Last Updated: 05/14/25

How Science Works

Student Workbook

10th & 11th Grade - Bioinformatics (I)

 

Scientist Name: ____

Teacher Name: ____

SciTrek Mentor Name: ____

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Welcome to SciTrek!

Hey there! Welcome to SciTrek—we're so excited to have you join us! This workbook is your guide to all the cool science activities and experiments you'll be doing throughout the program. You'll get to dive into some amazing concepts, work in teams, and learn from SciTrek Mentors and Leads who are here to help you explore the world of science.

Here's what to expect:

- **Day 1: Gene Regulation**
  Start your journey by learning how genes are turned on and off in our cells. SciTrek Leads will guide you through interactive activities to explore how gene regulation works—and why it matters.
- **Day 2: Understanding Cancer**
  What makes cancer different from healthy tissue? You'll dive into real-world examples with SciTrek Mentors to discover how cancer develops and why it's so tricky to treat.
- **Day 3: How Do We Know Cancer Is There?**
  Roll up your sleeves and analyze real data! With your small team and SciTrek Leads, you'll explore how scientists detect cancer by looking at gene expression patterns.
- **Day 4: Gene Expression Differences Between Cancer and Healthy Cells**
  You'll take a closer look at actual gene expression data, working in small groups with SciTrek Mentors to identify key differences between healthy and cancerous cells.
- **Day 5: Poster Symposium – Identify a Hallmark of Colorectal Cancer**
  It's your time to shine! Pull everything together to create a scientific poster with your team, presenting your findings on a hallmark of breast cancer. Celebrate your discoveries with the SciTrek Leads as the program wraps up!

Remember, your teacher and the SciTrek team are here to help you every step of the way, so don't be afraid to ask questions or share your ideas. This is your chance to explore, experiment, and have fun with science! Let's make this an unforgettable experience!

What You'll Learn in the Bioinformatics Module

In this module, you'll explore how scientists use computer-based tools to study genes and diseases—especially cancer! You'll work with real data, ask important scientific questions, and uncover how bioinformatics helps us understand what's happening inside our cells. By the end of the program, here's what you'll be able to do:

- **Gene Regulation Basics:**
  You'll discover how and why certain genes are turned on or off in different cell types—and why that matters for health and disease.
- **What Is Cancer?:**
  You'll explore what makes cancer cells different from healthy ones and how gene expression can reveal those differences.
- **Data Analysis with Real Tools:**
  You'll learn to use bioinformatics software (just like real scientists!) to analyze gene expression data from healthy and cancerous tissue.
- **Hypothesis Development:**
  You'll ask your own scientific questions about cancer biology and use real-world data to test your predictions.
- **Identifying Cancer Biomarkers:**
  You'll search for gene expression patterns that could help identify cancer—and learn how scientists use this information to improve diagnosis and treatment.
- **Scientific Poster Presentation:**
  You'll create and present a scientific research poster with your team, sharing your discoveries with peers and SciTrek Leads in a final symposium.

Get ready to analyze, investigate, and present like a real bioinformatics researcher!

Important Vocabulary

Gene Expression: How much a gene is "turned on" or "off" in a cell, often measured by how much mRNA is made from that gene.

Regulation: The control of when, where, and how much a gene is expressed in a cell.

DNA (Deoxyribonucleic Acid): The molecule that carries genetic instructions used in the growth, development, and function of living organisms.

RNA (Ribonucleic Acid): A molecule made from DNA that helps produce proteins. In gene expression studies, RNA levels tell us which genes are active.

Protein: A molecule made from RNA instructions that performs many functions in the body, such as building cells or sending signals.

Bioinformatics: A field that combines biology, computer science, and math to analyze biological data like DNA or RNA sequences.

mRNA (Messenger RNA): A type of RNA that carries the code from DNA to make proteins. Scientists often measure mRNA to study gene activity.

Biomarker: A biological sign (like a gene or protein) that can indicate a disease, such as cancer.

Cancer: A disease where cells grow uncontrollably and may spread. Cancer cells often show changes in gene expression.

Hypothesis: A scientific guess or prediction that you can test through experiments or data analysis.

Data Analysis: Looking at collected data to find patterns, differences, or trends. In this module, you'll analyze gene expression data.

Heat Map: A colorful chart used to show differences in gene expression levels between samples, such as healthy and cancerous tissue.

Differential Expression: When a gene is expressed at different levels between two or more sample types (e.g., cancer vs. healthy cells).

Hallmark of Cancer: A key trait or behavior of cancer cells, like growing too fast or avoiding the immune system.

Scientific Poster: A visual presentation of your research question, methods, results, and conclusion. You'll create one to share your work!

Day 1

Unlocking the Code: How Your Cells Decide What to Do (or "Gene Control 101: Why Some Genes Stay Silent)

Objective

Today, you'll explore how cells control which genes are turned on or off, a process called gene regulation. You'll learn why this control is essential for different cell types to do their specific jobs—even though they all have the same DNA. By the end of the day, you'll be able to explain the basics of gene regulation and why it plays a key role in health and disease.

Introduction to SciTrek

What's the Plan?

- Meet the SciTrek Leads.
- Discover what SciTrek is all about.
- Learn about gene regulation: What gene regulation is and why it matters, how cells with the same DNA do different jobs, how genes are turned "on" or "off", why gene control is important for health and disease, key terms: gene expression,transcription, regulation.

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The Most Influential Scientists in the Development of Medical informatics: Margaret Belle Dayhoff
Margaret Belle (Oakley) Dayhoff (1925-1983) was an American physical chemist and a pioneer in the field of bioinformatics. She dedicated her career to applying the evolving computational technologies to support advances in biology and medicine, most notably the creation of protein and nucleic acid databases and tools to interrogate the databases. Dayhoff was widely known in the scientific community for establishing a large computer database of protein structures as well as for being the author of the Atlas of Protein Sequence and Structure, a multivolume reference work.
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6-20 min | Activity: Watch & Learn: Video [Gene Expression and Regulation]

👉 **While watching, complete the worksheet below:**

1. **What is gene regulation?**
   → ____
2. **What is the role of a promoter?**
   → ____
3. **What does a repressor do?**
   → ____
4. **Why is gene regulation important?**
   → ____

21–35 min | Activity: Gene Regulation Analogies

Match parts of gene regulation to real-life systems. Think about light switches, dimmers, locks, and keys!

Gene Regulation Component	Real-Life Analogy	Why?
Promoter	_______________ _	______________________________ _
Repressor	_______________ _	______________________________ _
Enhancer	_______________ _	______________________________ _
Transcription Factor	_______________ _	______________________________ _

Bonus: Draw a diagram that shows your favorite analogy in action:
✏️ ____

Activity: Exploring Gene Regulation with PhET Simulation

Goal:
Use an online simulation to understand how genes are turned “on” or “off” and how this affects protein production in cells.

What You’ll Need:

- A computer or tablet with internet access
- Headphones (optional)

Step-by-Step Instructions:

1. **Go to the Simulation**
   Visit the PhET Gene Expression Essentials simulation:
   https://phet.colorado.edu/en/simulations/gene-expression-essentials
2. **Explore the Controls**
   - What happens when you turn a gene "on"?

   → ____

   - What changes when you turn it "off"?

   → ____

3. **Run a Test Scenario**
   - Turn on combinations of transcription factor, RNA polymerase, and gene switches.
   - Watch how mRNA and protein levels change.
   - Record your observations.

   → ____

4. **Try Challenge Mode** (if available)
   - Figure out how to activate gene expression under different conditions.
5. **Answer These Questions:**
   - What are the steps to turn on a gene?

   → ____

   - What happens if one component is missing?

   → ____

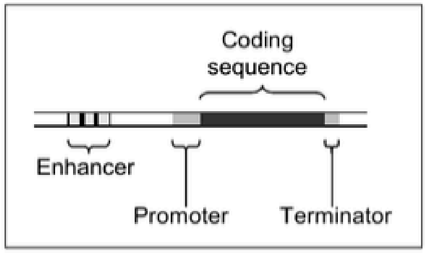
- Why is gene regulation important?

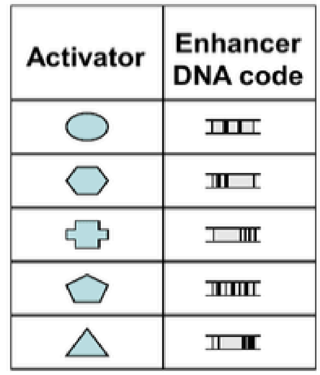
→ ____

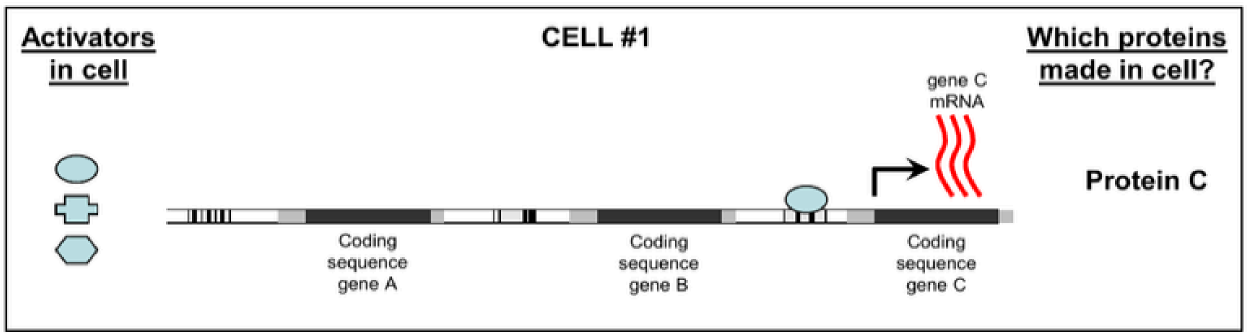
How can cells have the same DNA but different proteins?

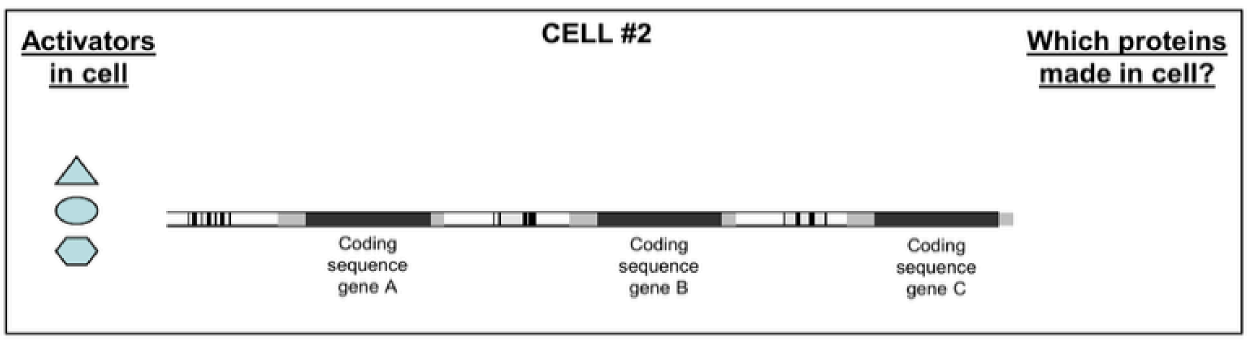
Different enhancers have different DNA sequences, much like different bar codes. Each activator recognizes one of the specific enhancer sequences and "turns on" transcription of the gene associated with it. The proteins made by a cell depend upon the cell's combination of activators. Note that the DNA sequences below are the same, but each cell has a different combination of activators.

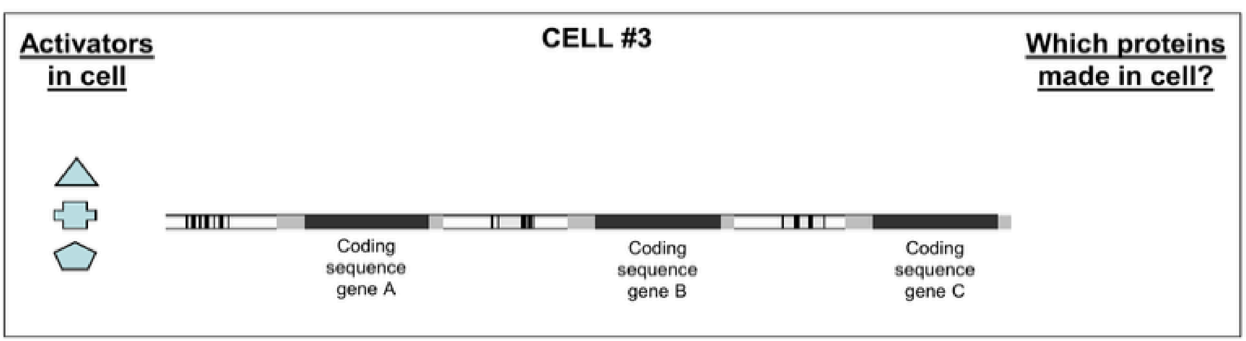
Use the table at right to determine which mRNA and proteins are made in each cell. Cell #1 is completed for you.











💥 36–50 min | Inquiry Discussion: What Can Go Wrong?

Let’s imagine: What could happen if one of these “switches” is broken?

Question:
What might go wrong if a repressor or promoter is damaged or missing?

Write your thoughts below:

→ ____
→ ____
→ ____

📝 51–60 min | Exit Ticket: Reflection

Prompt:
What might cause gene regulation to go wrong?

☑️ Write 2–3 bullet points or a short paragraph below:

- ____
- ____
- ____

🧠 *Hint: Think about mutations, environmental chemicals, radiation, or other stressors.*

Day 2

Objective

Today, you'll investigate what happens when the "instructions" inside a cell go away, leading to uncontrolled growth, known as cancer. By the end of the day, you'll be able to describe the hallmarks of cancer, explain how key molecules like p53 work to prevent tumor formation, and articulate why cancer is fundamentally a problem of cell-cycle regulation gone wrong.

What's the timeline?

- Brainstorm what cancer is and why it arises
- Watch a foundational video on cancer biology
- Explore the role of tumor suppressors through a case study of p53

0–5 min | Warm-Up Brainstorm

👉 **Prompt**: Using your own knowledge, answer the questions below:

What is Cancer?

→ ____

Why does cancer happen?

→ ____

Two questions I have about cancer?

→ ____

→ ____

6–20 min | Activity: Watch & Learn Video “What Is Cancer?”

(https://www.youtube.com/watch?v=tsXnVu3kUnM)

How does cancer differ from normal cell growth?

→ ____

Name two hallmarks of cancer you saw in the video.

→ ____

What role do mutations play in cancer development?

→ ____

Why is early detection important?

→ ____

21–40 min | Activity: Discover the Cell Cycle and Cancer Damage

https://www.biointeractive.org/classroom-resources/p53-gene-and-cancer

What are Oncogenes?

→ ____

What are Tumor suppressor genes?

→ ____

What are DNA repair genes?

→ ____

What is the normal function of p53 in a healthy cell?

→ ____

In two sentences describe how p53 works?

→ ____

→ ____

41–50 min | Activity: Discover the Cell Cycle and Cancer Damage

https://www.biointeractive.org/classroom-resources/eukaryotic-cell-cycle-and-cancer

Which checkpoint did you explore in your activity?

→ ____

Describe one "what-if" scenario you tested

(e.g., turning p53 off, overexpressing cyclin D, disabling the G2/M arrest).

What did you observe?

→ ____

How did the simulation reinforce your understanding of cancer development?

→ ____

51–60 min | Exit Ticket: Create a Metaphor for Cancer

Prompt: **"Cancer is like [____] because …"**

→ ____

→ ____

Day 3

Objective

Today, you'll explore how scientists figure out if a person might have cancer by looking at gene expression. Genes can act like "volume dials", either by being too loud or too quiet, which may signal that something is wrong. By the end of today, you'll understand how gene expression clues can point to cancer, and begin thinking like a diagnostic scientist.

0–5 min | Warm-Up Discussion

👉 **Prompt**: *If a gene is too "loud" (high expression) or too "quiet" (low expression), what might that mean?*

Write 1–2 sentences or bullet points below:

→ ____

→ ____

6–20 min | Activity: What Does Gene Expression Look Like?

Goal: Use a simplified activity to compare expression levels in different genes. You'll examine how "housekeeping" genes (always on) differ from genes that may be linked to cancer.

Instructions:

1. Look at the example gene charts or data cards.
2. Compare the expression of genes in healthy and cancerous cells.
3. Match the "loud" or "quiet" genes with their possible role (normal or suspicious).

What patterns do you notice?

→ ____

→ ____

21–40 min | Activity: Gene Detective – Create a Hypothesis

Imagine you are a gene detective! Use the "Gene Suspect Cards" and your observations to:

1. **Create a hypothesis**: What kind of gene behavior might help you identify if someone has cancer?
   → ____
2. **Pick your "suspect" genes**: Which ones look suspicious, and why?
   → ____
3. **Think like a scientist**: What kind of experiment would you design to test this?
   → ____

41–50 min | Guided Inquiry: Design an Experiment

Work in groups to sketch a plan for how you could test your hypothesis.
👉 Use drawings or flowcharts if it helps!

Questions to consider:

- What would you compare (healthy vs cancer)?
- What kind of data would you collect (expression levels)?
- How would you know if a gene is a good cancer marker?

Draw or describe your experiment:
→ ____
→ ____

51–60 min | Exit Ticket: Reflection

Prompt: **If you could investigate one gene for cancer, which would you choose and why?**

🧠 *Hint: Think about how different expression levels might reveal something unusual.*

→ ____

Day 4

Gene Expression Differences Between Healthy and Cancer Cells

Objective

Today, you'll practice how scientists use visual data to compare gene activity between healthy and cancerous cells. You'll learn how gene expression levels can act as clues, showing which genes are behaving differently in cancer. By the end of the day, you'll be able to identify genes that are more or less active in cancer and explain why that matters for diagnosis and treatment.

What's the Plan?

- Recap how gene expression works and why scientists study it.
- Explore gene expression patterns using simplified data visualizations.
- Practice identifying differences between healthy and cancerous cells.
- Build your Gene Data Dictionary using reliable resources like GeneCards and UniProt.
- Connect expression differences to real-world cancer diagnosis.

The Most Influential Scientists in the Development of Medical informatics: Janet Thornton Dame Janet Thornton (b. 1949) is a British bioinformatician whose work in protein structure prediction and computational biology has been foundational to modern bioinformatics. She was instrumental in the development of the Protein Data Bank in Europe (PDBe) and has led major initiatives in structural genomics. Thornton's research has focused on understanding the relationship between protein structure and function, critical for drug design and cancer research. Through her leadership and scientific contributions, she has advanced the use of computational tools to decode the complexities of biological molecules in health and disease.	

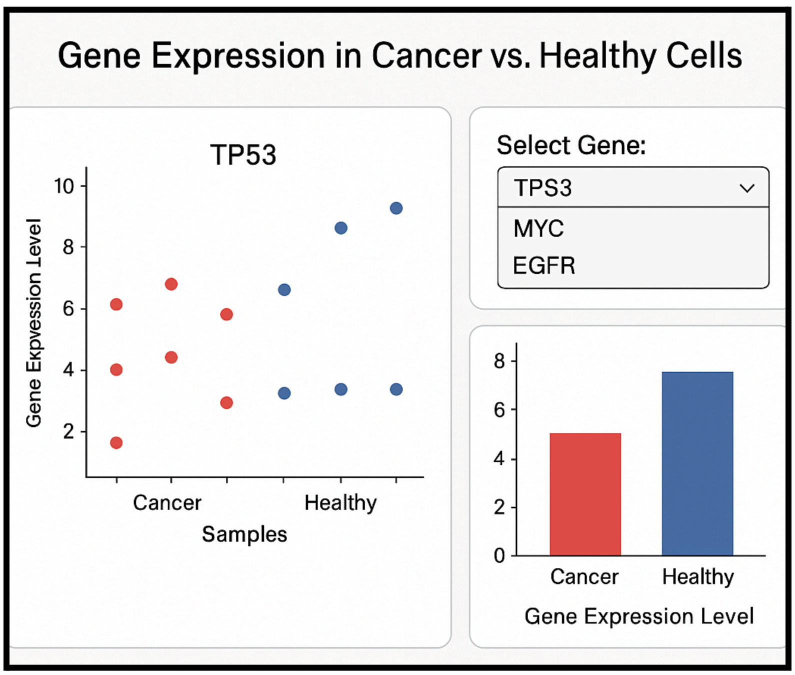
Warm-Up Question

If a gene is “turned up” in cancer cells, what might that tell you?

6–20 min | Visual Data Practice: Gene Expression Bar Graphs

For each gene below, explore the datasets with the interactive dashboard.

(placeholder image for interactive data viewer to be built with website)



21–35 min | Gene Function Matching

Use GeneCards or UniProt to match gene names to their normal functions.

(will be made interactive game with website)

Gene	Normal Function	"Why does it matter?" (One phrase)
TP53		
MYC		
EGFR		

36–45 min | Find the Difference: Healthy vs. Cancer

- Students will be assigned one gene, and must do some research on it (they will recieve it via the virtual inbox on the website)

For your assigned gene, answer:

1. **This gene is (🟥 higher / 🟦 lower) in cancer.**
   → ______________________________
2. **In normal cells, this gene helps with:**
   → ______________________________
3. **In cancer cells, the problem is:**
   → ______________________________

46–55 min | “Tell the Story” Practice

Complete the sentence below:

- **“My gene, __________, normally __________. But in cancer, it __________, which helps doctors understand __________.”**
  → ____

56–60 min | Reflection

What is one new thing you learned about gene expression differences today?
→ ____

Day 5

Telling the Story of a Gene: From Data to Diagnosis

Objective

Today, you'll synthesize everything you've learned into a scientific poster that explains how a specific gene behaves differently in breast cancer. You'll practice communicating scientific findings clearly and effectively, just like real researchers do. By the end of the day, you'll have created a poster that showcases your gene's role in cancer, with visuals and evidence to support your explanation.

What's the Plan?

- Learn how to communicate scientific data through posters.
- Use your Gene Data Dictionary and dashboard findings to build your poster.
- Include visual elements like bar graphs or heatmaps to illustrate gene expression differences.
- Practice presenting your poster to peers and receive feedback.
- Participate in a mini-poster symposium to share your findings with the class.

The Most Influential Scientists in the Development of Medical informatics: Dr. Charles Rotimi

Dr. Charles Rotimi is the Director of the Center for Research on Genomics and Global Health at the NIH. He is a pioneer in studying the genetic diversity of African populations and its implications for disease. His bioinformatics-driven research focuses on understanding the genetic basis of common diseases like hypertension and diabetes, particularly in African and African diaspora populations. Dr. Rotimi's leadership has been instrumental in ensuring that genomics research includes diverse populations and addresses global health disparities.

Warm-Up: Prepare Your Message

📝 If you had to explain your gene in 1 sentence to a family member, what would you say?
→ ____

6–20 min | Building Your Poster

Use the provided poster template to organize your work.

Poster Sections:

- **Title: The Role of __________ in Breast Cancer**
- **Background: What does this gene do normally?**
- **Expression Difference: How is this gene different in cancer?**
- **Visual Data: Bar graph or heatmap image (screenshot or hand-drawn)**
- **Clinical Relevance: Why does this matter for doctors or patients?**
- **Fun Fact or Analogy: A simple way to explain the gene's role**

Work Time:

- **Start by filling in the Background and Expression Difference sections.**
- **SciTrek Leads will circulate to guide you.**

21–35 min | Visual & Data Storytelling

Focus on your Visual Data section:

1. **Draw or paste your gene's expression difference (bar graph, heatmap).**
2. **Label which samples are healthy and which are cancerous.**
3. **Write 1-2 sentences explaining what your visual shows.**

36–45 min | Team Collaboration: Peer Feedback

Work in pairs:

1. **Swap posters with a partner group.**
2. **Give "Glow & Grow" feedback:**
    - 🌟 **One thing they did well**
    - 🔧 **One thing they could explain more clearly**

46–55 min | Poster Presentations

Each group shares their gene story to the class.
Use the sentence:
"Our gene, __________, normally __________. In breast cancer, it __________, which is important because __________."

SciTrek Leads will provide final feedback.

56–60 min | Final Reflection

📝 **What was your favorite discovery during this module?**

→ ____

📝 **How has your understanding of gene expression and cancer changed?**

→ ____