



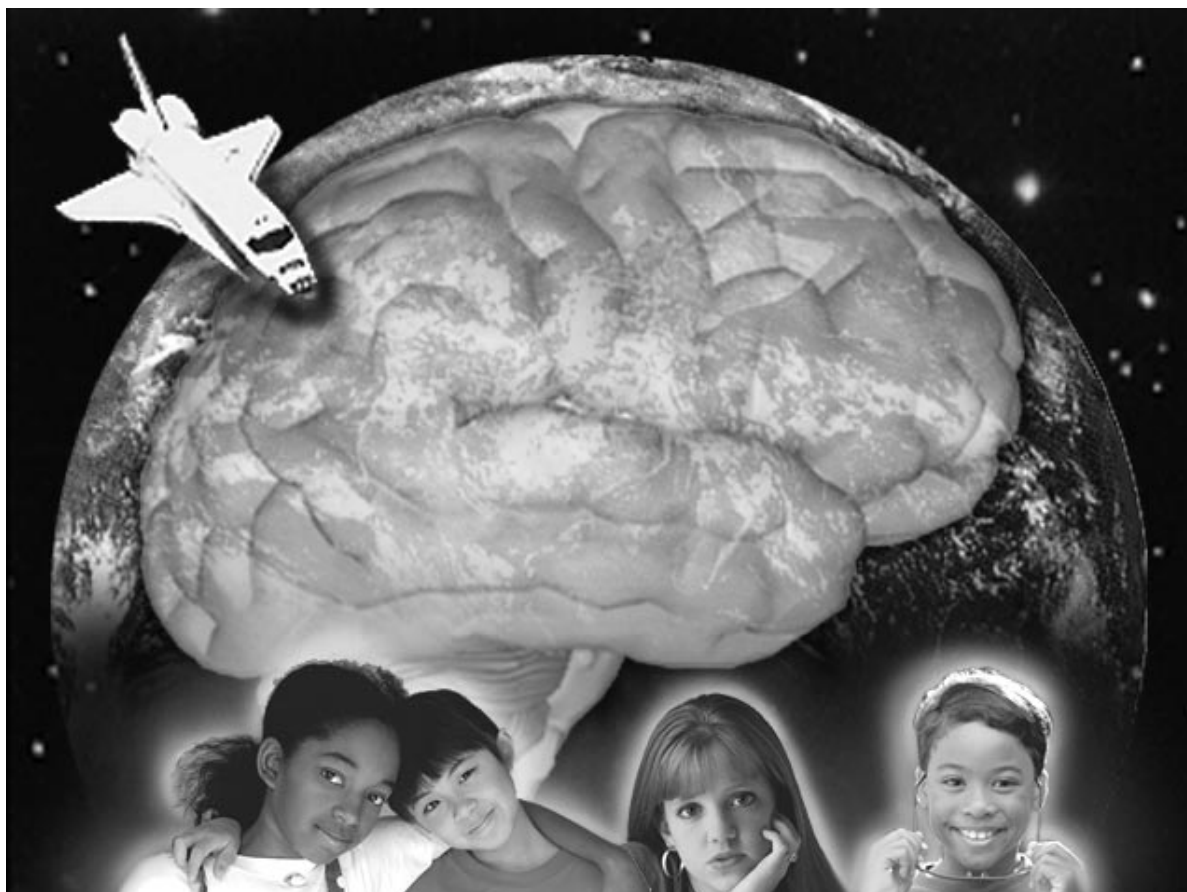
National Aeronautics and  
Space Administration

Educational Product	
Teachers	Grades 5-12

# The BRAIN in Space

*A Teacher's Guide With Activities for Neuroscience*

---



# The Brain in Space

A Teacher's Guide With Activities for Neuroscience

National Aeronautics and Space Administration

Life Sciences Division

Washington, DC



This publication is in the Public Domain and is not protected by copyright.  
Permission is not required for duplication.

EG-1998-03-118-HQ

# Acknowledgments

This publication was made possible by the National Aeronautics and Space Administration, Cooperative Agreement No. NCC 2-936.

## **Principal Investigator:**

Walter W. Sullivan, Jr., Ph.D.  
Neurolab Education Program  
Office of Operations and Planning  
Morehouse School of Medicine  
Atlanta, GA

## **Writers:**

Marlene Y. MacLeish, Ed.D.  
Director, Neurolab Education Program  
Morehouse School of Medicine  
Atlanta, GA

Bernice R. McLean, M.Ed.  
Deputy Director, Neurolab Education Program  
Morehouse School of Medicine  
Atlanta, GA

## **Graphic Designer and Illustrator:**

Denise M. Trahan, B.A.  
Atlanta, GA

## **Technical Director:**

Perry D. Riggins  
Neurolab Education Program  
Morehouse School of Medicine  
Atlanta, GA

# Contributors

This publication was developed for the National Aeronautics and Space Administration (NASA) under a Cooperative Agreement with the Morehouse School of Medicine (MSM). Many individuals and organizations contributed to the production of this curriculum. We acknowledge their support and contributions.

## **Organizations:**

Atlanta Public School System  
Society for Neuroscience  
The Dana Alliance for Brain Initiatives

## **NASA Headquarters:**

### **Code UL, Life Sciences Division**

Mary Anne Frey, Ph.D.  
Rosalind A. Grymes, Ph.D.  
David R. Liskowsky, Ph.D.

### **Code FE, Education Division**

Pamela L. Mountjoy  
Education Program Manager  
NASA Headquarters  
Washington, DC  
Jane A. George  
Educational Materials Specialist  
Teaching From Space Program  
Washington, DC  
Gloria Barnes  
Publications Manager  
Karol Yeatts, Ed.D.

## **NASA-Ames Research Center**

Joseph Bielitzki, D.V.S., M.S.

## **Morehouse School of Medicine**

### **Neuroscience Institute:**

Peter MacLeish, Ph.D.  
John Patrickson, Ph.D.  
Holly Soares, Ph.D.

Joseph Whittaker, Ph.D.

## **Neurolab Education Program Advisory Board:**

Gene Brandt  
Milton C. Clipper, Jr.  
Mary Anne Frey, Ph.D.  
Charles A. Fuller, Ph.D.  
Rosalind A. Grymes, Ph.D.  
William J. Heetderks, M.D., Ph.D.  
Peter R. MacLeish, Ph.D.  
Charles M. Oman, Ph.D.  
Rhea Seddon, M.D.  
Jane Smith, Ed.D.  
Ronald J. White, Ph.D.

## **Consulting Editors:**

Ron Booth, Ph.D.  
James Denk, M.A.  
Wyckliffe Hoffler, Ph.D.  
Roy Hunter, Ph.D.  
Fernan Jaramillo, Ph.D.  
Ollie Manley, Ph.D.  
Nancy Pearson Moreno, Ph.D.  
Barbara Tharp, M.S.  
Gregory L. Vogt, Ed.D.

## **Lesson/Activity Contributors:**

Timothy Aman, M.S.  
Kenneth M. Baldwin, Ph.D.  
Luis Benavides, Ph.D.  
Gunnar C. Blomqvist, M.D., Ph.D.  
Bernard Cohen, M.D.  
Charles A. Czeisler, Ph.D., M.D.

**Lesson/Activity Contributors (Continued):**

Dwain L. Eckberg, M.D.

Charles A. Fuller, Ph.D.

Kathleen Heffernan, Ph.D.

Stephen M. Highstein, M.D., Ph.D.

Gay Robbins Holstein, Ph.D.

Jerry L. Homick, Ph.D.

Eberhard R. Horn, Ph.D.

Kenneth S. Kosik, M.D.

Bruce L. McNaughton, Ph.D.

Richard S. Nowakowski, Ph.D.

Gina Poe, Ph.D.

Gordon Kim Prisk, Ph.D.

Danny Riley, Ph.D.

Muriel D. Ross, Ph.D.

Janet Silvera, B.Sc.

Dan Sulica, M.Sc.

Kerry D. Walton, Ph.D.

Bonita Waters-Alick, Ph.D.

John B. West, M.D., Ph.D., D.Sc.

Michael L. Wiederhold, Ph.D.

# Recommended Guide Usage

The lessons and activities in this guide will engage your students in the excitement of space life science investigations after the Neurolab Spacelab mission. It is our goal that the information in this guide will inspire both you and your students to become interested and active participants in this space mission. Few experiences can compare with the excitement and thrill of watching a Shuttle launch. This guide provides an opportunity for you and your students to go one step further by conducting the experiments on Earth that are relevant to the research conducted in space.

The Brain in Space teacher's guide is written for you, the teacher. The activities presented in The Brain in Space are most appropriate for middle and high school life sciences teachers and their students. The NASA Neurolab Space Shuttle flight, STS 90, was scheduled for lift-off in April 1998.

## National Science and Math Education Standards

The Brain in Space activities are compatible with the National Science and Math Education Standards. Because many of the activities and demonstrations apply to more than one subject area, a matrix chart relates activities to national standards in science and mathematics and to science process skills. In each matrix, the science and math content standards are listed along the left margin. Activities within a given section that fulfill a listed standard or include the development of a listed skill are designated with the symbol “•” in the appropriate column.

## Scientific Method

Since scientists' jobs frequently call for effective communication of scientific results to the community, special emphasis is placed on involving students in activities that require the development and delivery of scientific presentations. Appropriate scientific processes are modeled throughout The Brain in Space guide to assist students in acquiring basic investigative skills.

## Using The Brain in Space Activities

The Brain in Space activities focus on specific effects of weightlessness and other aspects of the space environment on:

- developmental and cellular neurobiology,
- vestibular function,
- spatial orientation and visuo-motor performance,
- autonomic nervous system regulation, and
- sleep and circadian rhythms.

Before beginning any hands-on activities with your students, you may want to learn more about the nervous system and how it is affected by the microgravity environment. This information is covered in the following introductory sections: “The Space Life Sciences” (page 3), “Space Neuroscience” (page 5), and “The Nervous System” (page 13). Additional information is provided for you in the “Things to Know” and “Background” sections in Part II.

This guide begins with an overview of Neurolab and background information on space life sciences, space neuroscience, and



space life sciences research. The sections on space life sciences focus on changes in organisms under conditions of microgravity, whether or not organisms can withstand these changes, finding ways to make space flight safer, and applying space technologies to solve scientific and medical problems on Earth.

Following Part I are lessons and activities that demonstrate and/or examine the effect of weightlessness and other aspects of the space environment on the nervous system. The many activities contained in this guide emphasize hands-on/minds-on involvement, prediction, data collection and interpretation, teamwork, and problem-solving. Most of the activities utilize basic and inexpensive materials. In each activity, you will find diagrams, material lists, and instructions. A brief science background section within each activity amplifies the concepts covered.

The length of time required for each activity varies according to its degree of difficulty and the developmental level of the students. Many of the activities can be completed in a single class period. Others require several periods for the completion of an investigation.

The guide concludes with a glossary of terms, NASA educational resources, and a printed “Teacher Reply Card.” We would appreciate your assistance by completing and mailing in the Teacher Reply Card at the end of this guide.



# National Science Education Standards

## Grades 5–8 Content Standards

### Correlation of Science Themes and Activities in *The Brain in Space:* Activities for Neuroscience

		Developmental and Cellular	Vestibular Function	Spatial Orientation	Autonomic Sleep
PHYSICAL SCIENCE	Objects have observable properties	•	•	•	•
	Substances react chemically	•			•
	Chemical elements				•
	Describing and measuring motion of an object			•	
	Forces and movement of objects			•	
	Energy (heat, light, electricity, motion, sound, etc.)				
	Heat transfer				
	Light (transmission, absorption, scattering)		•		
	Electrical circuits	•			
	Sun as source of energy on Earth				
LIFE SCIENCE	Organization of living systems	•	•	•	•
	All organisms are composed of cells	•	•	•	•
	Functions of cells necessary for life	•	•	•	•
	Specialization of functions (cells, tissues and organs)	•	•	•	•
	Basic human body systems	•	•	•	•
	Disease	•	•	•	•
	Reproduction (asexual and sexual)				
	Heredity, learning and characteristics of organisms				
	Resources needed by organisms	•			•
	Regulation of the internal environment	•			•
	Behavior	•	•	•	•
	Populations and ecosystems				
EARTH SCIENCE	Structure of the Earth				
	Earth forces	•	•	•	
	Soil				
	Water				
	Atmosphere and weather				
	Earth history and the fossil record				
	Earth in the solar system				
	Movement and gravity	•	•	•	



# National Science Education Standards

## *Grades 5–8 Content Standards (Continued)*

		Developmental and Cellular	Vestibular Function	Spatial Orientation	Autonomic	Sleep
<b>SCIENCE AND TECHNOLOGY</b>	Methods of science and technology	•	•	•	•	•
	Different contributions by people to science and technology	•	•	•	•	•
	Trade-offs and unintended consequences in technological designs	•	•	•	•	•
<b>SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES</b>	Personal health (exercise, safety, nutrition, tobacco, alcohol)	•	•	•	•	•
	Environmental health	•	•	•	•	•
	Degradation of environments					
	Natural and human-induced hazards					
	Risk analysis					
	Influence of science and technology on society	•	•	•	•	•
	Scientists and engineers work in many settings	•	•	•	•	•
	Ethical codes governing research with human subjects	•	•	•	•	•
Limitations of science and technology to solving problems						
<b>HISTORY AND NATURE OF SCIENCE</b>	Contributions of men and women to science	•	•	•	•	•
	Science requires different abilities	•	•	•	•	•
	Nature of science (method, research, evaluation)	•	•	•	•	•
	History of science	•	•	•	•	•



# National Science Education Standards

## Grades 9–12 Content Standards

### Correlation of Science Themes and Activities in The Brain in Space: Activities for Neuroscience

		Developmental and Cellular	Vestibular Function	Spatial Orientation	Autonomic	Sleep
<b>PHYSICAL SCIENCE</b>	Structure of atoms	•	•			
	Structure and properties of matter (elements, chemical bonds)	•				
	Properties of carbon-containing compounds	•			•	•
	Chemical reactions (energy, electron transfer, role in living systems)	•			•	•
	Motion and forces (gravitation, electric forces, charges, magnetism)	•	•	•		
	Conservation of energy and entropy		•			
	Interactions of energy and matter (waves, electromagnetic waves, conductance)	•	•	•		
<b>LIFE SCIENCE</b>	Cells (structure, chemical, functions, differentiation)	•	•	•	•	•
	Molecular basis of heredity	•				
	Biological evolution	•				
	Interdependence of organisms (energy flow in ecosystems, populations)	•	•	•	•	•
	Matter, energy and organization in living systems	•	•	•	•	•
	Behavior of organisms (nervous system, role of stimuli)	•	•	•	•	•
<b>EARTH SCIENCE</b>	Energy in the Earth system (role of sun, energy transfer, global climate)					•
	Geochemical cycles					
	Origin and evolution of the Earth system					
	Origin and evolution of the universe					
<b>SCIENCE AND TECHNOLOGY</b>	Aspects and abilities related to technological design	•	•	•	•	•
	Scientists in different disciplines use different methods	•	•	•	•	•
	Role of new technologies in advancing science	•	•	•	•	•
	Purposes of science and technology	•	•	•	•	•



# National Science Education Standards

## Grades 9–12 Content Standards (Continued)

		Developmental and Cellular	Vestibular Function	Spatial Orientation	Autonomic Sleep
<b>SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES</b>	Role of personal and community decisions in health (nutrition, disease, accidents)	•	•	•	•
	Population growth and carrying capacity				
	Natural resources (use and limitations)				
	Environmental quality				•
	Natural and human-induced hazards				
<b>HISTORY AND NATURE OF SCIENCE</b>	Role of science and technology in solving local, national and global problems	•	•	•	•
	Contributions of individuals and teams to science	•	•	•	•
	Ethics in science	•	•	•	•
	Nature of scientific knowledge	•	•	•	•
	History of science (cultural perspectives, how science advances)	•	•	•	•



# National Council of Teachers of Mathematics Curriculum and Evaluation Standards *Grades 5–8*

---

	Developmental and Cellular	Vestibular Function	Spatial Orientation	Autonomic	Sleep
Problem solving	•	•	•	•	•
Communication	•	•	•	•	•
Reasoning	•	•	•	•	•
Connections	•	•	•	•	•
Number relationships	•		•	•	
Computation and estimation	•	•		•	•
Patterns and functions		•	•	•	
Algebra					
Statistics		•		•	
Probability					
Geometry	•	•	•		•
Measurement	•	•	•	•	•

## *Grades 9–12*

---

Problem solving	•	•	•	•	•
Communication	•	•	•	•	•
Reasoning	•	•	•	•	•
Connections	•	•	•	•	•
Algebra					
Functions		•		•	
Synthetic perspective					
Algebraic perspective					
Trigonometry					
Statistics		•		•	
Probability					
Discrete mathematics					
Underpinnings of calculus					
Mathematical structure					



# Table of Contents

## Part I

National Science Education Standards Review

National Council of Teachers of Mathematics

Curriculum and Evaluation Standards Review

<b>Introduction</b> .....	1
Overview: Neurolab and The Brain in Space .....	2
The Space Life Sciences .....	3
Space Neuroscience: A Special Area Within the Space Life Sciences.....	5
Space Life Sciences Research.....	6
Neurolab: A Special Space Mission to Study the Nervous System .....	10
The Nervous System .....	13

## Part II

<b>Neurolab Lessons &amp; Activities</b> .....	21
The Scientific Method .....	22
Activity I: Introduction to the Scientific Method.....	26
<b>Section I: Developmental and Cellular Neurobiology</b> .....	33
Activity I: What Cells Can I See in Muscle and Spinal Cord Tissue?.....	37
Activity II: Target Recognition and Synapse Formation During Development.....	44
Activity III: Motor Skills Development.....	47
<b>Section II: Vestibular Function</b> .....	55
Activity I: Visualizing How the Vestibular System Works.....	59
Activity II: Vestibular-Ocular Reflex .....	66



# Table of Contents

<b>Section III: Spatial Orientation and Visuo-motor Performance</b> .....	75
Activity I: Finding Your Way Around Without Visual or Sound Cues .....	81
Activity II: Pitch, Roll and Yaw: The Three Axes of Rotation .....	87
Activity III: Building a Magic Carpet .....	89
Activity IV: Building a 3-D Space Maze: Escher Staircase .....	95
<b>Section IV: Autonomic Nervous System Regulation</b> .....	101
Activity I: Measuring Blood Pressure in Space .....	105
Activity II: Changing Body Positions: How Does the Circulatory System Adjust? .....	117
Activity III: Baroreceptor Reflex Role Play .....	123
<b>Section V: Sleep and Circadian Rhythms</b> .....	127
Activity I: The Geophysical Light/Dark Cycle .....	131
Activity II: How Quick Are Your Responses? .....	134
Activity III: Measuring Your Breathing Frequency at Rest .....	138
Activity IV: How Long Can You Hold Your Breath? .....	142
Activity V: Raising the Level of Carbon Dioxide in Your Blood .....	146
<b>Section VI: Appendices</b> .....	149
Glossary .....	150
NASA Resources for Educators .....	159

