MARIAN KOSHLAND
SCIENCE MUSEUM
OF THE NATIONAL ACADEMY OF SCIENCES
at 6th & E Streets, NW, Washington, DC

# Exhibition Guide for a Visit to the Koshland Science Museum

## *Putting DNA to Work* Focus

**TABLE OF CONTENTS**



**INTRODUCTION**

Welcome to the Koshland Science Museum. A visit to the museum is a unique experience. The Koshland Science Museum covers current issues in the headlines and provides scientific information that can be used to make decisions that affect visitors' daily lives. The information is presented in highly interactive exhibits.

Your class visit to the museum has been designed to model good learning and teaching practices. Using the Jigsaw method described below, your class will divide into smaller groups that will visit different parts of the museum. Together, the members of the groups will become "experts" as they seek information to share with their classmates during small-group and whole-class discussions. Students will collaborate in thinking about evidence and formulating ideas much like scientists do in their daily work.

Your visit to the museum will last approximately two hours. During that time, your class will study in detail the *Putting DNA to Work* exhibition. Your class also will spend some time with the museum's *Wonders of Science* and *Global Warming Facts & Our Future* exhibitions. All class visits must be scheduled in advance due to limited space.


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## The Museum's Exhibitions

The museum has three exhibitions.

The *Wonders of Science* exhibition asks, "What's the Universe made of?" It encourages visitors to think about some of the big unsolved questions in science, fostering creative thinking and a sense of wonder about the universe. All students will visit this exhibition briefly and ponder the questions it poses.

The *Global Warming Facts & Our Future* exhibition uses interactive displays to present evidence about natural climate variability and the effects of human activities on climate. The exhibition also provides tools for visitors to explore the consequences of climate change and potential responses to climate change. Your students will visit this exhibition briefly and consider some of the broad issues it raises.

The *Putting DNA to Work* exhibition introduces students to DNA sequencing and to some of the applications of this technique. The applications explored include genetic testing, disease identification, forensics, and crop improvement. This is the exhibition where your class will focus most of its attention.

## EDUCATIONAL OBJECTIVES AND PROCEDURES

The Koshland Science Museum embodies the inquiry-based approach to education set forth in the *National Science Education Standards* (National Research Council, 1996). By asking questions, gathering information, formulating explanations, and communicating those findings to others, students develop critical and logical thinking skills. Class visits to the museum also reflect current understanding about the processes of learning, as described in *How People Learn* (National Research Council, 2000). Active learning in collaborative teams combined with peer teaching gives students a powerful and meaningful experience with the information and ideas they encounter.

Your class's overall objective will be to address the following question:

***How can the knowledge of DNA sequencing be applied in the future?***

To break down this question into manageable parts, the students will divide into groups and gather information from a specific part of the *Putting DNA to Work* exhibition. They then will communicate their findings and conclusions within their groups and to the entire class.

### A Step-By-Step Agenda for a Class Visit

1. Orientation (15 minutes)

A trained field trip leader will join your class to describe the mission to be accomplished over the following two hours. With the assistance of the teacher and adult chaperones, the field trip

leader will manage the flow of the class through the museum and guide the class discussion. Classes should arrive 10 minutes before their start time to enter the building and congregate in the area where the orientation will occur. (Note: The time allotments shown include the time required to move from one stage of the visit to the next.)

2. Touring the Exhibitions (50 minutes)

You will assign your students to three groups: red, yellow, or blue (see the Group Assignment Form). Each group will cycle through three rotations in the museum. During one rotation, they will become experts in one aspect of the *Putting DNA to Work* exhibition. During another rotation, they will tour the *Wonders of Science* exhibition and the general information areas in the *Putting DNA to Work* exhibition. During the third rotation, they will visit the *Global Warming Facts & Our Future* exhibition. Thus, in two of the three stations, students will be reading the big messages of the exhibitions and briefly using the interactive displays. In the third station, students will be digging more deeply into a subject to build a base of knowledge that they will use during the group discussions later in their visit.

For your visit to the *Putting DNA to Work* exhibition, the rotations will be as follows (in this schedule the gray boxes are the stations that each group will study in the greatest detail):

| Groups | Rotation #1 | Rotation #2 | Rotation #3 |
|---|---|---|---|
| **Yellow** | • *Wonders of Science*<br>• *Putting DNA to Work*<br>– Introduction<br>– Probe the Sequence | • *Putting DNA to Work*<br>– Can You Inherit Disease?<br>– Can Sequences Tell Us Apart? | • *Global Warming Facts & Our Future* |
| **Blue** | • *Putting DNA to Work*<br>– Can Reading Genes Improve Crops? | • *Global Warming Facts & Our Future* | • *Wonders of Science*<br>• *Putting DNA to Work*<br>– Introduction<br>– Probe The Sequence |
| **Red** | • *Global Warming Facts & Our Future* | • *Wonders of Science*<br>• *Putting DNA to Work*<br>– Introduction<br>– Probe The Sequence | • *Putting DNA to Work*<br>– Can DNA Sequencing Protect Public Health? |

Each student will receive a clipboard, pencils, and two worksheets. The first worksheet will facilitate analysis of the "Introduction" and "Probe the Sequence" areas in the *Putting DNA to Work* exhibition. The second worksheet, which is tailored to each of the three groups, will help the Expert Groups analyze in detail the area they are assigned. Because your class is focusing on the *Putting DNA to Work* exhibition, your students will not receive worksheets on either the *Wonders of Science* or the *Global Warming Facts & Our Future* exhibitions.

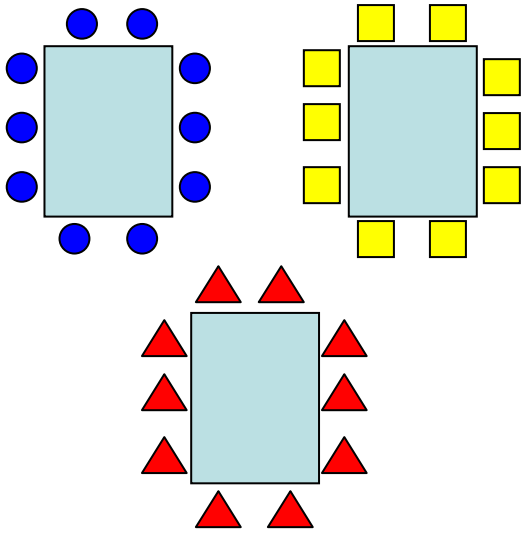
Students should use their worksheets to record any questions they have about any of the data or other information presented. Students also can ask questions of the field trip leader.

3. Expert-Group Discussions (15 minutes)

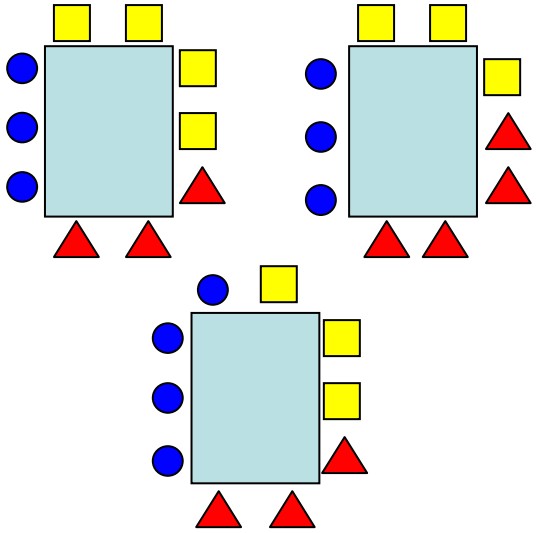
After the students have cycled through all three rotations, each Expert Group will move to a discussion area where they will meet separately to discuss the topic they were assigned to analyze in detail. Working together, each Expert Group will prepare their main points to present during the following Interdisciplinary-Group discussions. By working cooperatively, each of the students in the Expert Groups can become knowledgeable in that area. Students will be responsible for summarizing the material discussed by the Expert Groups in subsequent group discussions.

4. Interdisciplinary-Group Discussions (15 minutes)

Next, the students in the Expert Groups will be split up and redistributed to form three new "Interdisciplinary Groups." (The Interdisciplinary Groups correspond to the numbered groups on the Group Assignment Form.) Each member of the Interdisciplinary Groups will share some of the main points learned earlier and discussed in the Expert Groups. The Interdisciplinary Groups will think about the major question they have been asked to address and will formulate recommendations or suggestions for action. The Interdisciplinary Groups will discuss key pieces of evidence that support their conclusions. The groups also may outline possible additional research questions that need to be answered.



**Expert Group Example**



**Interdisciplinary Group Example**

5. Plenary Discussion (25 minutes)

Your visit to the museum will conclude with a discussion involving the entire class and guided by the field trip leader. The discussion will center on the major question being addressed by the class:

**How can knowledge of DNA sequencing be applied in the future?**

Students will synthesize the discrete information they have learned into a "big picture." They will discuss the pros and cons of the applications of DNA sequencing that are current in use.

Students will be asked to think about how DNA sequencing could affect the United States in coming years from biomedical, economic, and political perspectives. What will it mean for people to be more responsible for their health as it becomes possible to predict and treat inherited diseases? If you have your DNA sequenced, how will that sequence be used? A particular focus of this discussion will be how the evidence gathered by the students supports their conclusions and what uncertainties remain.

The Jigsaw method requires that students become actively engaged with the information they are studying and that they develop an understanding sufficient to enable them to share their understanding with other classmates and make informed recommendations. Students with some experience in working collaboratively and taking responsibility for their own learning will have the most to gain from the visit. Pre- and post-visit materials will offer guidance to teachers to enhance the value of the museum visit to their students.

### The Role of Docents, Teachers, and Chaperones

During your class visit, the field trip leader will:

- Instruct your class on its mission.
- With your assistance, manage your class's flow through the museum.
- Lead the class discussion after the Expert-Group and Interdisciplinary-Group discussions.
- Encourage comments based on evidence.

Teachers and chaperones are asked to:

- Help promote students' inquiry.
- Prepare their classes for the visit.
- Maintain appropriate behavior of students.

## MAKING THE MOST OF YOUR MUSEUM VISIT

To help ensure a successful visit:

- Prepare your students for their museum visit based on the information in this and other documents available on the museum's web site and that you receive when you register for your class's visit.
- Have your students leave backpacks, portable devices and other items on the bus or at school.
- Discuss appropriate behavior with your students ahead of time. Remember, the museum is housed in the Keck Center, the workplace of the National Research Council.
- Refer to the group visits section of the Koshland Science Museum web site for information on motorcoach parking.
- Have enough chaperones for a ratio of no more than ten students to one chaperone.

- Read through the science content of the exhibition you are studying in detail. Think about how the visit will fit into your curriculum.
- Have your class carry out some of the pre-visit activities suggested on the web site.
- Assign students to Expert and Interdisciplinary Groups using the Group Assignment Form prior to the visit. Each group should have a student leader. Each group will tour the exhibits together and become an expert at one of the three stations of the exhibition you are studying in detail. The student group leader may help delegate tasks where appropriate.
- At the end of your visit, contribute comments on the postcards provided, including one new thing that was learned and offering suggestions to improve the museum experience. After the museum staff use the postcards to evaluate the program offered, they will mail the postcards to your school.

**PROCEDURES FOR SIGNING UP FOR A FIELD TRIP**

All field trips must be scheduled in advance due to limited space. Field trips are offered in the morning on Tuesday, Wednesday, and Thursday and in the afternoon on Tuesday (subject to availability). Field trips are limited to 35 or fewer students due to the nature of the experience. Unscheduled visits by school groups will not be offered the field trip program.

To request a field trip:

1. Complete the online field trip request form at http://www.koshlandscience.org/teachers/fieldtripform.jsp or call 202-334-1201. Requests must be submitted at least four (4) weeks in advance of the requested date. You will be contacted within two (2) business days to confirm available dates.
2. Schools from the greater DC metropolitan area are free. The greater DC metropolitan area is defined as Washington DC, Montgomery County MD, Prince George's County MD, Charles County MD, Arlington County VA, Fairfax County VA, Prince William County VA, Loudon County VA and all cities and towns within these counties.
3. For groups from outside the greater DC area, admission payment is required to finalize your reservation. See the Group Payment, Refund, and Cancellation Policy for details on payment.
4. Once your field trip is confirmed you will receive a field trip packet in the mail. This contains the Exhibit Guide, the Group Assignment Form, a sample of the Student Worksheets, and the Roles and Responsibilities of Student Leaders. Please review this information carefully and contact the museum's education office at (202) 334-1201 with any questions or concerns.
5. At least two (2) weeks before your field trip, please finalize all arrangements with your school district, send out field trip permission forms to your class's parents, and arrange for chaperones.
6. One (1) week before your trip you must return our completed Field Trip Group Assignment form. Failure to return the form will result in the cancellation of the field trip for schools in the greater DC area. Hand out the Roles and Responsibilities of the Student Leader sheet out to the students you selected as student leaders.

## THE CONTENT OF THE *PUTTING DNA TO WORK* EXHIBITION

### Station 1: Orientation to DNA (Introduction and Probe the Sequence)

**The main messages of this station are:**

- DNA is shared by all living organisms.
- There is great similarity in the DNA sequences of different species.
- DNA sequences are more similar than different among individuals within species.
- DNA is found in nearly every living cell in all organisms.
- The DNA molecule is encoded with information, which can be visualized as a series of letters.
- The two strands of the DNA molecule are complementary.
- Short DNA probes have a higher probability of finding matches in a DNA sequence than longer probes, but DNA sequences are not random and the probability of finding matches is not necessarily obvious.
- An individual has two sets of sequences, one of which is inherited from each parent.

This station provides an introduction to DNA structure, an exploration of DNA sequence, and a brief overview of inheritance. Students can use an interactive exhibit to see how many genes they have in common with a wide range of organisms such as the fruit fly and mouse. The centerpiece of this section is the probe tower. With this interactive device, students can create their own short, electronic DNA probes and look for matches in part of the human genome. Surrounding the tower are explanations about the structure and function of DNA. This station ends with a brief explanation of inheritance.

### Station 2: Diagnosing Disease

**The main messages of this station are:**

- Some human diseases are linked to mutations in inherited sequences.
- Genetic testing can reveal whether a person has inherited copies of such mutations.
- Early detection can improve health management and actually prevent some genetic diseases.

Station 2 features two significant inherited diseases, hemochromatosis and sickle cell anemia. Assisted by an interactive computer display explaining mutations, students will discover that a single base pair mutation results in the malformation of blood cells. They will use an interactive video to test a family for a mutation in the gene that causes hemochromatosis and will see whether the children are carriers or are affected.

### Station 3: Find the Sequences that Make Us Unique (Forensics)

**The main messages of this station are:**

- Although people differ by only 0.1% of their DNA sequences, each person is unique.
- Individuals are identified using sequences that tend to show greater variability among individuals.
- DNA identification is based on the very low probability that multiple individuals will share identical sequences in these regions.

In this station, students will learn about the FBI's CODIS system. Using a wall-sized display, students will match the sequences of DNA collected at a crime scene with sequences from suspects. They will see the comparisons of the short tandem repeats at the 13 locations used by the CODIS system. A short video about the impact of DNA testing in the courtroom helps to put the display in perspective.

**Station 4: Sequences that Improve Crops**
**The main messages of this station are:**

- Modern produce hardly resembles its ancient wild-type ancestors.
- Humans have been modifying crops from about 10,000 years ago.
- Scientific crop development began about a century ago, and genetic engineering of crops began in the 1990's.

This station focuses on the long history of human manipulation of crop plants through selective breeding and, more recently, genetic engineering. The station focuses specifically on modifications made to the corn plant. Students will be able to see the differences between corn and its putative ancestor, teosinte. They will explore the amount of acreage planted with genetic modified plants worldwide. By moving a slider next to a physical representation of each of the chromosomes in a corn cell, students will see the locations of different genes and how mutations in those genes contribute to a wide variety of phenotypes.

**Station 5: Can DNA Sequences Protect Public Health?**
**The main messages of this station are:**

- Knowledge of DNA sequences helps to identify novel viruses and bacteria
- Microarrays are a new tool for detecting relationships between known and emerging infectious agents.

Station 5 features cutting-edge technology that was used to uncover the virus responsible for the SARS epidemic in early 2003. Students will learn how microarrays, which allow scientists to examine thousands of genes at one time, are being used to identify new infectious agents. They will see the actual sequences used on the arrays and will be able to identify for themselves the family of viruses that includes the SARS virus.

## HOW IS THE MUSEUM EXPERIENCE CORRELATED WITH THE NATIONAL SCIENCE EDUCATION STANDARDS?

Fieldtrips to the Koshland Science Museum are modeled on recommendations made in the *National Science Education Standards* (National Research Council, 1996). Through the information presented and opportunities to interact with hands-on displays, the *Putting DNA to Work* exhibition meets the following Inquiry and Science Content standards.

**For Middle School Students**

- Content Standard A – Science **as Inquiry**

"All students should develop understandings about scientific inquiry."
"Think critically and logically to make the relationships between evidence and explanations"

- Students have an opportunity to think critically and logically about DNA, the information carried in DNA sequences, and how scientists have used that information to solve problems and answer questions. Students also think about the relationships between evidence and explanations, the nature of science, and how new knowledge is generated. In addition, they experience peer teaching and consider how science makes use of logical analysis and problem solving.

- Content Standard C - **Life Science**
  "All students should develop understanding of structure and function in living systems and of reproduction and heredity."
  - Students enhance their understanding of how the structure of DNA enables it to perform its main functions of information storage and inheritance between generations. In station 1, students have an opportunity to develop a better understanding of inheritance patterns. In stations 2 and 3, students explore genetic diseases, modes of inheritance, and the use of DNA sequences in forensics. Stations 4 and 5 provide ways to think about how knowledge of DNA sequences is applied to such problems as increasing crop yields and identifying unknown disease-causing agents.

- Content Standard E – **Science and Technology**
  "All students should develop understandings about science and technology."
  - Students enhance their understanding of how science and technology work together in generating new knowledge. In stations 2 and 3, students use their understanding of DNA sequences to probe genetic disorders and identify criminals. In station 5, they identify infectious agents using DNA sequencing technology. The interactive displays allow students to manipulate sequences and better understand how DNA can be similar among people yet very different in specific ways. Students come to understand that DNA sequences are vast sources of information and knowledge.

- Content Standard F - **Science in Personal and Social Perspectives**
  "All students should develop understanding of personal health, populations, resources, and environments."
  - Using the microarray technology described in station 5, students are encouraged to think about the application of DNA sequence information to health-related issue. They also consider, in station 2, the appropriate uses of genetic testing to diagnose or predict disease.

- Content Standard G – **History and the Nature of Science**
  "All students should develop understanding of science as a human endeavor and of the nature of science."
  - All of the stations demonstrate that DNA sequencing can be used to pursue a wide range of goals such as increasing food production, identifying disease-causing agents, or finding new drugs to treat illnesses.

**For High School Students**

- Content Standard A **– Science as Inquiry**
  "All students should develop understandings about scientific inquiry."
  "Think critically and logically to make the relationships between evidence and explanations"
  - Using evidence and logical thinking, students develop an understanding of the DNA sequence as the universal language of all living systems. This commonality allows for the use of model organisms in scientific inquiry to gain knowledge about how life works. Students see how DNA sequence technology will affect their lives, both as individuals susceptible to genetic diseases and infectious agents and as members of populations in need of greater food supplies. Students are asked about the need for and implications of greater public understanding of DNA sequences.

- Content Standard B – **Physical Science**
  "All students should develop an understanding of chemical reactions."
  - In station 1, students enhance their understanding of chemical reactions and atomic structure by looking more deeply at the structure and function of DNA. In Station 3, students see how chemical reactions enable forensic scientists to use DNA sequences as a tool to identify criminals and to exonerate individuals who are falsely accused. Similarly, students can apply their understanding of DNA sequences while learning about the genetic modification of agricultural crops in Station 4 and about the identification of new infectious agents in Station 5.

- Content Standard C – **Life Science**
  "All students should develop an understanding of the cell and of the molecular basis of heredity."
  - Students strengthen their understanding of the molecular basis of heredity, the chemical basis of life, and the impact of mutations on living systems. All of the exhibits provide an opportunity to study ways in which scientists have used an understanding of DNA sequences to solve problems: the identification of unknown infectious agents in station 5, the improvement of agricultural crops in station 4, the identification of criminals in station 3, and the diagnosis of genetic disease in station 2.

- Content Standard E – **Science and Technology**
  "All students should develop understandings about science and technology."
  - Students have an opportunity to think about how technological advances have enabled the understanding of DNA sequences to move forward. As understanding advances, new technologies are developed that make use of new knowledge to solve human and societal problems. Stations 2 and 3 illuminate this interplay by reviewing the study of genetic diseases and the development of interventions to curtail resulting medical problems. Station 5 shows how the new microarray technology has made possible the rapid identification of infectious agents, and station 4 demonstrates how

DNA sequences from different organisms can be used to give plants new and desired traits.

- Content Standard F - **Science in Personal and Social Perspectives**
  "All students should develop an understanding of personal and community health and of population growth."
  - Stations 1 and 2 allow students to think more deeply about how DNA sequences can affect their own personal health. Station 5 challenges students to think about public health issues and disease prevention issues. Challenges related to human health and global population growth are presented in station 4 as students consider the use of DNA sequences to modify crops such as corn.

- Content Standard G – **History and Nature of Science**
  "All students should develop understanding of science as a human endeavor and of the nature of scientific knowledge."
  - In all of the stations, students see the many ways in which technology and science each drive the other forward in a leapfrog manner. Students discuss the application of DNA sequence technologies, share their interpretations, pose questions, and debate the significance and implications of new knowledge. Students discuss possible policies that may be needed to regulate future work and protect individual privacy. Students deliberate on why the general public may need a better understanding of DNA sequences and how that knowledge may empower then to be more proactive with respect to health issues and genetic testing.