Escape Room Kit: Build Your Own Synthetic Biology Escape Room

Introduction

This kit explains how to turn a synthetic biology project into a short, card-based escape room in which players make the main design decisions of the project themselves. It is based on Operation Priorat, the escape room we designed around our project Vinesys.

If you want to play Operation Priorat as it is, use its own organiser's guide and printable materials, available on our wiki together with an online version. This kit is for teams who want to build a new escape room around their own project that is similar in structure to ours.

General base information:

	Details
Audience	Ages 13 and over with younger players only in mixed teams with an adult organiser.
Group size	Teams of 2-7 players with one box per team.
Duration	Around 25 minutes of play, plus a 10-minute introduction and a 10-minute debrief.
Organisers	One per table for young players or players with no biology background.
Prior knowledge	None for players, but organisers need to read the Organiser background section of this kit.
Design time	Several team sessions because the challenges take time to design and the physical cards need to be prepared as well.
Preparation	30-60 minutes per box, mostly cutting cards and making sure everything is in its place.
Cost	Colour printing, envelopes, a pencil and a box with a 3-digit combination lock per team.

In this guide, you will find:

1. Learning objectives.
2. Organiser background.
3. Designing your escape room.
4. Materials and preparation.
5. Session plan.
6. Worksheets.
7. Debrief questions.
8. Possible adaptations.
9. Evaluation.

Learning objectives

An escape room built with this kit should leave players with ages 13 and over able to:

1. Explain that an engineered organism is designed step by step, through decisions about which organism to use, what it does, when it acts and how it is contained.
2. Give at least one reason why a particular organism is a better choice than others for a given task.
3. Describe in simple words what each functional part of the project does.
4. Understand that a gene carries the instructions to make a protein and that the same instruction can be written differently in different organisms.
5. Explain why an engineered organism should only act under the right conditions and why it needs to be contained.

You can add more objectives or adapt these ones depending on the type of project your team is designing and the key things you want players to notice and understand.

Organiser background

Organisers do not need to be biologists, but they should be comfortable with the few ideas the game relies on. These are the ones Operation Priorat uses and you should adapt the list to your own game.

- **iGEM** is an international synthetic biology competition in which student teams design an engineered organism to solve a real problem. Teams can win medals (bronze, silver, gold) and special prizes.
- **Synthetic biology** designs organisms with new functions by giving them new genetic instructions, like programming a computer.
- **The chassis** is the organism that carries the new functions and it has to survive where it will be used and also be safe for the environment.
- **DNA has two complementary strands.** In RNA, A always pairs with U and G with C. In DNA, A pairs with T and G with C.
- **Codons** are groups of three letters and each one codes for an amino acid. Different organisms prefer different codons for the same amino acid.
- **Containment** means making sure an engineered organism cannot survive or spread outside the place where it is meant to be. Common strategies are kill switches, auxotrophy (the organism depends on a nutrient only available where it is released) and toxin-antitoxin systems.

If a player asks something you cannot answer, write it down and look it up together after the game.

Designing your escape room

We built Operation Priorat in seven steps. The first four decide the content of the game and the last three turn it into a physical game.

Step	What you decide/do
1. Map your project	Select which parts of your organism the game will cover.
2. Give biosafety importance	Discuss how containment appears in the game.
3. Fit the game to your audience	Determine age range, prior knowledge and which concepts are content or only mechanics.
4. Design the challenges	Design one challenge per part, how each one gives a digit and how they connect.
5. Design the cards	Layout, colour code, front and back, team sheet.
6. Explain the rules	Write the introduction cards with rules and decide what will be the organiser's role during the session.
7. Build the boxes	Buy padlocks (or normals boxes and locks) and envelopes. Print, cut and set up the cards.
8. Test before you publish	Check every answer with someone outside the design group and run a full playtest.

1. Map your project

Start from your organism, not from puzzle ideas. Put the organism at the centre and divide it into the biological parts or mechanisms that make your project work: the chassis, each functional module, how it is regulated and how it is contained. Each of these parts is a candidate for a challenge and you can fill in the Project map worksheet to do this (see worksheets).

Then decide which parts are worth teaching. In our case, the genes of the two functional modules and the biocontainment strategy were what we most wanted the public to understand, so they became the core of the game. Parts too technical to explain in a few lines of a card, such as our intein system, were left out and simplified into a general idea. Aim for three or four challenges, which gives a game of around 25 minutes. However, if one of your challenges is too long or has may sub-parts, you can adapt the total number or keep in mind your activity is going to be longer.

In Operation Priorat, the four parts became the four challenges: the chassis (*Bacillus subtilis*), the ACC deaminase module that reduces the plant's stress hormone, the γ-PGA module that retains water around the roots and the activation logic, while biocontainment became the extra challenge. Following our same logic, you can create a core structure for your game and then add a few extra missions that can be played by those who want more or finished earlier.

2. Give biosafety its own place

Any game about an engineered organism will make adult players ask whether it is safe to release it. Instead of answering this with a sentence on a card, give biosafety its own challenge so that players have to think about containment themselves.

We made it the extra challenge at the end and called it Gold Medal. The card tells players that their bacterium works, but that if it escaped from the vineyard and colonised a stream or a neighbour's field, nobody would allow it out of the lab. Then they had to choose one of three strategies (kill switch, auxotrophy or toxin-antitoxin), imagine how it would work and explain it to the organiser to earn a prize badge. They do not need to know how these systems work, only to propose how they would use them. Placing this challenge at the end means players reach it right after building something that works and slower teams can skip it without missing the main game, but you should consider adding biocontainment in the centre of your game to give it even more importance. For example, if you want biosafety to be compulsory, make it one of the digit challenges or put it inside the box as the last step before players win.

3. Fit the game to your audience

Decide the age range and level of biology expertise before designing the challenges because it determines how much biology the cards can assume or need to explain. Most players, especially younger ones, have very little biology background and some of our first challenges were too difficult for this reason. This is why we simplified them several times before getting the final design of our game.

For every concept in the game, decide whether it is content (something players should understand and take away) or only a mechanic (a way to hide or transform a number). In our third challenge, the genetic code works as a cipher: younger players only need to read a table and follow two rules (A with U, G with C), while older players can also learn that this is how cells turn DNA into proteins. Write this kind of decision down in your organiser guide so organisers know which parts to explain and which to simply guide.

Here is a short table about the concepts we have found out work best for each age range and which ones don’t and need to be adapted:

Age range	**What works**	**What to avoid or adapt**
Under 10	Choosing between options with pictures, matching pairs, searching for simple clues in the cards.	Long texts or multi-step rules without help. You should add at least an adult per table.
10–13	Ciphers, matching, choosing against clear criteria.	DNA-based steps only as a mechanic, with an organiser helping.
More than 13	All of the above, plus steps where the biology is the content (codons, complementary strands, regulation).	Add a short introductory session before playing.
Adults	Can discuss real applications and regulation after the game.	Do not oversimplify and leave time for questions, people are more curious and passionate about science than you might think!

4. Design the challenges

Each challenge should correspond to one part of your project map and give one digit for the lock. Write each challenge first as a decision the player has to make ("which organism would you use?") and only then decide how that decision turns into a number. Use the Challenge planner worksheet to plan them. These are the challenge types we used:

Type	**How it works**	**How it gives a digit**	**Example from Operation Priorat**
Choose among candidates	Several cards, each with real pros and cons; only one meets all the conditions	Each candidate card has a number	Four microorganisms; only B. subtilis lives in soil, survives drought and is safe (card 4)
Decode	A message hidden with one or two substitution tables	Count a letter or symbol in the decoded word	Twelve numbers → symbols → letters = ACC DEAMINASA; count of C = 2
Transform with a biological rule	Apply a real rule (codons, complementary strand) to a sequence	Count something in the result or sum different elements together	Codons plus complementary strand of γ-PGA; total G = 8
Match pairs	Memory game or matching cards	The correct pair opens an envelope	The pair of signals that only occurs during drought
Open proposal	Players imagine a solution and explain it	No digit, so this needs to be validated by the organiser (who then can give them a number, for example)	Gold Medal: a containment strategy

We have kept the answers out of this table on purpose, which is also our advice to you: see “Publishing your game” at the end of this kit.

Here we also leave a list of possibles types of challenges that could be adapted to your project:

Type	**How it works**	**How it gives a digit**
Put steps in order	Players receive shuffled cards with the steps of a process and have to arrange them correctly.	Each card has a number, so when players put them in order, they form a sequence of numbers that can be the combination or could be summed together to find a single number.

Type	How it works	How it gives a digit
Build a genetic circuit	Players fit together puzzle pieces of genetic parts in the right order to make a working gene.	Count the pieces used, or read the number printed on the piece that goes in a given position.
Read a graph	Players interpret a growth curve, fluorescence plot or dose-response graph to answer a question.	The answer is read directly from the axis (an specific time, concentration or value).
Spot the mistake	A lab protocol, notebook page or plasmid map contains one or more deliberate errors.	The digit is the number of errors or the number of the line where the error appears.
Hidden message under UV light	Clues are written in invisible ink and only appear under a UV torch.	The hidden text or number is the digit.
Simple calculation	A short dilution or growth calculation with the numbers given on the cards.	The result of the calculation is the digit.
Split informatio n	Each player gets a card with part of the information and no one can solve it alone.	The answer only appears when all the cards are combined.
True or false	A set of statements about synthetic biology or the project, some of them common myths.	Count the true statements or read a code from the order of true and false answers.
Identify under the microscope	Players compare printed microscope images with a description to find the right organism or cell	Each image has a hidden number.

Additionally, three design choices made our game work:

The first is making challenges depend on each other. For example, the codon table in our challenge 3 depends on the organism chosen in challenge 1, so a team that chose the wrong organism gets the wrong digit and has to go back. We added this after trying out the game ourselves and it reflects what happens in a real iGEM project, where a wrong early decision

affects everything that follows and it is better to go back and fix it than to continue. If you add a dependency like this, tell organisers in the guide where to send a team when the lock does not open.

The second is making wrong answers explain themselves. In our last challenge, each pair of signals opens an envelope, and the envelopes for the wrong pairs explain why they are wrong.

The third is revealing information step by step: each pile stays face down until the previous challenge is finished and each new pile starts with a card that explains the next part of the project, so the story and the biology advance together.

Finally, check the combination: avoid codes like 0-0-0 or 1-2-3 that players could guess before doing all the challenges and make sure each digit can only be reached through its challenge.

5. Design the cards

We designed all the cards in Canva. Whatever tool you use, keep the same layout on every card so players learn to read them quickly. For example, the structure could be: a title at the top, a short text and the activity name and project name in the footer.

Some tips from our experience:

- Give each pile its own colour and print the activity name on the back of every card, so piles do not get mixed up between teams or challenges.
- Never let colour be the only difference between two things players have to tell apart. Around one in twelve men cannot reliably distinguish red from green, and our three answer envelopes were mustard, turquoise and red. Add a large letter or symbol to each envelope and each pile, so the colour is a convenience and not a requirement.
- Keep one idea per card. If a card needs more than five or six lines, split it in two.
- End each challenge with a card that tells players where to write the result and which digit of the lock it is.
- Include a team sheet with a space for each answer and for the three digits to help players find the information faster at the end of the game. Also, it shows the organisers in which step the team is at all times.
- Prepare reference cards that stay on the table, such as one genetic code card per organism if you want to use that type of encoding as well.

In Operation Priorat, one team needs 36 cards in five piles, six memory cards, three coloured envelopes, one Gold Medal envelope with badges, a team sheet and a pencil.

6. Explain the rules before starting

Players need to know how the game works before the clock starts. We used two introduction cards: one with the story (the year, the problem and the mission) and one with the rules (three piles in order, each one gives a number, write everything on the team sheet, you win when you open the box, do not open a new pile until you have finished the previous one). Read them aloud with each team and leave them on the table.

Write down in advance where teams are most likely to get stuck and the hint that unblocks each point because this will help you save time during the session and makes everything more organised so other people can run the activity without having doubts. During the game, organisers should let players read and discuss, keep unused cards face down and give hints only

when a team is stuck, without revealing later cards, giving answers, opening the box or handing out envelopes early.

7. Build the boxes

Each table needs its own complete set, and preparing all of them takes between 30 minutes and an hour, mostly cutting cards. Prepare all the boxes before the day of the event, using the list in Materials and preparation. Keep a note of the combination somewhere only the organisers can see it and plan what you will do if a lock jams, because a box that will not open ends that team's game.

8. Test before you publish

Check the answers with someone outside the design group. Give them the answer key and your cards and have them solve every challenge from scratch. Our own organiser guide went out with an incorrectly paired codon in the solution to challenge 3, written as GUG where the complementary strand of CUC is GAG. The puzzle still worked, because the error did not change the number of G's players had to count and that is exactly why nobody noticed it for months.

Then run a full playtest with people who did not design the game. Time each challenge separately, write down where teams stall and watch which cards they read twice. This is where we found that one challenge needed to depend on another and where you will find out that your longest challenge takes more time than all the others together. Playtest with someone from the age range you are aiming at, not only with your own team, because you already know the answers and they do not.

Materials and preparation

Per table:

- 1 box
- 1 lock with a 3-digit combination
- 1 full set of printed cards, cut and sorted into piles
- 1 coloured envelope per possible answer of the final challenge
- 1 envelope for the extra challenge
- 1 team sheet per game and 1 pencil

Before each team starts:

- All cards back in their piles, in order and face down
- Final challenge, envelopes and extra challenge inside the box
- Lock set to the code and box locked
- New team sheet and pencil on the table, introduction cards on top

Between teams (if you run multiple sessions in the same day), put every card back into its pile, reset the lock to 0-0-0 and replace the team sheet.

Session plan

This is the session plan we recommend after running Operation Priorat. At CosmoCaixa we only had the game itself because the introduction and the debrief are what we would add next time after reviewing our performance.

Time	Step	What the organiser does
0-10 min	Introduction	Explain the few biology ideas the game uses that are key to understand everything that will appear (for our game: DNA has two complementary strands, genes are instructions for proteins, organisms write the same instruction with different "letters").
10-12 min	Rules	Read the two introduction cards aloud with each team.
12-37 min	Game	Stay with the team, let them discuss and give hints only when they are stuck.
37-42 min	Extra challenge	Teams that want to continue open the Gold Medal envelope and explain their idea.
42-50 min	Debrief	Bring all teams together and ask the debrief questions, to check that everyone understood the same thing and did not solve the challenges mechanically. Hand out the feedback form here, in writing.

Worksheets

Project map

Part of your organism	Relevant information	Key idea a player should take away	Challenge?
Chassis			Yes / No
Module 1			Yes / No
Module 2			Yes / No
Module X…			Yes / No
Regulation or activation			Yes / No
Biocontainment			Yes / No

Challenge planner

Challenge	Decision the player makes	Content	How it gives the digit	Digit	Most likely mistake
1					
2					
3					
X …					
Box				-	
Extra				-	

Organiser guide template

Write a short guide for your own game so other people can run it. This is the structure we used for the three-page guide of Operation Priorat:

Section	What to include
Overview	The sequence of challenges and the lock combination, with the digit each challenge gives
Materials	Checklist of everything needed per table
Printing and assembly	Which files to print, single or double-sided, how to assemble cards with their backs
Table and box setup	What goes on the table, in what order, and what goes inside the locked box
How to run the game	Step by step, from the introduction cards to the final challenge and when players may turn over each pile
Organiser notes	The solution of each challenge and why
Where teams get stuck	The most common mistakes and the hint for each one
Organisers rules	What to do and what not to do
Adapting the game	What to do with fast teams, slow teams and younger players
Final checklist	Everything to check before a team sits down

Team sheet template

Field	Team's answer
Team name and start time	
Result challenge 1	
Result challenge 2	
Result challenge 3	
Lock code	
Extra challenge	

Debrief questions

Ask these when all teams have finished. Choose only three or four depending on the time and the age of the group.

1. Which decision was the hardest, and why?
2. If you had chosen a different organism at the start, what would have changed?
3. Why should the bacterium only switch on in certain conditions?
4. What could go wrong if the bacterium left the place where it was released? How would you prevent it?
5. Would you use this organism in a real field? What would you need to know first?

Possible adaptations

Situation	Change
Younger players (under 12)	Mixed teams with adults and one organiser per table and present the difficult concepts only as a way to get closer to the end of the game (avoid doing this with teams that could potentially understand the biology behind the challenge).
Adults or university students	Treat every biology step as content and add discussion of real applications and regulation to the debrief.
Large teams (8 or more)	Give each player a role (reader, writer, decoder) so nobody is left watching.
Only 20-30 minutes in total	Skip the introduction part but keep a short debrief to make sure everyone achieved the objectives of the session.
Teams going very fast	Hand them the extra challenge early and ask them to draw their idea on the back of the team sheet.
Teams going very slow	Simplify the hardest step or help them more actively.

Situation	Change
No padlock box or 3-digit lock	Use a sealed envelope that the organiser only hands over when the team says the correct code or use a regular lock with a regular box (even if there is no space to add the lock). Adapt the final number to the type of lock you have.
Online	Build an online version just like we did with our escape room! You can use AI-tools to assist you during this task (always revising and modifying the output).
Other languages	Translate the cards and the team sheet.

Evaluation

Use three sources together: whether teams could open the box and how long they took, what you hear in the debrief and a short form at the end.

Collect that form in writing, even if it is one sheet per team. We asked our questions out loud at CosmoCaixa and players answered by raising their hands, which left us with no usable numbers and let the first hands up influence everyone else.

Possible feedback form:

1. How much did you enjoy the game? (1-5)
2. How difficult was it? (too easy / about right / too hard)
3. Which challenge was the hardest?
4. Write one thing you learned about how scientists design an organism.
5. Age range: under 12 / 12-17 / 18 and over

Publishing your game

If you put your escape room on a wiki or share it publicly, describe the design decisions behind each challenge, but not the answers. Explain why you chose that structure, how the challenges connect and what you would change and keep the solutions in the organiser guide, which is the only document the person running the game needs. A page that walks through every puzzle and then links to the playable version has spoiled its own game for everyone who reads before playing. We made this mistake in our first write-up of Operation Priorat.