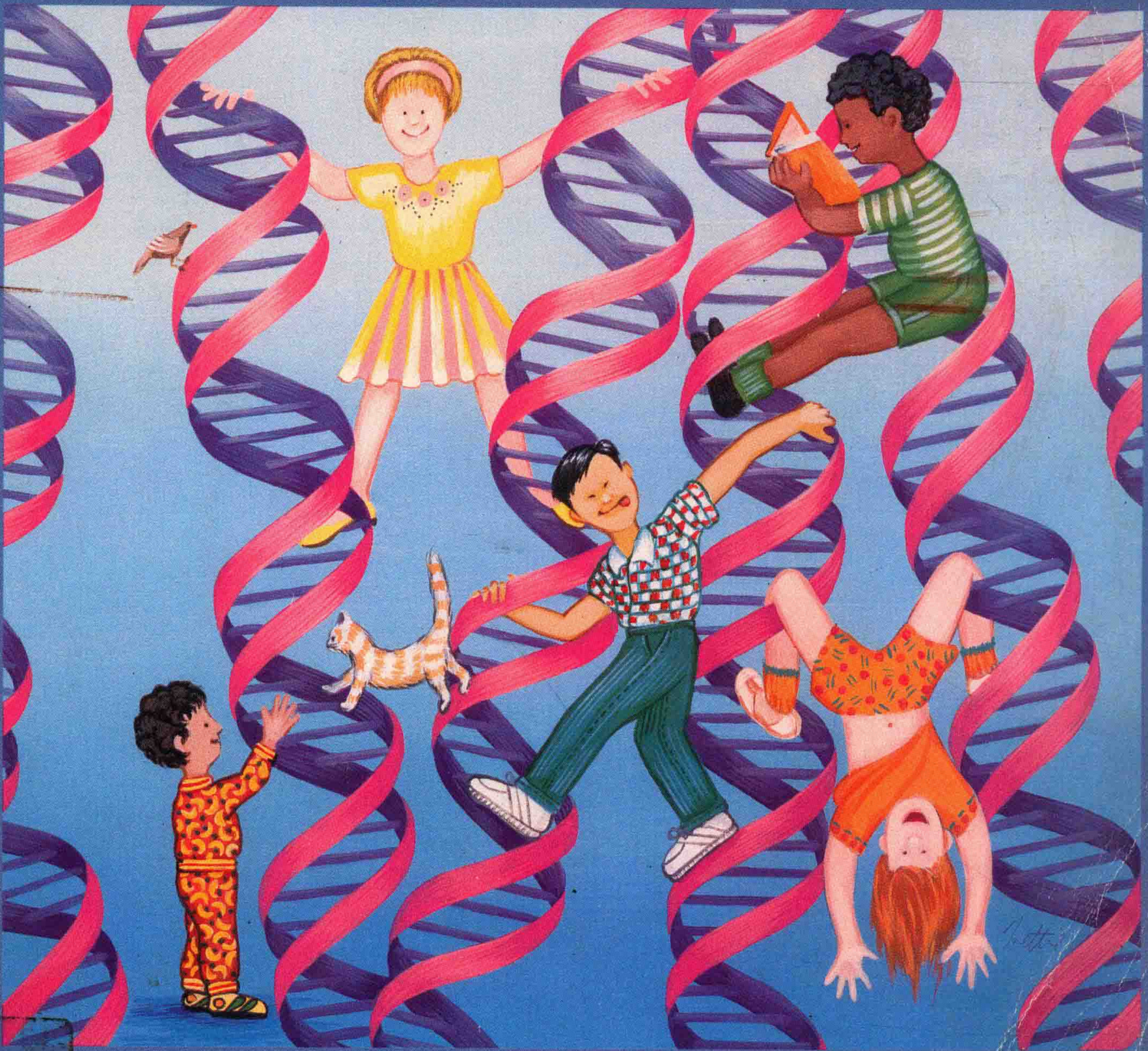
Biotechnology

THE TECHNOLOGY OF LIFE



A Sourcebook for Teachers Grades K-12: Classroom Activities, Lesson Plans, Experiments, Visual Aids and Support Materials

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Biotechnology: The Technology of Life

A Sourcebook for Teachers of Classroom Activities, Support Materials, Lesson Plans, Labs, and Visual Aids for Grades K–12.

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4050 Westmark Drive Dubuque, Iowa 52002

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One Innovation Drive
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ISBN 0-7872-0565-6

Printed in the United States of America.
This material is based upon work supported by the U.S. Small Business Administration under Grant Number SB-BD-92-001-01

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MASSACHUSETTS BIOTECHNOLOGY RESEARCH INSTITUTE

Spring 1995

Letter from the President:

The Massachusetts Biotechnology Research Institute (MBRI) is a private, independent economic development corporation. Its mission is to accelerate the growth of biotechnology and other technology driven industries.

MBRI believes that education is important, not only to provide an educated workforce to the biotechnology industry, but also to help the public reach enlightened and informed resolutions on those issues which will continually arise as the technology advances.

Toward that end, MBRI has dedicated many of its resources over the past several years educating teachers in the science and issues of biotechnology.

The Resource Book is a composite of much of what we have learned and done over these past few years. It incorporates the information, lessons, activities, games and other materials that MBRI has developed or refined and that MBRI-trained teachers have used successfully in their classrooms. The materials that follow have been designed by teachers from kindergarten to 12th grade and used by them.

The Resource Book was initially developed with substantial input and an overall collaboration with the Worcester Polytechnic Institute (WPI) and the New England Science Center (NESC). In just over two years of distribution, it has reached teachers and students in 30 states and 5 foreign countries. We are pleased, with this edition, to include several new activities and up-to-date resource and career information. We are also pleased to make the Resource Book available through Kendall-Hunt Publishing, which will allow many more teachers to learn about the work we have done.

We know that the students of today, even those whose career choices will have no direct link to biotechnology, will be responsible in the future for determining the impact and success of this industry. We hope this Resource Book will help them and their teachers better understand this new and evolving industry.

Marc E. Goldberg
President and Chief Executive Officer

One Innovation Drive, Worcester, MA 01605

Acknowledgements

Worcester Polytechnic Institute (WPI) is the third oldest private college of science and engineering in America. Its department of Biology and Biotechnology is comprised of a faculty with research interests including cell and molecular biology, immunology, genetics and genetic engineering and bioprocess engineering.

Dr. Jill Rulfs is an assistant professor of Biology and Biotechnology at Worcester Polytechnic Institute, and an adjunct professor of Biochemistry and Molecular Biology at the University of Massachusetts Medical School. She received her PhD from Tufts University and her teaching certification from the Massachusetts Board of Higher Education in 1973. She has taught in two inner city school systems, Miami, Florida and Boston, Massachusetts, where she was a participant in the Magnet School Program which paired Tufts University with Boston Technical High School. She has consulted with the MBRI in the development of teacher training programs and served as an instructor. Dr. Rulfs also directs a funded research effort in diabetes.

Special thanks to: Dr. Pamela Weathers, Anthony Chiulli, John Kurdziolek, Louis Roberts, Sharon Savage.

The New England Science Center (NESC), located in Worcester, Massachusetts has a firm commitment to enhancing the public's understanding of the natural sciences. The NESC education staff researches and develops science classes, field trips and outreach visits to local schools. The NESC is also an active member of the non-profit corporation Museum Institute for Teaching Science (MITS).

Dr. Douglas Dawson is the program director at the New England Science Center and holds a PhD in psychobiology from the University of California at Irvine. His primary research interests have been in the areas of neuroanatomy and neurophysiology. He is an adjunct professor at the University of Hartford. At the NESC, he is responsible for coordinating the activities of the Education, Exhibits, and Zoo departments. He participates in the design of permanent exhibits, and teaches special programs and classes. Dr. Dawson has developed several teaching kits, including those for the pilot program in teacher training. He designed and implemented the Museum Institute for Teaching Science summer program for science-shy teachers. Dr. Dawson has been an invited speaker to the New England Museum Association, the New England Environmental Education Association, and the Association of Science and Technology Centers.

Acknowledgements

Individual activity authors:

Cell Membranes, Cell Reproduction, Cell Culture, and Cell Growth Rate: John Kurdziok, Sharon A. Savage, and Pamela Weathers

Chromatography: Lori J. Currie, Loree A. Griffin, Rebecca A. Griffith, and Pamela Weathers

Cranberry Juice Fermentation: Adam Fields, Mike Gatta, Ankur Patel, and Pamela Weathers

Contact Lensymes: David Form and Paul McLean

How to use this book

Most of the exercises and activities in this resource book have been developed for use in teacher training courses run by the MBRI in collaboration with WPI and the NESC. A few of the activities were developed by students at WPI, working with public school teachers on projects to introduce science concepts in the classroom.

You will note that the activities and lesson plans in this book are designated according to grade level. We hope this designation will not limit your investigation but will, instead, encourage you to be even more creative. These activities can be used across grade levels. For example, in the section on Cell Biology, *"Build a Giant Cell"* lesson was the last presented in our K-4 workshop, the first for teachers of grades 5-8, and continues as an offering for the 9-12th grade teachers. We have reports from teachers at all these levels who have successfully used this activity with appropriate modification. By presenting these ideas in a resource book format, we are hoping to make them more accessible to teachers at all levels.

Each activity or lesson begins with an overview, a list of objectives, and a list of skills associated with each activity. You will find that the skills for a lesson designated K-4 may well overlap with those for a lesson designated 5-8 or even 9-12. This is because the skills emphasized are those associated with the process of scientific inquiry and discovery based learning, and are reinforced throughout the curriculum.

The format of this book was developed to allow updates and additions. As the book grows, we hope to include activities which have been developed by teachers, many of whom were participants in our programs. If you have an activity or an idea which you would like to share, please send it along.

The Editors

What is Science?

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What is Science?

Introduction

"Science is a continuous stream of ideas that are constantly being reshaped, added to, subtracted from and built upon." With that introduction, this section presents some of the basic concepts of discovery based or inquiry based learning within the context of science. The lessons in this section are designed to introduce and apply the skills used in scientific investigation. Throughout these activities the ideas that scientists are "everyday people" and that the tools of critical thinking can be applied to "everyday life" are reinforced.

Contents:

The reference sheets, which follow under the title *"What is Science",* set out the tools of critical thinking and begin to demonstrate their application to problem solving in science. The *"Great Truths"* reinforces the concept of science as a continually changing field, beginning in 40,000 B.C. and continuing to the present.

Lesson 1, *"What is a Scientist?"* is designed to dispel stereotypes about scientists and to present the concept that a career in science is attainable by anyone.

Lesson 2, *"Super Scientist",* is a paper activity which encourages students to explore scientists as role models using language skills and art. A list of famous scientists is provided, or students may be encouraged to select a scientist they have learned about. They might consider interviewing a contemporary scientist from a local company or university. Perhaps they could write a science adventure starring themselves as scientists. Materials needed include paper, pencil and imagination.

Lessons 3 and 4, "*Sorting and Sizing"* and *"Sponge Animals",* are hands-on activities in creative thinking and problem solving, which use materials available at toy and department stores. Both of these activities are adaptable to any grade and skill level. Both are also adaptable as math lessons, introducing concepts such as set theory and graphic analysis.

Lesson 5, *"Curiosity and Crickets",* allows the student to design his or her own experiment to both formulate and begin to answer specific questions. Again, data collection can lead to graphic analyses. This activity is always fun, but beware of escapees !

Relevance to Biotechnology:

Basic science is the foundation of biotechnology. Introducing the concepts of critical thinking and inquiry based learning will provide students with the tools they need to solve problems whether they eventually pursue careers in science or vote on public policy issues which affect the growth and development of the biotechnology industry.

What is Science?

Maybe it's easier to begin by telling you what science is **NOT.**

Science is <u>not</u> a massive jigsaw puzzle that is slowly being pieced together one piece at a time. In a jigsaw puzzle, once you get a piece to fit, it stays there forever.

Science is **always changing!** Things that people were positive about 500 years ago are things that we laugh at today! Science is a continuous stream of ideas that are constantly being re-shaped, added to, subtracted from, and built upon... more like a lump of silly putty than a puzzle.

Science is, and always has been, about **PREDICTABILITY.**
The science that we "know" today gives us the ability to predict certain things about the world around us. What time will it get dark tonight? What will happen if I stick my tongue to a flagpole that's below freezing? What will happen if I mix flour, sugar, eggs and milk in the right combinations and bake it in the oven? In each case, science allows us to PREDICT what will happen.

How to Think like a Scientist

Anyone can think like a scientist! You just need to exercise your brain in a few simple ways. Some things are better predictors than other things. We are constantly looking for better predictors, and throwing away predictors that don't do the job. To do this, you need to:

a) **BE CURIOUS** - you need to look around you and ask questions about things! Why is the sky blue? How do amoebas eat? How can I get energy from the sun?

b) **BE SKEPTICAL** - don't always believe the first thing you hear. Look for ALL the possible explanations, see which facts support which explanations, and then pick the best one. Do you believe in UFOs? Bigfoot? Is Elvis alive? WHY? (These may all be true... but is there really any evidence to support them NOW?)

c) **BE FLEXIBLE** - even after you've found an explanation, keep looking! Sometimes you can find an even better one later on. Don't be afraid to give up old ideas for new ones, as long as they've passed the skepticism test!

These three brain exercises add up to what we call **CRITICAL THINKING**... What scientists do all the time!

Critical thinking is not a guarantee to truth. Even scientists can be fooled by clever hoaxes, or spend years believing things until new information surfaces (see the list of "*Great Truths*").

How to Act like a Scientist

Once you're in the habit of thinking like a scientist, it's a simple matter to APPLY it to real life. Scientists apply their critical thinking skills by:

a) **OBSERVING** - collecting data, measuring things, and watching the world around them in an objective manner. (Objective means that they use standard units and equipment so that somebody else using the same units or equipment could measure the same things and hopefully get the same results.)

As a general rule, the more quantifiable (measurable in objective units), the more valuable as a predictor.
For example :

"It rains when the barometer says 29.3"
is a better predictor than
"It rains when my left knee joint hurts ".

b) **COLLECTING DATA** - the recording and storage of observations over time. The two main things to remember about data collection are selectivity, and repeatability.

Selectivity - There are a lot of possible things to measure out there, but not all of them are relevant as predictors. Which is more important as a predictor of how warm a pair of socks will be, the thickness or the color?

Repeatability - The data you collect should be collectable by somebody else using the same equipment. You shouldn't require any ESP or special techniques that you couldn't pass along to somebody else.

c) **USING STATISTICS** - sometimes relationships between things are not immediately apparent, and you need to look at many examples and average them together to see the real trend.

For example: you may know a 30-year old non-smoker who drops dead, and a 99 year old chain smoker who is still going strong. But if you look at a large population and do some statistics, you'll see that despite these two cases, there's a strong trend for non-smokers to outlive smokers.

What happens when you act and think this way?

You can use critical thinking skills plus data you collect to come to a CONCLUSION about something. The conclusion (which is a predictor, remember) usually falls into one of two categories...

CORRELATIONS are two things that tend to happen together.

CAUSE-EFFECTS are cases where one thing actually causes a second thing.

For example:

Correlation: Every time I go ice skating : I get cold
I bruise my bottom
(I notice that both of these things happen when I go ice skating, but don't know that one causes the other)

Cause - Effect: Every time I go skating : I fall down and
I bruise my bottom.
(In this case, I notice that if I can prevent the first one from happening, I can prevent the second... So A causes B!)

Correlations can be established through observation. You just need to notice that two things always seem to occur together.

Cause - Effect is tougher to establish, because once you notice two things occurring, you need to TEST to see if they are really linked to each other.
Cause - Effect is a better predictor than Correlation.

Why bother?

Throughout evolution, it has always been to an animal's advantage to be able to predict things around it.

If a deer smells a wolf, it can predict danger, and run the other way.
If a ground squirrel feels the temperature drop, it can predict winter, and go hibernate.
Humans predict too. There are warning signs in our lives that predict tax raises, spoiled food, birth of babies, etc., and we alter our behaviors based on these predictions we make.

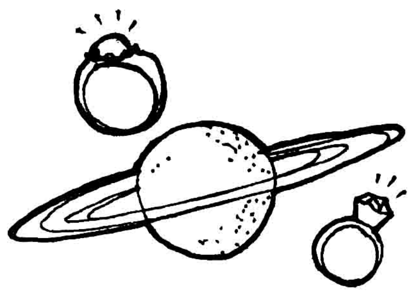
Science is just a way of making predictions.

The predictions are things like:
Using medicine X will clear up symptom Z.
Using a seat belt will keep you from flying through the window.
Losing the ozone layer may increase the risk of skin cancer.
And predicting these things allows us to make decisions about our future.

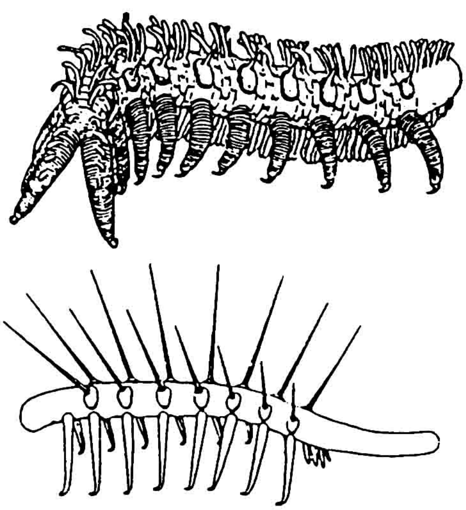
Great Truths

At various times in history, scientists "knew" these things-although today we "know" differently!

40,000 B.C.	The moon is eaten once each month by a large invisible beast.
1400 A.D	Diseases are caused by evil spirits which inhabit a body.
1500	Flies develop spontaneously from rotten meat.
1600	The brain pumps fluid into the muscles to make them bulge and contract.
1800	Tyrannosaurus Rex walked vertically and dragged its tail.
1850	The planet Mars is covered with canals that could only be made by intelligent life.
1900	The apatosaurus and brontosaurus are two different dinosaurs.
1970	Saturn is the only planet with rings around it.
1980	Eating eggs makes your cholesterol levels rise.
1985	Pandas are bears.
1990	Tadpoles eat plants, frogs eat meat.
1991	The fossil millipede Hallucigenia from China walked on stiff spines.



What do we know today that scientists 500 years from now will laugh at?



Newly discovered Cambrian fossil (top) and revised view of Hallucigenia.

Great Truths: Today

These are our explanations for "Great Truths" today:

- The moon darkens each month because the angle between the Earth, Moon, and Sun changes.
- Diseases are caused by microscopic agents called "germs".
- Flies lay their eggs in rotten meat and hatch.
- The brain contracts muscles using tiny electrical and chemical signals.
- Tyrannosaurus Rex leaned forward and its tail balanced it but it didn't touch the ground.
- Mars is covered by icy cracks that were once rivers.
- Apatosaurus and brontosaurus are the same species.
- Uranus also has rings.
- Some people's cholesterol levels stay the same or go down even if they eat eggs.
- Pandas are genetically in between bears and raccoons.
- Some frogs have been found in South America that eat berries.
- The spines on the millipede were on its back-it walked on mushy legs!