THE MESSENGER

Teaching Guide

IN THE CLASSROOM

"There is this concept that science is a lonely quest by a solitary genius, isolated from the world, frantically scribbling equations on a scrap of paper, and then shouting Eureka and running out onto the street to tell the world about the discovery. There's no question that phenomena like that happened in the history of science. But in truth, the things that make a difference in the real world have features which are kind of hard to make a good movie out of."

—Fyodor Urnov, in "THE MESSENGER: A Story of mRNA"

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TARGET AUDIENCE

This teaching guide is designed for students in their final years of secondary education or early university studies (college or undergraduate level), particularly those enrolled in biology, biochemistry, or related life-science courses. Originally developed within the Swiss Gymnase/Collège framework, it is equally suited for first-year biology programs or introductory interdisciplinary science courses in international settings.

Educational Level and Context

- Age group: 16–20 years old
- Level: Pre-university / Undergraduate
- Disciplines: Biology, Chemistry, or Interdisciplinary Science Modules
- Pedagogical use: Suitable for classroom teaching, interactive discussions, and laboratory or practical sessions.

Pedagogical Note

Some topics are presented through a historical perspective (e.g., the work of Mendel, Pasteur, Watson and Crick, or Darwin) to illustrate the concept of scientific models and the evolving nature of the scientific method.

This guide can be used during regular lessons and/or practical laboratory sessions, integrating the film THE MESSENGER into units on genetics, biotechnology, physiology, and the process of scientific discovery.

LEARNING OBJECTIVES

The objectives are grouped into four main Themes, each connected to specific lessons from the guide.

Theme: Molecular Biology and Gene Expression:

- Explain the role of messenger RNA in protein synthesis, from the transcription of DNA to translation. → LESSON 1
- Describe the stages of the central dogma of molecular biology: DNA → RNA → Protein. → LESSON 1
- Compare RNA and DNA in terms of structure and function (nitrogenous bases, single/double strands, stability, cellular location). → LESSON 1
- Explain how lipids and lipid nanoparticles (LNPs) enable safe delivery of mRNA into cells. → LESSON 2
- Understand the regulation of gene expression and how the artificial synthesis of mRNA can be used to intervene in this process. → LESSON 4

Theme: Biotechnology and Health

- Explain the principle of mRNA vaccines — how they enable the immune system to recognize a viral protein without exposure to the whole virus. → LESSON 1, 2, 5
- Identify the advantages and limitations of mRNA technologies (speed of production, adaptability, storage, side effects). → LESSONS 5
- Distinguish between vaccines and therapies and understand why mRNA does not alter the human genome. → LESSON 6

Theme: Science, Society, and Communication

- Discuss the ethical, economic, and social implications of mRNA technologies in global health. → LESSONS 7, 8
- Evaluate how patents and intellectual property influence innovation, investment, and access to medicine. → LESSON 8
- Develop critical thinking when analyzing media information and public debates about vaccination, biotechnology, and biomedical research. → LESSON 7
- Evaluate the importance of scientific communication and the need to counter misinformation about vaccines and genetics. Reflect on science as a non-linear, collaborative, and evolving process, rather than a sequence of “Eureka” moments. → LESSON 7
- Analyze the role of fundamental research and molecular biology discoveries in recent medical advances. Link each biotechnological innovation to its historical and scientific context, recognizing the contributions of key researchers (Karikó, Weissman and other researchers). → LESSON 3

Theme : Cross-Disciplinary Competencies

- Illustrate the interdisciplinary nature of modern biology — the interactions between biology, chemistry, medicine, informatics, and health policy. → LESSONS 2, 5, 7
- Interpret and diagram molecular mechanisms shown in the film — transcription, translation, lipid encapsulation, and immune response. → LESSONS 1, 2, 5
- Build and defend scientific arguments using real examples from THE MESSENGER about the benefits and challenges of mRNA. Develop critical thinking to identify fake new from real news. → LESSON 7

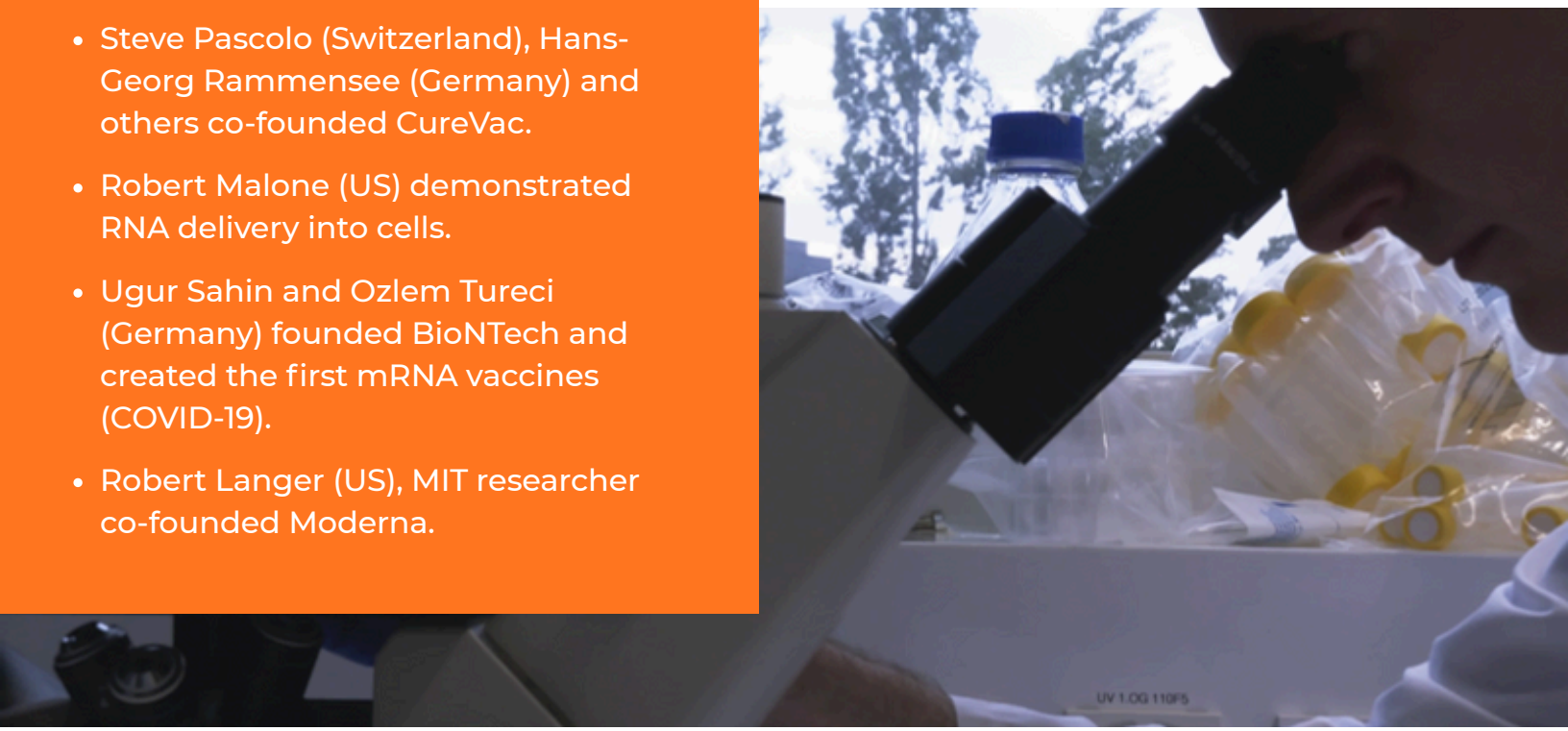
INTRODUCTION

THE MESSENGER is more than a film - it is an educational journey into the very heart of biology. At its core, the film explains how life works at the molecular level with vivid animations and the playful “Petit Chef” metaphor to make complex science accessible to students. It showcases fundamental biological concepts: DNA as the master code, mRNA as its working copy, ribosomes as the protein factories of the cell, and lipids as protective envelopes that safely deliver RNA into targeted cells to produce proteins for vaccinations and therapeutics.

At the same time, the film tells the human story behind these discoveries. Students meet the pioneering scientists who took mRNA from fragile laboratory experiments to life-saving vaccines and therapies. From Katalin Karikó and Drew Weissman’s Nobel Prize–winning work on RNA modifications, to Pieter Cullis’s lipid delivery systems, to BioNTech’s Sahin and Türeci who created the first COVID-19 mRNA vaccine, the film reveals decades of persistence, failure, and breakthrough. THE MESSENGER shows science not as a straight line, but as a global, messy, and deeply human journey that continues to shape the future of medicine.

KEY FEATURED SCIENTISTS:

- Katalin Karikó and Drew Weissman (US) 2023 Nobel Prize in Medicine.
- Pieter Cullis (Canada) created revolutionary lipids.
- Steve Pascolo (Switzerland), Hans-Georg Rammensee (Germany) and others co-founded CureVac.
- Robert Malone (US) demonstrated RNA delivery into cells.
- Ugur Sahin and Ozlem Tureci (Germany) founded BioNTech and created the first mRNA vaccines (COVID-19).
- Robert Langer (US), MIT researcher co-founded Moderna.



LESSON ONE:
What is mRNA in the central dogma

Curriculum Anchor:

"Explain the structure and function of DNA, RNA, and proteins; describe the processes of transcription and translation."

Film Extracts:

- What is mRNA in simple terms [04:26-05:07]
- "Petit Chef" animation [08:47-10:06]

DNA as a cookbook, RNA as recipe copy, ribosome as chef, protein as finished meals. As soon as the "cooking" is done, the mRNA copy is destroyed. The clip provides a visual and memorable metaphor for the central dogma of DNA → RNA → Protein. Delivering artificial mRNA into cells to produce targeted proteins for therapeutics, has been a long standing challenge for scientists.

Discussion Questions:

1. What is DNA and how RNA is different?
2. Why is RNA often called fragile? Why does Dr. Pascolo call it robust?
3. What role do ribosomes play in the Central Dogma?
4. Why is understanding the Central Dogma important for medicine?

Suggested Classroom Activity:

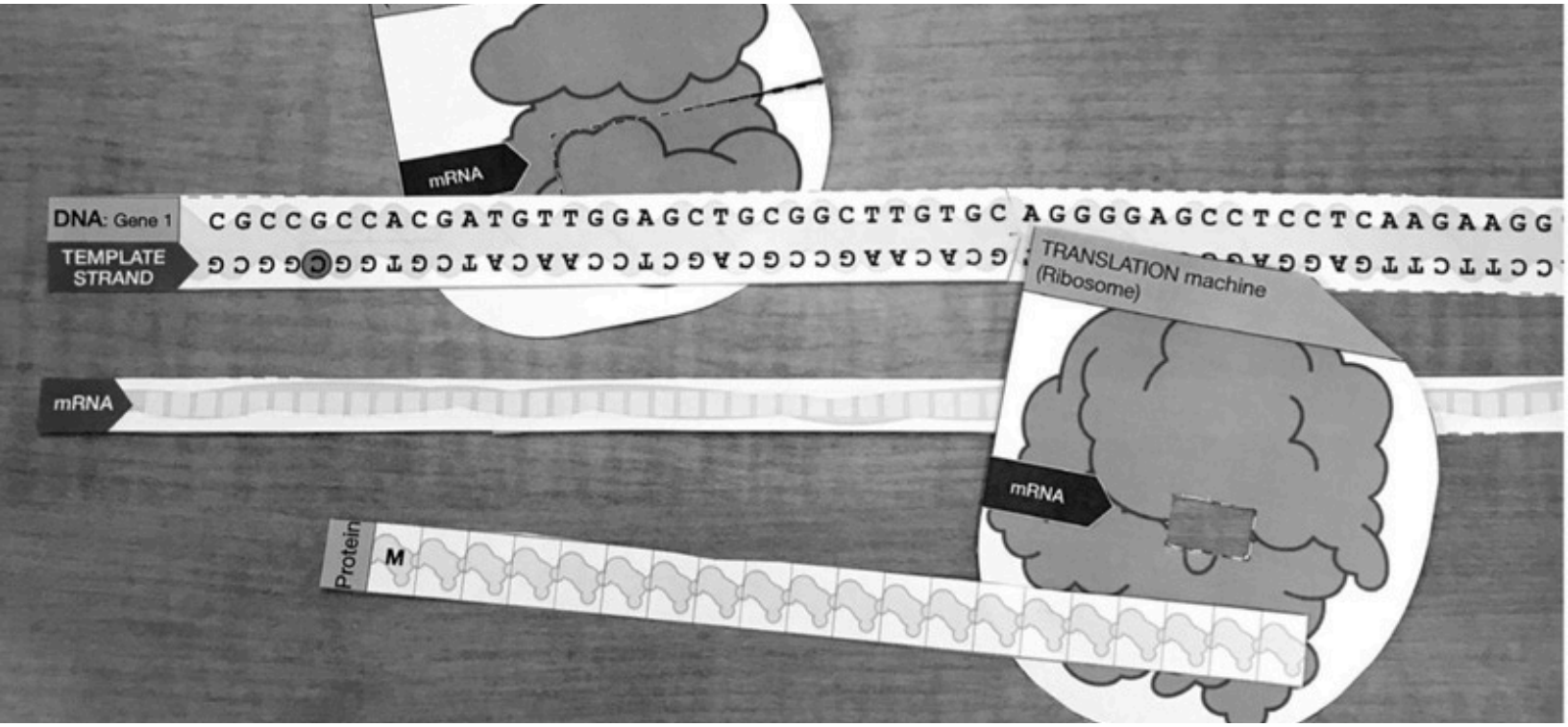
Through a hands-on simulation of transcription and translation, students bring the Central Dogma to life. Using printed DNA sequences, scissors, colored pens, and codon tables, they transcribe DNA into mRNA and translate it into amino acid chains, identifying the resulting protein and discussing its role. The activity can be done on paper or digitally using online simulators such as *Learn Genetics* [1], *Swiss Institute of Bioinformatic* [2] or *3D Modelling* [3] workshops. To conclude, students link what they built to the Petit Chef animation from the film — realizing that the same process used in cells is also the principle behind mRNA vaccines, where synthetic RNA encodes a viral protein that trains the immune system safely.

Materials:

- Printed DNA sequences (or digital versions provided online)
- Scissors, colored pens/pencils, and a codon table
- A ribosome model (paper or 3D)
- (Optional) Computers or tablets with online simulators

Procedure:

1. Students cut out DNA sequences and transcribe them into complementary mRNA codons.
2. Using a codon table, they translate each codon into the corresponding amino acids.
3. They identify the resulting protein and discuss its possible biological function.
4. The class connects this process to mRNA vaccines: synthetic mRNA encodes a viral protein, which safely triggers an immune response without infection.



LESSON TWO:
Lipids - Delivering mRNA and Therapeutics

Curriculum Anchor:

"Explain the structure of biological membranes and the function of lipids in cells and in biotechnology."

Film Extracts:

- Phil Felgner's cationic lipids (1980s-1990s) [10:24-11:05]

Robert Malone shares a story of scientists' struggle searching ways to deliver artificial RNA into cells and first successful attempts of such delivery using cationic lipids from California.

- Animation of Cationic Lipids [11:07-12:07]

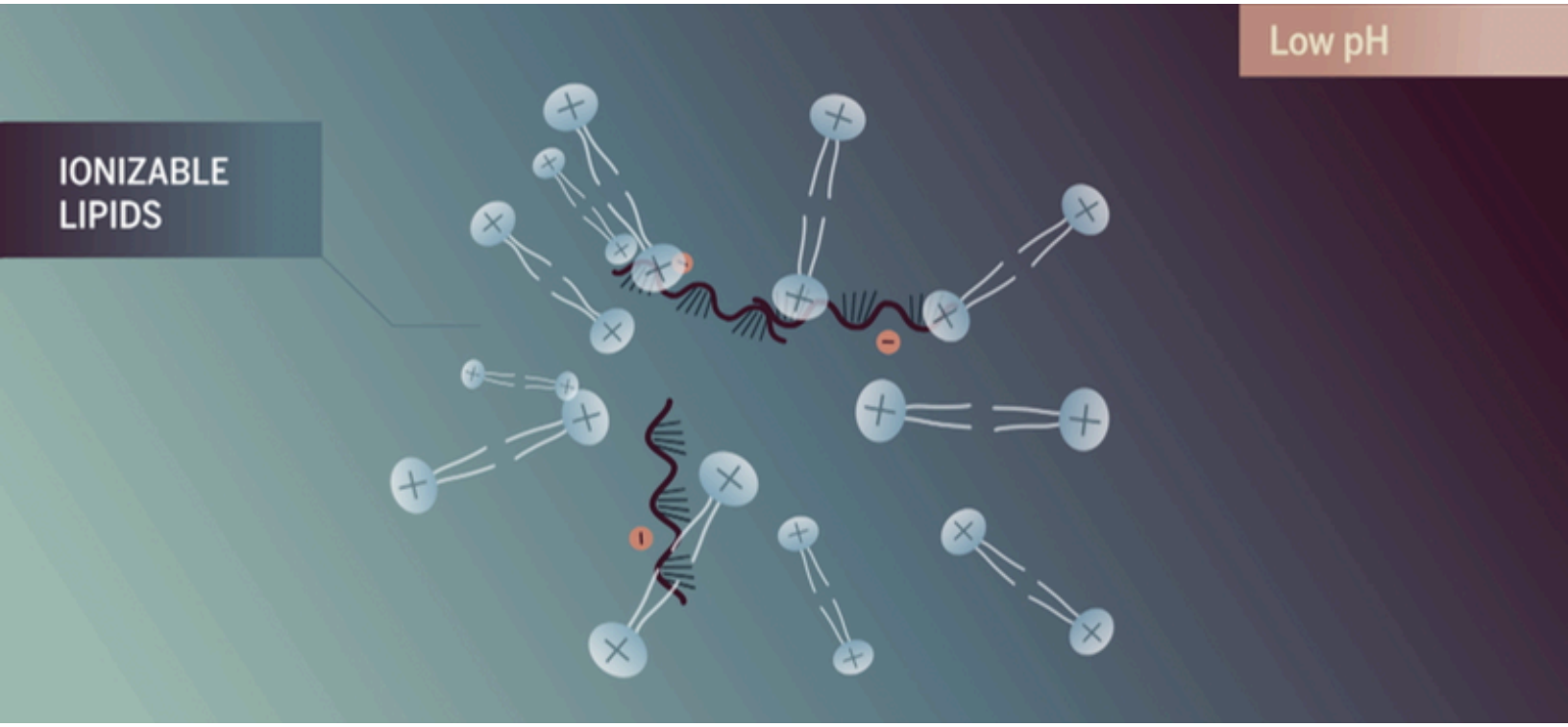
Lipids are little molecules of fat. In nature they are neutral or negatively charged. RNA is always negatively charged. Synthetic cationic lipids are positively charged to capture RNA via electrostatic interactions.

- Pieter Cullis' Lipid Nanoparticles (2000s-2010s) [17:20-18:30]

Cullis explains the challenge of cationic lipids being toxic in vivo for human body.

- Animation of Ionizable Cationic Lipids [18:30-18:30]

The new lipids created by Cullis is a game changer. They reduce toxicity and serve as the foundation for lipid nanoparticles (LNPs) — advanced carriers derived from early liposome research. Unlike conventional liposomes, LNPs have a distinct ultrastructure, enabling safe and efficient large-scale delivery of mRNA for modern vaccines and therapeutics.



Discussion Questions:

1. Why did Felgner's cationic lipids work but remain limited?
2. How did Cullis' nanoparticles improve safety and effectiveness?
3. Why are lipids so essential for delivering genetic medicines?
4. What challenges do scientists still face in making lipid nanoparticles reach the right cells or organs?

Suggested Classroom Activity:

Through a hands-on soap-bubble experiment, students explore how lipids form protective membranes and why they are crucial for delivering mRNA into cells. Using simple materials such as dish soap, distilled water, and wire loops, they model the lipid bilayer and observe key physical properties — fluidity, fusion, self-repair, and selective permeability. These behaviors mirror how lipid nanoparticles (LNPs) encapsulate and protect mRNA in vaccines. To conclude, students connect their observations to the film segment on Pieter Cullis, understanding that the same physical principles make modern mRNA medicines possible. A variety of activities can be done following *Exploratorium* [4], *Centre of Sciences Ontario* [5], *French Educational Platforms* [6] or *Belgium Education platforms* [7] experiments.

Materials:

- Distilled water
- Dish soap (or surfactant solution)
- Straws, thin wire, wire loops or rings

Procedure:

- Students cut out DNA sequences and transcribe them into complementary mRNA codons.
- Using a codon table, they translate each codon into the corresponding amino acids.
- They identify the resulting protein and discuss its possible biological function.
- The class connects this process to mRNA vaccines: synthetic mRNA encodes a viral protein, which safely triggers an immune response without infection.

Teacher Background :

- The Challenge: Naked RNA is destroyed rapidly by enzymes (RNases) and cannot pass through the negatively charged cell membrane.
- Phil Felgner (California, 1980s):
  - Developed cationic lipids (positively charged fats) that could bind to negatively charged RNA/DNA. These lipids formed complexes that fused with cell membranes and delivered genetic material inside.
  - Problem: Early lipids worked but were often too toxic for safe use in humans.
- Pieter Cullis (Vancouver, 2000s):
  - Perfected the concept into lipid nanoparticles (LNPs) — tiny fat bubbles with multiple layers. In low PH in laboratory conditions, LNPs act as positively charged lipids to capture RNA, then they are neutralised before injected into the bloodstream, and fused efficiently with cells, limiting toxic effects.
  - This innovation made it possible for Moderna and BioNTech vaccines to deliver mRNA safely at scale.
- Analogy: Lipids are like an envelope protecting a fragile letter (mRNA). Felgner built the first crude envelope, and Cullis engineered the secure, reliable version.

LESSON THREE:
Discovery of mRNA - from Paris to a Nobel Prize

Curriculum Anchor:

"Describe the discovery of nucleic acids and the milestones of molecular biology, and explain how new knowledge emerges through scientific research."

Film Extracts:

- History summary of mRNA discovery [05:56-07:03]

In 1960 François Jacob, Jacques Monod, and François Gros demonstrated the existence of messenger RNA.

- Summary of major recent discoveries and inventions [46:04-47:28]

Elie Dolgin discusses betting on the Nobel Prize and lists four key scientists whose contributions to mRNA technology could be recognised.

Discussion Questions:

1. Why did it take decades for mRNA's discovery to become medicine?
2. What role do "failed" or "early" experiments play in progress?
3. Is it ethical for scientists to test new technologies on themselves?
4. How does this history challenge the idea that science is always linear and predictable?

Teacher Background Timeline :

Selected timeline of major discoveries, experiments and inventions

1960

- 1961 — mRNA discovered identifying that DNA does not directly instruct robosomes, but through a temporary copy – messenger RNA; Jacob, Monod and Gros (Institut Pasteur)

1970

- 1973 — Dendritic cell identified as specialized APC; Steinman & Cohn
- 1977 — Discovery of RNA splicing in eukaryotic mRNAs; Phillip A. Sharp (MIT) and Richard J. Roberts (Cold Spring Harbor) independently discovered that genes in higher organisms are "split", Nobel Prize 1993

1980

- 1987 — First cationic lipid for nucleic acid delivery ("lipofection"); Philip L. Felgner (with colleagues at Syntex)
- 1989 — mRNA Cationic lipid-mediated delivery of mRNA to cells in vitro, Malone
- 1990 — First in vivo protein expression from injected mRNA, Jon A. Wolff & colleagues
- 1993 — mRNA vaccines induce cellular immunity, Martinon, Rammensee & collegues

2000

- 2000 — First mRNA company CureVac is founded
- 2005 — Design of first-generation ionizable lipids, Heyes
- 2005 — Nucleoside modification suppresses innate immunity, Katalin Karikó & Drew Weissman (pseudouridine modification in mRNA), Nobel Prize 2023
- 2006 — First successful lipid nanoparticle (LNP) test in monkeys, Zimmermann & colleagues
- 2007 — First human injection of synthetic mRNA, Steve Pascolo (self-injected GMP mRNA coding luciferase)

2010

- 2012 — Ionizable lipid design rules are established, Pieter Cullis & colleagues
- 2016–2018 — Protective mRNA-LNP vaccines in animals, Barney Graham, Norbert Pardi, Drew Weissman, Ugur Sahin & Özlem Türeci (Zika, cancer, influenza models)
- 2018 — First FDA-approved LNP-based RNA therapeutic (Onpattro), Pieter Cullis & Alnylam team

2020

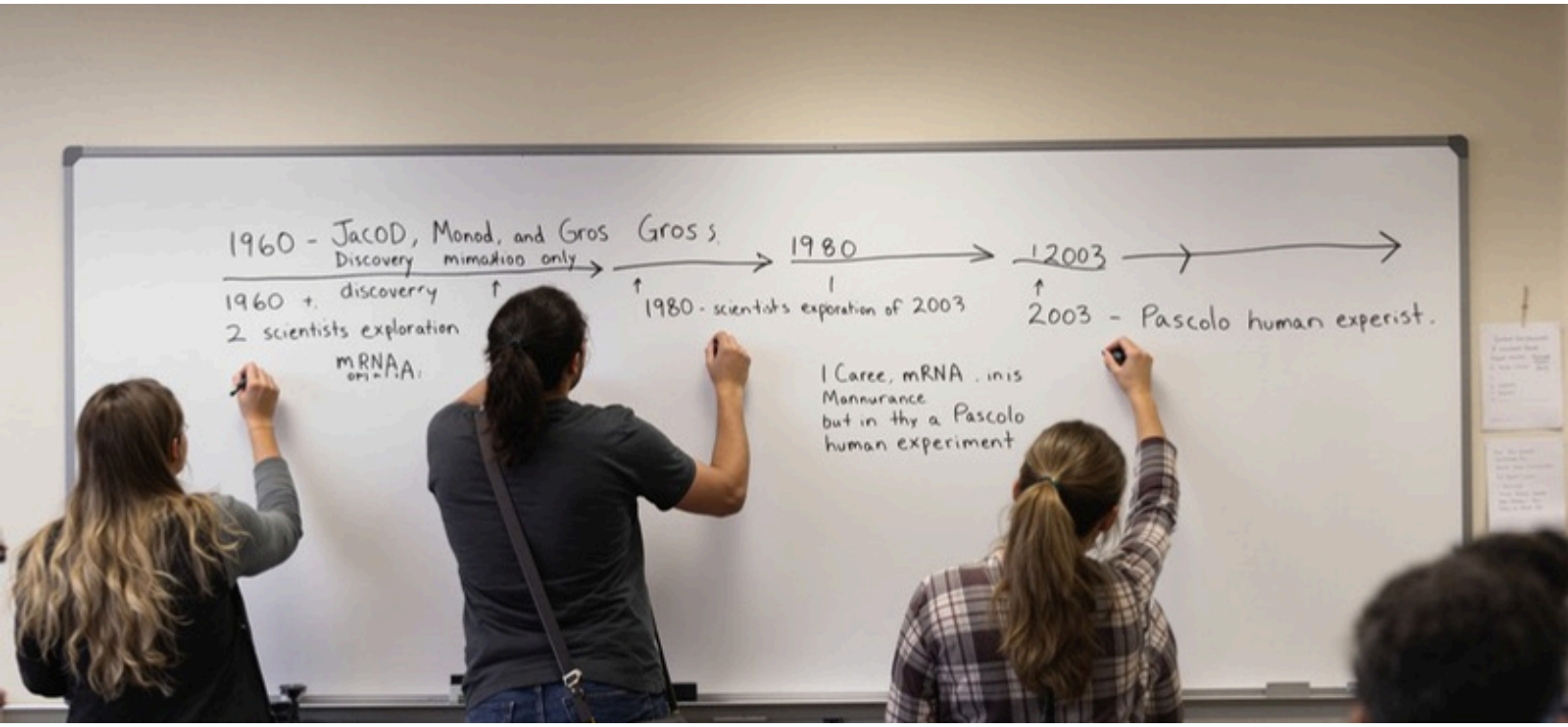
- 2020–2021 — First approved mRNA-LNP vaccines (COVID-19) Ugur Sahin & Özlem Türeci (BioNTech/Pfizer, BNT162b2); Stéphane Bancel (Moderna, mRNA-1273); Katalin Karikó & Drew Weissman (underpinning modifications); Pieter Cullis (ionizable lipid delivery system).
- 2021–2024 — LNP chemistry refined, Pieter Cullis, Ying Tam, Thomas Madden

Suggested Classroom Activity:

- Students build a timeline on the classroom wall with major milestones:
  - 1960: Discovery of mRNA in Paris.
  - 1980s: First attempts to deliver mRNA into cells.
  - 2000: First mRNA company CureVac
  - 2020: COVID-19 vaccines.
  - ...
- Each group of students researches one event and presents it in 2–3 minutes.

Teacher Tip:

Conclude the lesson with a forward link:
“We’ve followed the story of how mRNA was discovered and tested, and how different scientists built upon each other’s work. The next major turning point came when Katalin Karikó and Drew Weissman found a way to make synthetic mRNA safe and effective — a discovery that would change medicine forever.”



LESSON FOUR:
Making Synthetic mRNA Safe - Karikó & Weissman's Breakthrough

Curriculum Anchor:

"Explain how mutations and chemical modifications of nucleic acids can influence gene expression and protein production."

Film Extracts:

- Karikó & Weissman at the University of Pennsylvania [28:50-31:42]

Katalin Karikó shares the story of discovery of chemical modification of RNA nucleosides — replacing uridine with pseudouridine (Ψ) — prevents immune overreaction and stabilizes RNA.

- Bonus Animation (not part of the film)

The animation explains the chemical modification discovery, which received a Nobel Prize in 2023.

Discussion Questions:

1. Why did the immune system attack synthetic RNA at first?
2. How can a small chemical change (U → Ψ) make RNA safe but still functional?
3. Why was this discovery considered Nobel-worthy?
4. How do collaboration and persistence (Karikó's decades of underfunded research) shape scientific progress?

Teacher Background :

- The Problem:
  - Early attempts to use mRNA in therapy caused strong immune reactions.
  - The body treated injected RNA as a virus and destroyed it.
- The Discovery (2005):
  - Katalin Karikó (Hungary → US) and Drew Weissman (US) discovered that swapping one letter — uridine (U) — with a modified form, pseudouridine (Ψ), tricked the immune system.
  - The modified RNA still carried the genetic instructions, but no longer triggered destructive inflammation.
- Impact:
  - This breakthrough made mRNA safe, stable, and practical as a medicine.
  - It contributed to COVID-19 vaccines.
- Recognition:
  - Karikó & Weissman were awarded the 2023 Nobel Prize in Medicine for this discovery.

Teacher Tip:

Close the lesson by linking back to previous ones:
“We’ve now seen the two keys that unlocked mRNA medicine: lipid nanoparticles to deliver it and chemical modification to make it safe. These breakthroughs, together, turned an unstable molecule into a powerful new class of drugs.”

LESSON FIVE:
COVID-19 – The First mRNA Vaccines

Curriculum Anchor:

"Explain the principles of vaccination and the role of the immune system in recognizing antigens and producing immune memory."

Film Extracts:

- COVID-19 pandemic plamets the world [32:55-35:54]

Elie Dolgin explains how, once the pandemic hit, biotech companies like Moderna and BioNTech were uniquely prepared to respond quickly with new mRNA vaccines.

- Arrival of first vaccines [35:55-37:31]

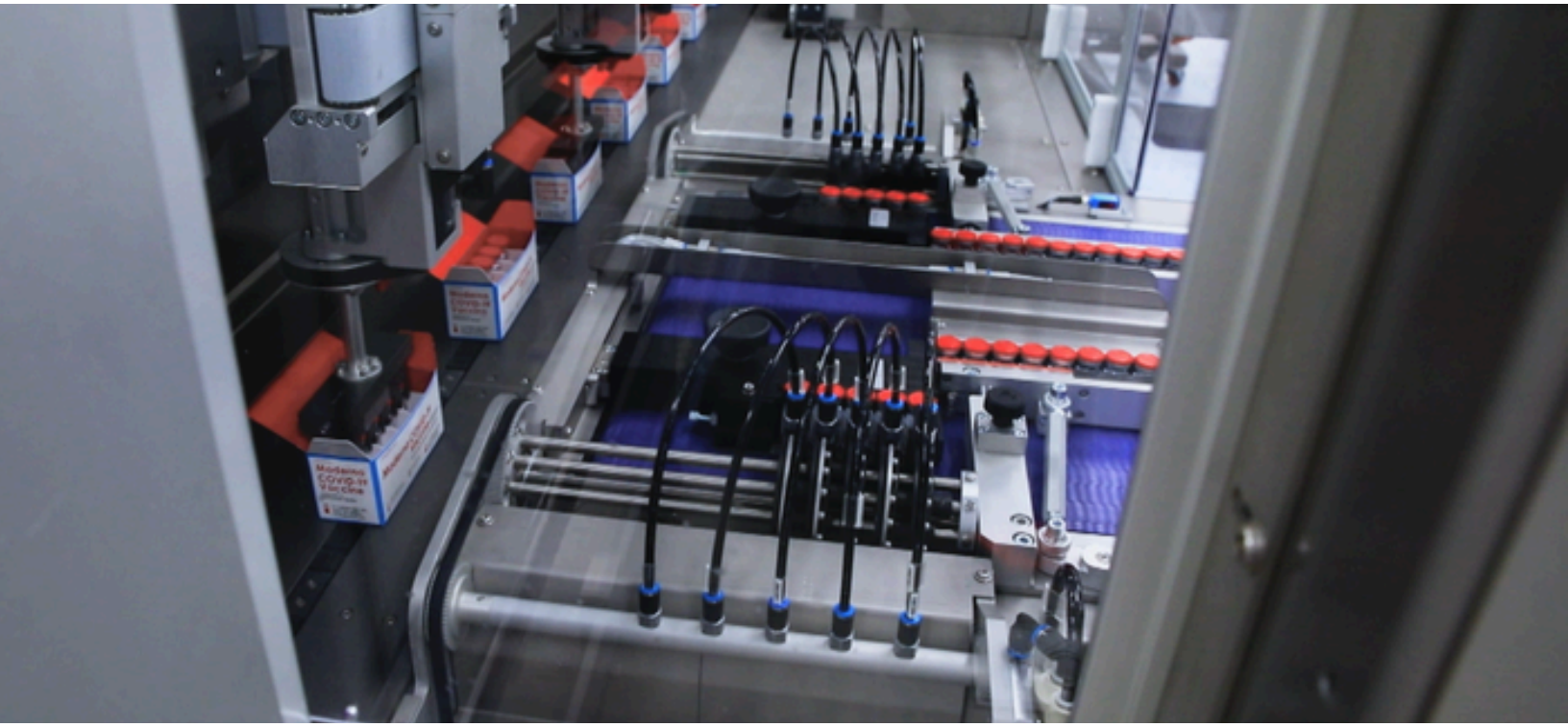
Fyodor Urnov highlights how extraordinary and revolutionary this moment was for science — the culmination of decades of research finally transforming into life-saving medicine.

Discussion Questions:

1. Why could mRNA vaccines be developed so quickly compared to traditional vaccines?
2. What were the main challenges in scaling up from lab success to billions of doses?
3. How did decades of "failed" cancer research become the foundation for COVID-19 vaccines?
4. What lessons can we take from the global collaboration and rapid rollout?

Teacher Background :

- Pandemic Trigger (2020): SARS-CoV-2 spreads rapidly worldwide. Scientists race for vaccines.
- Why mRNA?
  - Fast to design: once the viral genome was sequenced, researchers could quickly code an mRNA vaccine.
  - LNP technology was already established as a proven drug delivery modality in 2018. LNP's versatility to carry different types of nucleic acids makes it a plug-and-play delivery technology supporting rapid development and manufacturing of mRNA-LNP vaccines.
  - Flexible platform: mRNA could teach cells to produce the viral spike protein, training the immune system.
- BioNTech (Germany): Ugur Sahin & Özlem Türeci quickly adapted their cancer immunotherapy platform to target COVID-19. Partnered with Pfizer for trials and distribution.
- Moderna (US): Already working on infectious diseases, rapidly created another mRNA vaccine candidate.
- Outcome:
  - Clinical trials proved high efficacy and safety.
  - Billions of doses distributed globally.
  - First large-scale demonstration of mRNA as a medical technology.
- Impact: Saved millions of lives and opened the door for new mRNA therapies for cancer, rare diseases and more.



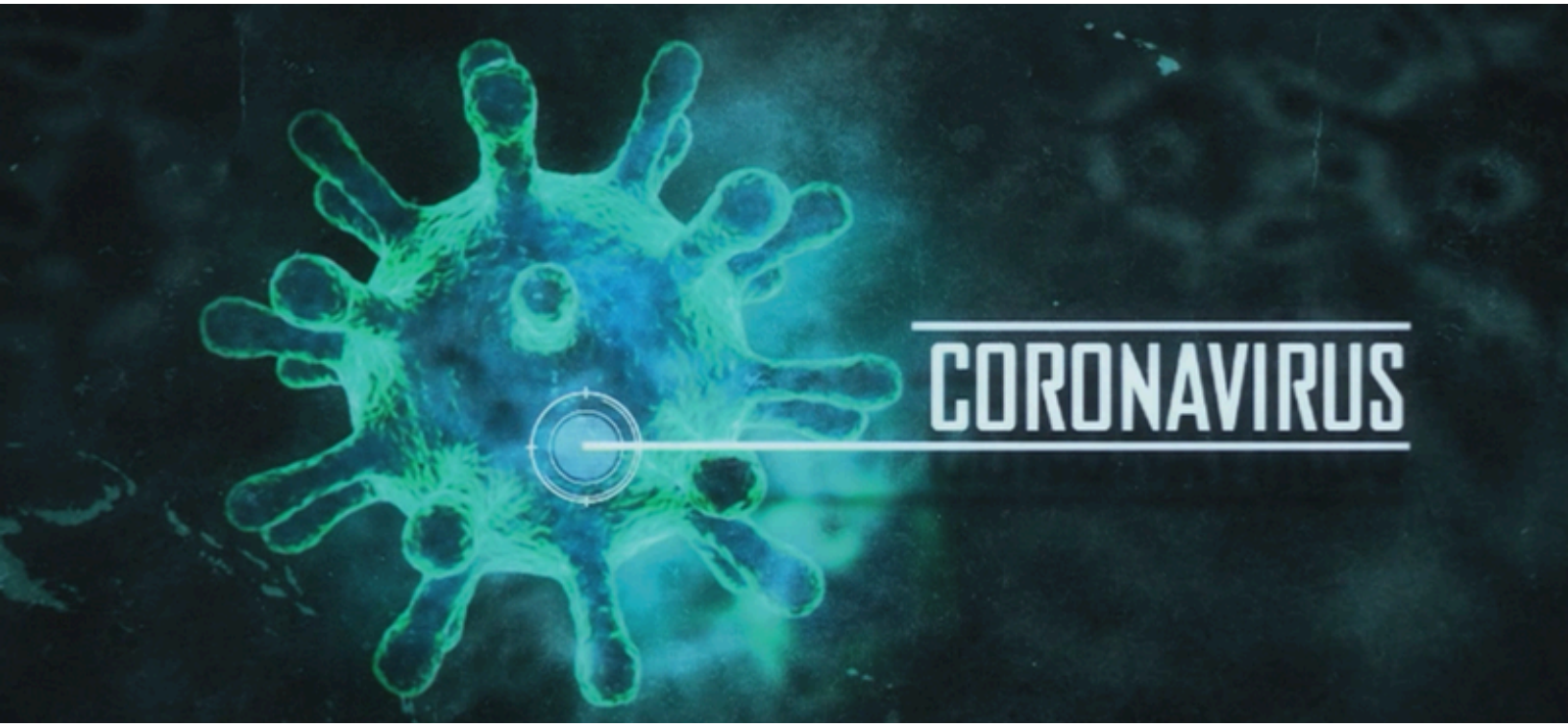
Suggested Classroom Activity:

Through a collaborative investigation into mRNA biotechnology, students connect the fundamental discoveries in molecular biology to their real-world applications during the COVID-19 pandemic. Working in small groups, they research and analyze simplified scientific and media articles from trusted sources (e.g., WHO, RTS, Le Temps, Nature). Each group identifies key stages in the development of mRNA vaccines — from early research to public rollout — and explores how science interacts with politics, ethics, and communication.

To conclude, the class discusses what THE MESSENGER reveals about the relationship between science, society, and the media, and how collaboration and trust shaped one of the most significant scientific achievements of the 21st century.

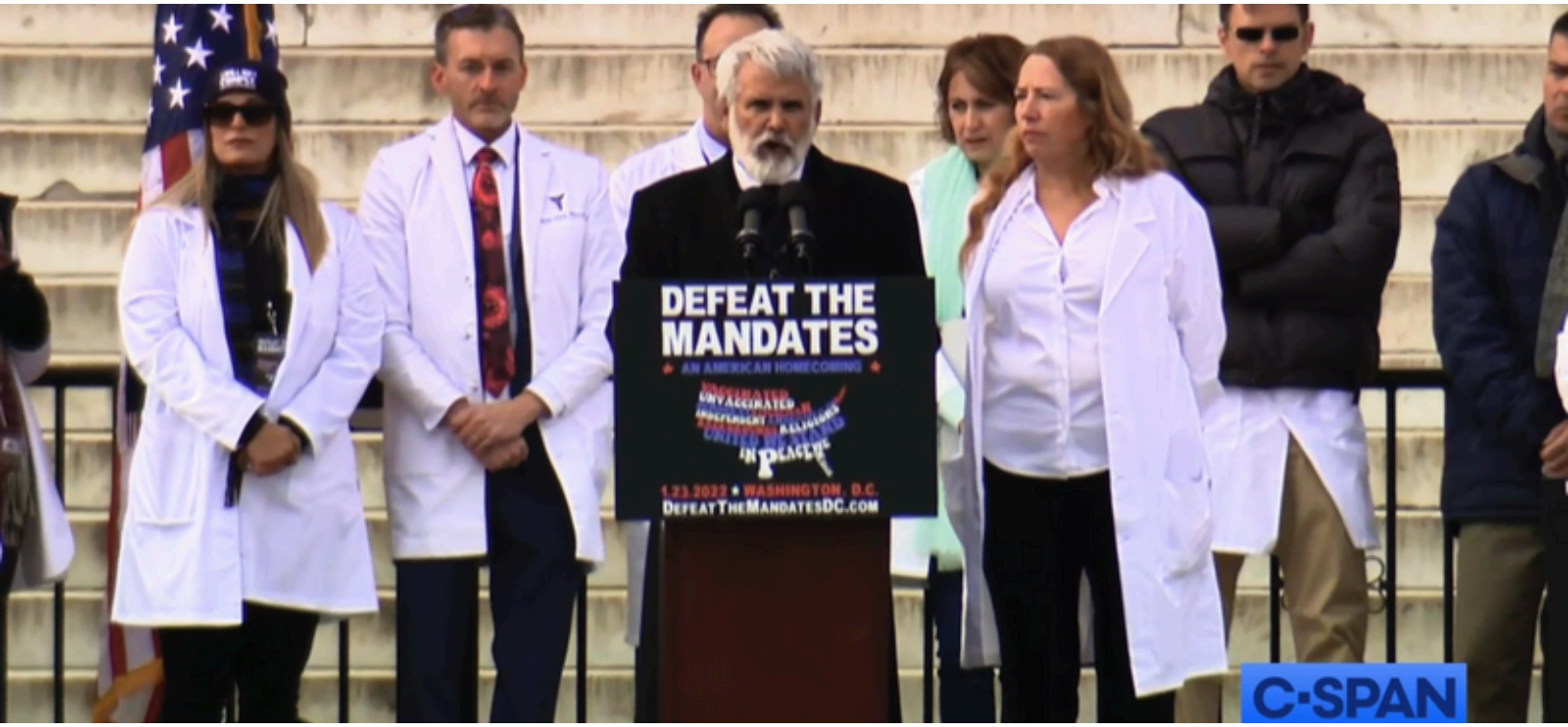
Materials/ Online Resources:

- *World Health Organization* (WHO) on vaccines development [8]
- *Swiss Institute of Bioinformatics (SIB)* Workshops on understanding of mRNA vaccines [9]
- *Swiss Academy of Natural Sciences (SCNAT)* on how mRNA vaccines work [10].



Procedure

- Form small groups (3–4 students). Each group analyzes accessible educational or news articles on mRNA vaccines.
- Students identify and summarize one key aspect of the mRNA story:
  - Scientific discovery: Karikó & Weissman's RNA modification research.
  - Vaccine principle: How mRNA trains the immune system.
  - Ethical or social dimension: Public trust, misinformation, and global access.
- Group presentations: Each group presents their findings in 3 minutes using short visuals or posters.
- Class discussion: What does THE MESSENGER reveal about the intersection of science, policy, and media?



LESSON SIX:

Vaccines vs. Therapies - and Why mRNA Does Not Change the Human Genome

Curriculum Anchor:

"Explain the principles of vaccination, distinguish between preventive and therapeutic interventions, and discuss ethical and societal implications of biotechnology."

Film Extracts:

- Vaccines vs. Therapies [07:04-07:40]

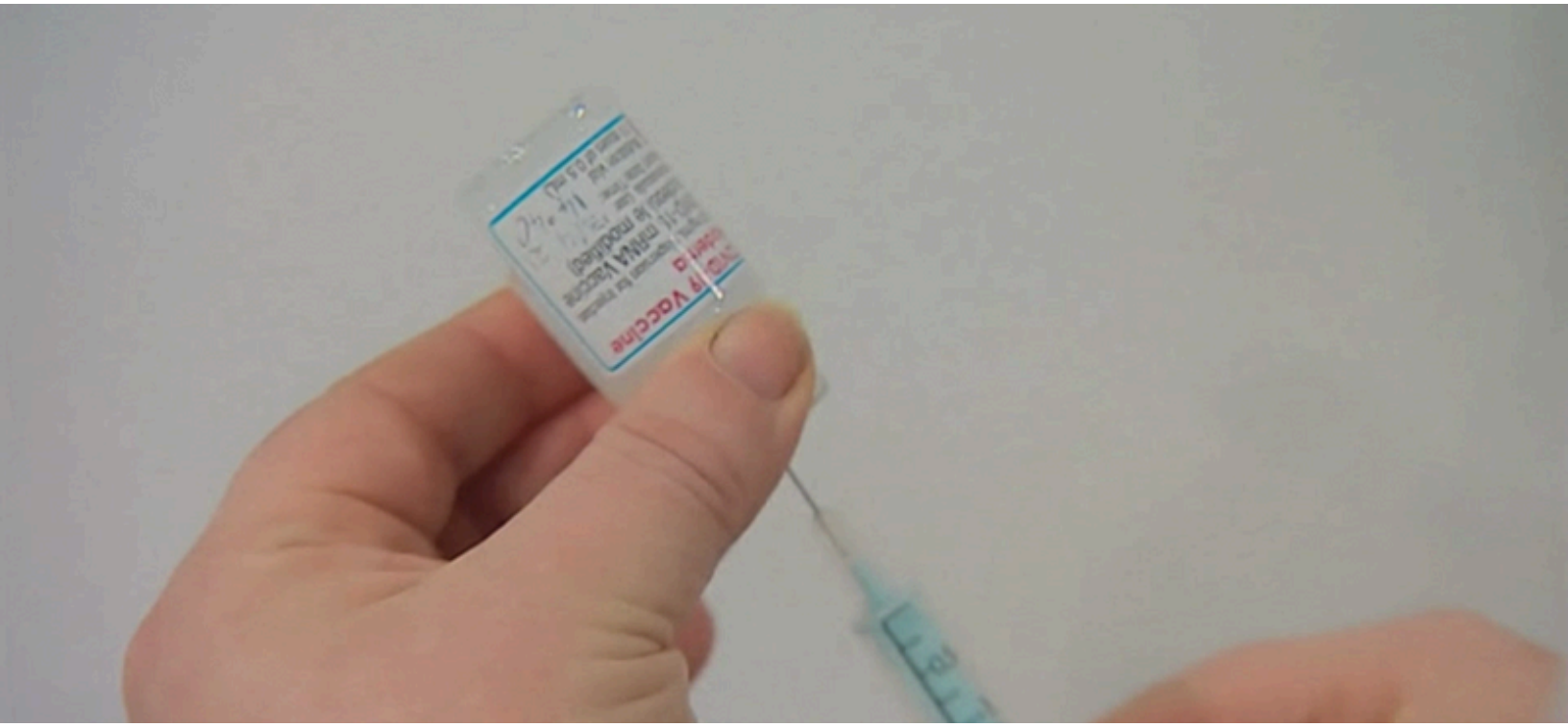
Steve Pascolo explains the difference between vaccines (prevention — training the immune system in advance) and therapies (treatment — helping the body fight an existing disease, like insulin for diabetics).

- Fydor Urnov on DNA and vaccination [41:00-42:40]

Urnov describes how vaccination activates normal DNA functions inside immune cells as part of the body's response, yet not changing the human genome, as mRNA does not enter the cell nucleus.

Discussion Questions:

1. What is the main difference between an mRNA vaccine and an mRNA therapy?
2. Why can mRNA vaccines not alter human DNA?
3. Which diseases should be prioritized for vaccines, and which for therapies?
4. How should society deal with fears and myths around biotechnology?



Teacher Background :

- How DNA is involved — but not changed:
  - When vaccinated, immune cells activate many genes to produce proteins and antibodies. This is gene expression, not gene editing.
  - mRNA vaccines instruct cells to make a temporary protein that triggers this response.
  - The DNA sequence in the nucleus remains the same — it is used, not modified.
  - Analogy: mRNA is like a Snapchat message — it gives instructions, then disappears without changing the original "photo album" (DNA).

Suggested Classroom Activity:

Objective: Students explore how mRNA could solve tomorrow's health challenges.

- Divide the class into small groups ("Future Labs"). Each group chooses a disease they want to fight (e.g., influenza, malaria, cystic fibrosis, cancer, Alzheimer's). Will they create an mRNA vaccine (prevention) or an mRNA therapy (treatment)?
- Preparation:
  - Why is this disease important to tackle?
  - How could mRNA be used to fight it (vaccine, therapy, replacement protein)?
  - What challenges might scientists face (delivery, cost, acceptance)?
- Presentation: Groups present a 2–3 minute pitch as if convincing a panel of scientists or funders.
- Wrap-up: Teacher/peers provide feedback — feasibility, creativity, societal value.

LESSON SEVEN:

The Future of mRNA — and How Science Really Works

Curriculum Anchor:

"Discuss current and emerging applications of biotechnology, evaluate potential benefits and risks, and reflect on the nature of scientific discovery as a process of trial, error, and collaboration."

Film Extracts:

- Sahin and Tureci for the best technologies to fight cancer [25:17-28:19]

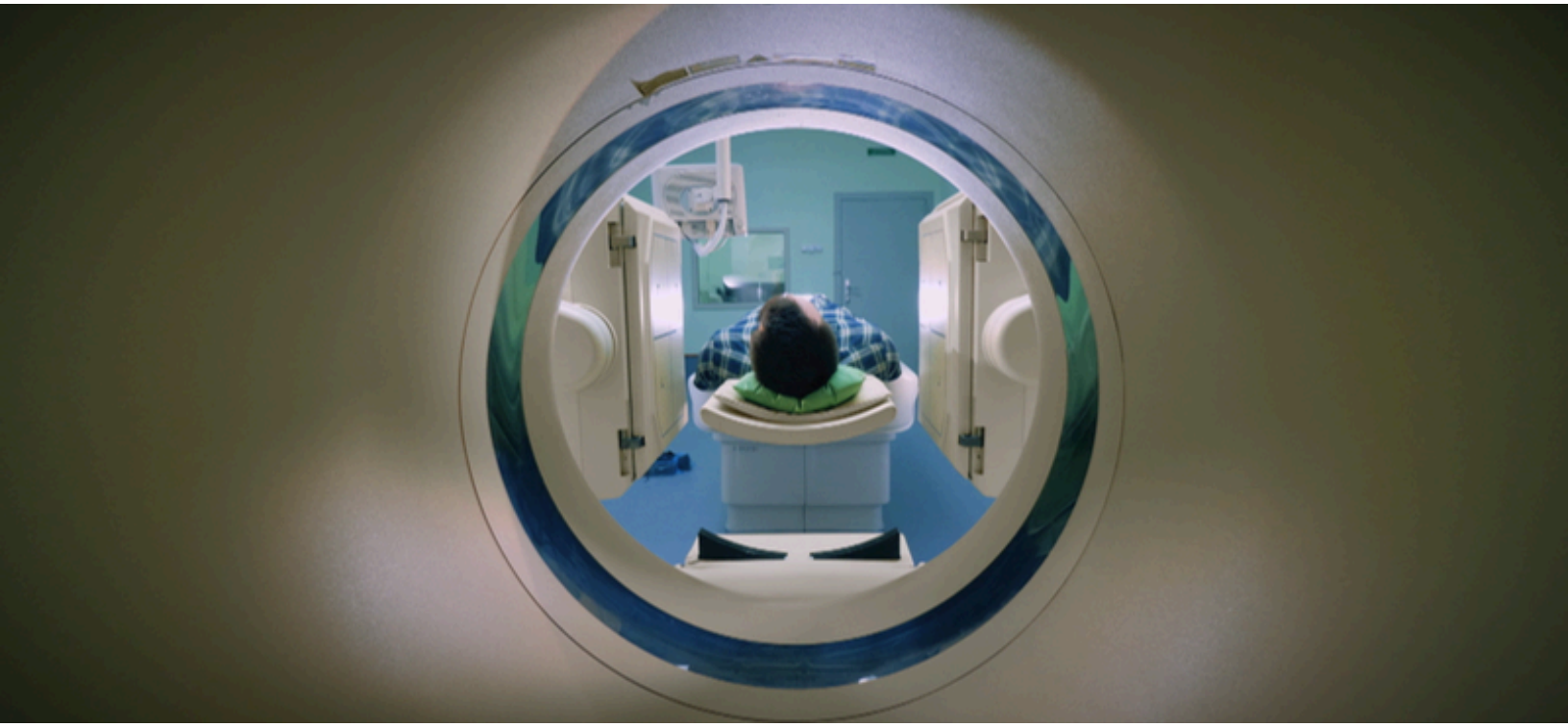
BioNTech founders Ugur Sahin and Özlem Türeci describe how their quest to cure cancer led them to mRNA as the most promising technology for training the immune system.

- Future for mRNA [47:49-53:18]

Pieter Cullis and other scientists highlight future challenges and opportunities and reflect on what remains to be discovered.

Discussion Questions:

1. Why could mRNA vaccines be developed so quickly compared to traditional vaccines?
2. What were the main challenges in scaling up from lab success to billions of doses?
3. How did decades of "failed" cancer research become the foundation for COVID-19 vaccines?
4. What lessons can we take from the global collaboration and rapid rollout?



Teacher Background :

- Future Applications:
  - Cancer immunotherapy — teaching immune cells to detect and attack tumor antigens by engineering CAR T cells in the body to recognise and destroy pathogenic cells.
  - Rare diseases — replacing defective or missing proteins.
  - Infectious diseases — new vaccines for malaria, HIV, and flu.
  - Personalized medicine — tailor-made treatments based on genetic profiles.
- Advantages: Fast to design, flexible platform, scalable production.
- Challenges: Delivery to target tissues, cold-chain logistics, long-term safety, equitable access, and building public trust.
- Key Insight: As Sahin, Türeci, and Cullis emphasize, scientific progress is not linear — it depends on persistence, collaboration, and openness to failure. The same resilience that built the first mRNA vaccines will shape the next generation of discoveries.

Suggested Classroom Activity:

Through an interactive “Myth vs. Science” challenge, students strengthen their scientific reasoning and communication skills by identifying and debunking misinformation about biotechnology and science in general. Working in two alternating groups, they explore how misinformation spreads and how scientists communicate accurate, evidence-based knowledge. Students create plausible-sounding myths about future mRNA technologies or other scientific issues — such as vaccines, genetics, climate change, or artificial intelligence — and then craft scientific explanations to counter them. This helps students learn how to recognize misinformation, verify facts, and understand the importance of trustworthy sources in science communication.

To conclude, students test their fact-checking and media literacy skills using verified educational portals such as RTS, CIIP, and Le Monde Vérification, comparing reliable sources to misleading ones to see how misinformation is constructed and countered.

Materials / Online Resources [11-26]

- Reliable sources for information checking among a few:
  - RTS – Media Literacy Workshops for Students
  - Le Monde – Fact Checking Platform
  - University of Cambridge – Get Bad News Game
  - Harmony Square – Disinformation Simulation Game
  - TinEye – Reverse Image Search Tool

Procedure

1. Form two sets of groups:
   - Group A – Myth Makers: invent plausible-sounding myths about mRNA or other science-related topics.
   - Group B – Science Explainers: prepare short, factual statements to debunk each myth.
2. Presentations:
   - Group A presents their myth to the class.
   - Group B responds with evidence-based counterarguments.
   - The teacher moderates and corrects inaccuracies.
3. Rotation: groups switch roles so all students practice both myth-making and myth-busting.
4. Verification: students use online tools to verify real vs. fake information and reflect on how credibility is established.

LESSON EIGHT:
Patents – Protecting Scientific Discovery

Curriculum Anchor:

"Explain the social, ethical, and economic dimensions of biotechnology, including how intellectual property influences research, innovation, and access to medicine."

Film Extracts:

- Discussion on patents [41:19-44:12]

In the final sequence, Hans-Georg Rammensee criticizes the patent system, arguing that it restricts free scientific exchange. Robert Langer counters that patents are essential for attracting investors and turning discoveries into real medical products. Elie Dolgin explains that as early mRNA patents expired, the field opened for new players, creating intense competition but also unprecedented room for innovation. The narrator concludes that this tension between protection and openness defines how science evolves.

Discussion Questions:

1. Why do patents exist, and what benefits do they bring to scientific innovation?
2. What are the risks of patenting discoveries that affect global health?
3. How can open science and commercial protection coexist?
4. In your opinion, who is right — Rammensee, Langer, or both?

Teacher Background :

- What is a patent? A legal protection that gives inventors exclusive rights to make, use, or sell their invention for a limited time (usually 20 years).
- Why patents matter: They allow researchers and companies to recover development costs and attract investment — crucial in biotech, where bringing one therapy to market can cost billions.
- Why patents are controversial: Some scientists believe patents slow discovery, limit access to life-saving drugs, or privilege profit over public good.
- The mRNA case: Early broad patents lapsed, allowing new companies (BioNTech, Moderna, CureVac) to innovate freely. Now, newer patents are being contested, reflecting the balance between open science and proprietary technology.

Suggested Classroom Activity:

Objective: Students explore how mRNA could solve tomorrow's health challenges.

- Divide the class into three groups:
  - Group A – Open Science Advocates (Rammensee's view): Argue that knowledge should be shared freely for humanity's benefit.
  - Group B – Patent Defenders (Langer's view): Argue that without patents, innovation and investment would stall.
  - Group C – Jury (Dolgin's perspective): Weigh both sides and decide what balance between openness and protection best promotes progress.
- Debate format: Each group gives a 2-minute statement, followed by rebuttals.
- Jury delivers a verdict: Which model best serves science and society?

Teacher Tip :

Pros Why Patents Matter	Cons Why Patents Limit Research
• Encourage investment by giving companies time to recover huge development costs and scale up production; • Protect innovators from immediate imitation, rewarding decades of research like Karikó & Weissman's mRNA modifications and Cullis's lipid nanoparticle technology; • Promote commercialization — patents helped move mRNA from academic labs to billions of real-world doses; • Support regulation and quality control, ensuring vaccines were produced under strict safety and manufacturing standards.	• Can limit access to life-saving drugs in poorer countries that cannot afford licensing fees; • May slow collaboration, though during COVID-19, many scientists temporarily shared data and research openly to accelerate progress in vaccine design, manufacturing, and cold-chain infrastructure; • Concentrate power in large corporations, making small biotech startups or public institutions dependent on patent holders; • Risk turning science into a profit-driven race rather than a collaborative effort for public health.

ENDNOTES

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Find “THE MESSENGER” film on Film Platform

“...there's so much excitement and so much energy and research and investment going into this field now that I think we will see all sorts of these problems being solved. It just might not be the Moderna's or the BioNTech’s that have the next key innovations. We might see it through any number of well-established big pharma companies or all the many startups that are entering the field.”

—Elie Dolgin, in “THE MESSENGER: A Story of mRNA”