The Yeast We Can Do

56
CARDS
19 MISSIONS

HOW TO READ A CARD

Every card names a **category** at the top left in its own colour. That colour is the ring segment where the finished cargo has to be delivered. Under the title sits the **code**, something like #M52QZ4. Write that code on your score pad and you always know which column belongs to which card.

The chain is built **from left to right**. A dashed slot with a ring in it takes **any** amino acid of that colour. A solid slot with a letter takes exactly that one and nothing else. Most slots are group slots, because in a real protein most positions only need the right property and not one exact building block.

24
TIER 1 · 5 SLOTS · 3 PTS · 4× EACH

18
TIER 2 · 7 SLOTS · 5 PTS · 3× EACH

14
TIER 3 · 9 SLOTS · 8 PTS · 2× EACH

Tier 1 consists of group slots only. Tier 2 has at most two specific amino acids and at most one rare one. Tier 3 has at least three specific ones and at least two rare ones. That is where you still find **cysteine** written out, because that exact cysteine is what holds the cofactor of nitrogenase.

ALL 19 MISSIONS

CATEGORY	CODE	MISSION AND CARGO	CHAIN	TIER	PTS	COPIES
BIOREMEDIATION	#C52EA4	**Legacy Pesticides** Organophosphate Hydrolase	negative nonpolar polar nonpolar nonpolar	1	3	4×
BIOREMEDIATION	#L43YR2	**Oil Spill on the Coast** Naphthalene Dioxygenase	**C** polar positive nonpolar negative nonpolar polar	2	5	3×
BIOREMEDIATION	#U93VD7	**Forever Chemicals** Fluoroacetate Dehalogenase	**D H R** nonpolar **W** polar negative nonpolar nonpolar	3	8	2×
BIOCATALYSIS	#P93HR8	**Plastic Degradation** PETase	polar negative nonpolar nonpolar polar	1	3	4×
BIOCATALYSIS	#H82ZX5	**Lignin Degradation** Peroxidase	**H** polar negative nonpolar nonpolar polar nonpolar	2	5	3×
BIOCATALYSIS	#V65PU7	**Selective Oxidation** Unspecific Peroxygenase (UPO)	**C** polar **R** nonpolar **H** negative nonpolar polar nonpolar	3	8	2×
BIOCATALYSIS	#C82CH2	**Halogenation without Chlorine Chemistry** Vanadium Chloroperoxidase (VCPO)	**H** positive **R** nonpolar **W** polar negative nonpolar nonpolar	3	8	2×
CLIMATE	#Q83VT8	**CO_2 from Flue Gas** Carbonic Anhydrase	polar negative polar nonpolar nonpolar	1	3	4×
CLIMATE	#E88YM4	**CO_2 Capture** Rubisco	**K** negative **M** nonpolar polar nonpolar negative	2	5	3×
CLIMATE	#D58NQ7	**The Biological Haber Bosch** Nitrogenase	**C C H** nonpolar **R** polar negative nonpolar nonpolar	3	8	2×
MEDICINE	#Z52YA7	**Fight Cancer** Binding Pocket for Doxorubicin	negative negative nonpolar polar nonpolar	1	3	4×
MEDICINE	#V58CF4	**Gene Silencing Delivery** siRNA Binding Protein	**K** positive **R** polar nonpolar nonpolar negative	2	5	3×
MEDICINE	#R99BE2	**An Alternative to Antibiotics** Antimicrobial Peptide (AMP)	positive **R W** positive **W** nonpolar polar nonpolar nonpolar	3	8	2×
TRANSCRIPTOMICS	#F57VV5	**Time Machine** Pab1p, Poly(A) Binding Protein	nonpolar nonpolar nonpolar polar negative	1	3	4×
TRANSCRIPTOMICS	#X59SF5	**Better Baker's Yeast** dCas9, CRISPR Interference	**D** nonpolar **H** nonpolar positive polar nonpolar	2	5	3×
TRANSCRIPTOMICS	#A23ER7	**The Bigger Archive** Pab1p with an INT Domain for Vaults	**W Y** nonpolar **R** polar **H** nonpolar negative nonpolar	3	8	2×
NANOMATERIALS	#M52QZ4	**The Iron Core** Encapsulin Associated Ferritin	negative negative polar nonpolar nonpolar	1	3	4×
NANOMATERIALS	#A82WS3	**Glass at Room Temperature** Silicatein	**S** polar **H** negative nonpolar polar nonpolar	2	5	3×
NANOMATERIALS	#B24SM3	**Magnetite Made to Measure** Mms6, Magnetosome Protein	nonpolar nonpolar negative negative **H C R** polar nonpolar	3	8	2×

BIOREMEDIATION

3 pts · tier 1

Legacy Pesticides

#C52EA4

An old store full of organophosphate pesticides is leaking into the groundwater. Build the enzyme that takes them apart before they reach the river.

CARGO

Organophosphate Hydrolase

An enzyme with two zinc ions in its active site. It cleaves the phosphate ester bond in pesticides and makes them harmless.

BACKGROUND

Organophosphates are among the most widely used insecticides in the world. They block the nervous system and are toxic to many organisms that were never the target. In the soil of old storage sites they last for years.

It works almost as fast as its substrate can diffuse up to it. Chemically there is no way to go faster.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

The two zinc ions in the active site are held in place by **acidic** residues, and the funnel in front of them is **fat loving**. Which amino acid exactly does not matter to the enzyme, as long as the charge is right.

EASY · 5 SLOTS, 5 OF THEM FREE

4× IN THE DECK

BIOREMEDIATION

3 pts · tier 1

Legacy Pesticides

#C52EA4

An old store full of organophosphate pesticides is leaking into the groundwater. Build the enzyme that takes them apart before they reach the river.

CARGO

Organophosphate Hydrolase

An enzyme with two zinc ions in its active site. It cleaves the phosphate ester bond in pesticides and makes them harmless.

BACKGROUND

Organophosphates are among the most widely used insecticides in the world. They block the nervous system and are toxic to many organisms that were never the target. In the soil of old storage sites they last for years.

It works almost as fast as its substrate can diffuse up to it. Chemically there is no way to go faster.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

The two zinc ions in the active site are held in place by **acidic** residues, and the funnel in front of them is **fat loving**. Which amino acid exactly does not matter to the enzyme, as long as the charge is right.

EASY · 5 SLOTS, 5 OF THEM FREE

4× IN THE DECK

BIOREMEDIATION

3 pts · tier 1

Legacy Pesticides

#C52EA4

An old store full of organophosphate pesticides is leaking into the groundwater. Build the enzyme that takes them apart before they reach the river.

CARGO

Organophosphate Hydrolase

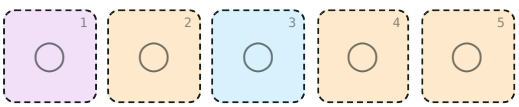
An enzyme with two zinc ions in its active site. It cleaves the phosphate ester bond in pesticides and makes them harmless.

BACKGROUND

Organophosphates are among the most widely used insecticides in the world. They block the nervous system and are toxic to many organisms that were never the target. In the soil of old storage sites they last for years.

It works almost as fast as its substrate can diffuse up to it. Chemically there is no way to go faster.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

The two zinc ions in the active site are held in place by **acidic** residues, and the funnel in front of them is **fat loving**. Which amino acid exactly does not matter to the enzyme, as long as the charge is right.

EASY · 5 SLOTS, 5 OF THEM FREE

4× IN THE DECK

BIOREMEDIATION

3 pts · tier 1

Legacy Pesticides

#C52EA4

An old store full of organophosphate pesticides is leaking into the groundwater. Build the enzyme that takes them apart before they reach the river.

CARGO

Organophosphate Hydrolase

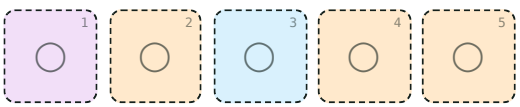
An enzyme with two zinc ions in its active site. It cleaves the phosphate ester bond in pesticides and makes them harmless.

BACKGROUND

Organophosphates are among the most widely used insecticides in the world. They block the nervous system and are toxic to many organisms that were never the target. In the soil of old storage sites they last for years.

It works almost as fast as its substrate can diffuse up to it. Chemically there is no way to go faster.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

The two zinc ions in the active site are held in place by **acidic** residues, and the funnel in front of them is **fat loving**. Which amino acid exactly does not matter to the enzyme, as long as the charge is right.

EASY · 5 SLOTS, 5 OF THEM FREE

4× IN THE DECK

BIOREMEDIATION

5 pts · tier 2

Oil Spill on the Coast

#L43YR2

A tanker is leaking. Immobilise Naphthalene Dioxygenase on encapsulins and clear the water of polycyclic aromatics.

CARGO

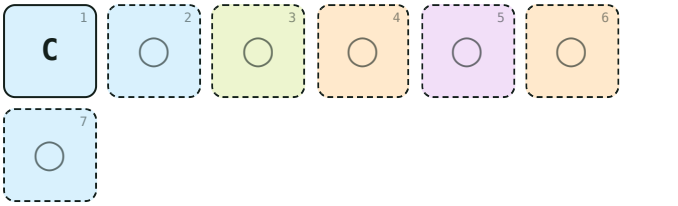
Naphthalene Dioxygenase

An iron containing enzyme from Pseudomonas that takes on the first and hardest step in breaking down polycyclic aromatic hydrocarbons.

BACKGROUND

PAHs form wherever something burns incompletely, in car exhaust, in cigarette smoke or at industrial sites that process coal and oil. Many of them cause cancer and build up in soil and sediment.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

The **cysteine**, together with a **positively charged** histidine, holds the Rieske iron sulfur cluster that the electrons flow through.

MEDIUM · 7 SLOTS, 6 OF THEM FREE

3× IN THE DECK

BIOREMEDIATION

5 pts · tier 2

Oil Spill on the Coast

#L43YR2

A tanker is leaking. Immobilise Naphthalene Dioxygenase on encapsulins and clear the water of polycyclic aromatics.

CARGO

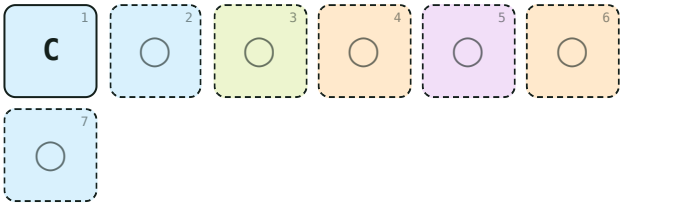
Naphthalene Dioxygenase

An iron containing enzyme from Pseudomonas that takes on the first and hardest step in breaking down polycyclic aromatic hydrocarbons.

BACKGROUND

PAHs form wherever something burns incompletely, in car exhaust, in cigarette smoke or at industrial sites that process coal and oil. Many of them cause cancer and build up in soil and sediment.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

The **cysteine**, together with a **positively charged** histidine, holds the Rieske iron sulfur cluster that the electrons flow through.

MEDIUM · 7 SLOTS, 6 OF THEM FREE

3× IN THE DECK

BIOREMEDIATION

5 pts · tier 2

Oil Spill on the Coast

#L43YR2

A tanker is leaking. Immobilise Naphthalene Dioxygenase on encapsulins and clear the water of polycyclic aromatics.

CARGO

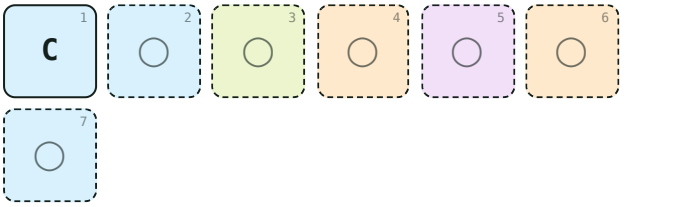
Naphthalene Dioxygenase

An iron containing enzyme from Pseudomonas that takes on the first and hardest step in breaking down polycyclic aromatic hydrocarbons.

BACKGROUND

PAHs form wherever something burns incompletely, in car exhaust, in cigarette smoke or at industrial sites that process coal and oil. Many of them cause cancer and build up in soil and sediment.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

The **cysteine**, together with a **positively charged** histidine, holds the Rieske iron sulfur cluster that the electrons flow through.

MEDIUM · 7 SLOTS, 6 OF THEM FREE

3× IN THE DECK

BIOREMEDIATION

8 pts · tier 3

Forever Chemicals

#U93VD7

Help develop a biotechnological way to break down PFAS and test Fluoroacetate Dehalogenase on encapsulins.

CARGO

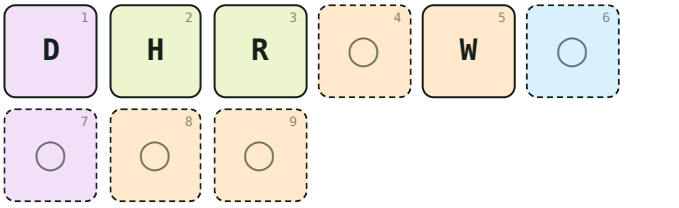
Fluoroacetate Dehalogenase

One of the few known enzymes that can cleave a carbon fluorine bond on purpose.

BACKGROUND

PFAS have been used since the 1940s in textiles, fire fighting foam, non stick coatings and packaging. Because they are so stable they build up in the environment and in the body, and they are suspected of causing damage to health.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

Aspartate attacks the carbon atom, **histidine** activates the water, and **arginine** and **tryptophan** form the pocket that holds the released fluoride. Four building blocks that really have to sit there.

HARD · 9 SLOTS, 5 OF THEM FREE

2× IN THE DECK

BIOREMEDIATION

8 pts · tier 3

Forever Chemicals

#U93VD7

Help develop a biotechnological way to break down PFAS and test Fluoroacetate Dehalogenase on encapsulins.

CARGO

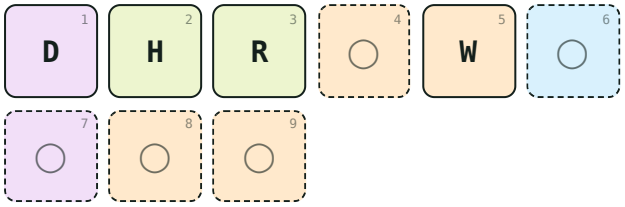
Fluoroacetate Dehalogenase

One of the few known enzymes that can cleave a carbon fluorine bond on purpose.

BACKGROUND

PFAS have been used since the 1940s in textiles, fire fighting foam, non stick coatings and packaging. Because they are so stable they build up in the environment and in the body, and they are suspected of causing damage to health.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

Aspartate attacks the carbon atom, **histidine** activates the water, and **arginine** and **tryptophan** form the pocket that holds the released fluoride. Four building blocks that really have to sit there.

HARD · 9 SLOTS, 5 OF THEM FREE

2× IN THE DECK

BIOCATALYSIS

3 pts · tier 1

Plastic Degradation

#P93HR8

Immobilise PETase on encapsulins and rid the oceans of microplastic.

CARGO

PETase

A bacterial enzyme that cleaves PET plastic, the material most drinks bottles are made of. It takes the long polymer chains apart into their basic building blocks.

BACKGROUND

More than 350 million tonnes of plastic are produced worldwide every year, and much of it ends up in landfills or in the environment. Chemical recycling needs a lot of energy. Enzymatic breakdown is the gentler alternative.

PETase was discovered in 2016 in Ideonella sakaiensis, a bacterium from a Japanese recycling plant that had specialised in a PET diet. Today there are variants that break bottles down in hours instead of weeks.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

A **polar** and an **acidic** residue are two thirds of the catalytic triad that cracks the ester bond in plastic. The third member is a histidine, and that one only shows up in the hard missions.

EASY · 5 SLOTS, 5 OF THEM FREE

4× IN THE DECK

BIOCATALYSIS

3 pts · tier 1

Plastic Degradation

#P93HR8

Immobilise PETase on encapsulins and rid the oceans of microplastic.

CARGO

PETase

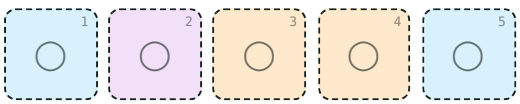
A bacterial enzyme that cleaves PET plastic, the material most drinks bottles are made of. It takes the long polymer chains apart into their basic building blocks.

BACKGROUND

More than 350 million tonnes of plastic are produced worldwide every year, and much of it ends up in landfills or in the environment. Chemical recycling needs a lot of energy. Enzymatic breakdown is the gentler alternative.

PETase was discovered in 2016 in Ideonella sakaiensis, a bacterium from a Japanese recycling plant that had specialised in a PET diet. Today there are variants that break bottles down in hours instead of weeks.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

A **polar** and an **acidic** residue are two thirds of the catalytic triad that cracks the ester bond in plastic. The third member is a histidine, and that one only shows up in the hard missions.

EASY · 5 SLOTS, 5 OF THEM FREE

4× IN THE DECK

BIOCATALYSIS

3 pts · tier 1

Plastic Degradation

#P93HR8

Immobilise PETase on encapsulins and rid the oceans of microplastic.

CARGO

PETase

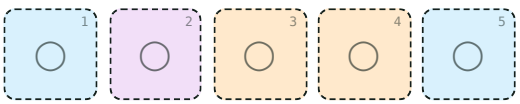
A bacterial enzyme that cleaves PET plastic, the material most drinks bottles are made of. It takes the long polymer chains apart into their basic building blocks.

BACKGROUND

More than 350 million tonnes of plastic are produced worldwide every year, and much of it ends up in landfills or in the environment. Chemical recycling needs a lot of energy. Enzymatic breakdown is the gentler alternative.

PETase was discovered in 2016 in Ideonella sakaiensis, a bacterium from a Japanese recycling plant that had specialised in a PET diet. Today there are variants that break bottles down in hours instead of weeks.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

A **polar** and an **acidic** residue are two thirds of the catalytic triad that cracks the ester bond in plastic. The third member is a histidine, and that one only shows up in the hard missions.

EASY · 5 SLOTS, 5 OF THEM FREE

4× IN THE DECK

BIOCATALYSIS

3 pts · tier 1

Plastic Degradation

#P93HR8

Immobilise PETase on encapsulins and rid the oceans of microplastic.

CARGO

PETase

A bacterial enzyme that cleaves PET plastic, the material most drinks bottles are made of. It takes the long polymer chains apart into their basic building blocks.

BACKGROUND

More than 350 million tonnes of plastic are produced worldwide every year, and much of it ends up in landfills or in the environment. Chemical recycling needs a lot of energy. Enzymatic breakdown is the gentler alternative.

PETase was discovered in 2016 in Ideonella sakaiensis, a bacterium from a Japanese recycling plant that had specialised in a PET diet. Today there are variants that break bottles down in hours instead of weeks.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

A **polar** and an **acidic** residue are two thirds of the catalytic triad that cracks the ester bond in plastic. The third member is a histidine, and that one only shows up in the hard missions.

EASY · 5 SLOTS, 5 OF THEM FREE

4× IN THE DECK

BIOCATALYSIS

5 pts · tier 2

Lignin Degradation

#H82ZX5

Help break lignin down and use immobilised Peroxidase to do it.

CARGO

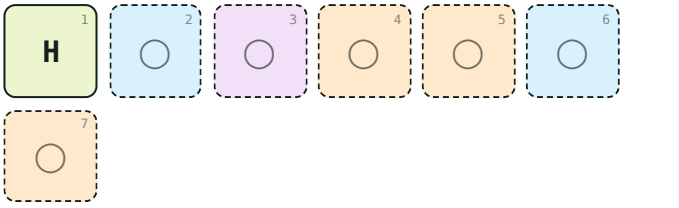
Peroxidase

Peroxidases use hydrogen peroxide to oxidise other molecules such as dyes, phenols or lignin.

BACKGROUND

Lignin is one of the most complex and most stable natural materials on Earth. It gives wood its strength, but it is extremely hard to break down.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

Two **histidines** clamp the heme iron between them. One holds it from below, the other activates the hydrogen peroxide from above. You really do need one of them.

MEDIUM · 7 SLOTS, 6 OF THEM FREE

3× IN THE DECK

BIOCATALYSIS

5 pts · tier 2

Lignin Degradation

#H82ZX5

Help break lignin down and use immobilised Peroxidase to do it.

CARGO

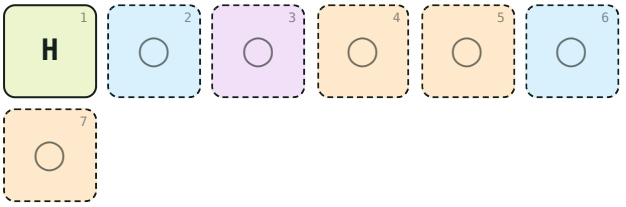
Peroxidase

Peroxidases use hydrogen peroxide to oxidise other molecules such as dyes, phenols or lignin.

BACKGROUND

Lignin is one of the most complex and most stable natural materials on Earth. It gives wood its strength, but it is extremely hard to break down.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

Two **histidines** clamp the heme iron between them. One holds it from below, the other activates the hydrogen peroxide from above. You really do need one of them.

MEDIUM · 7 SLOTS, 6 OF THEM FREE

3× IN THE DECK

BIOCATALYSIS

5 pts · tier 2

Lignin Degradation

#H82ZX5

Help break lignin down and use immobilised Peroxidase to do it.

CARGO

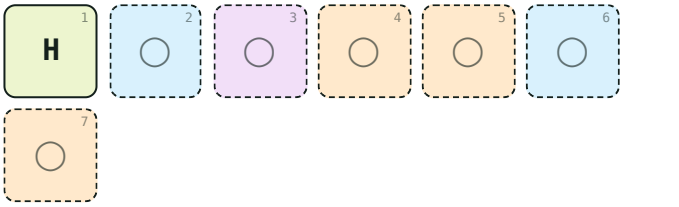
Peroxidase

Peroxidases use hydrogen peroxide to oxidise other molecules such as dyes, phenols or lignin.

BACKGROUND

Lignin is one of the most complex and most stable natural materials on Earth. It gives wood its strength, but it is extremely hard to break down.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

Two **histidines** clamp the heme iron between them. One holds it from below, the other activates the hydrogen peroxide from above. You really do need one of them.

MEDIUM · 7 SLOTS, 6 OF THEM FREE

3× IN THE DECK

BIOCATALYSIS

8 pts · tier 3

Selective Oxidation

#V65PU7

Build a production platform for ibuprofen with the help of Peroxygenase immobilised inside encapsulins.

CARGO

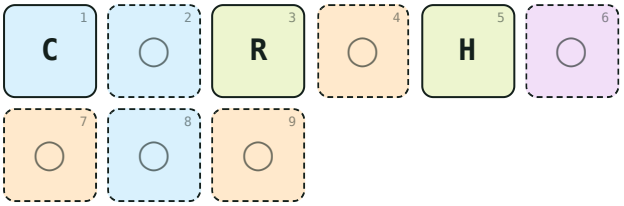
Unspecific Peroxygenase (UPO)

A haem enzyme that uses hydrogen peroxide as its oxygen source to carry out targeted oxidations, for example hydroxylations on carbon hydrogen bonds that are otherwise sluggish.

BACKGROUND

Drug production needs highly selective biocatalysts. A single hydroxyl group in the wrong place turns an active ingredient into a byproduct.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

The difference from the peroxidase sits in a single building block. Under the heme there is a **cysteine** here instead of a histidine. Exactly that swap turns the oxidation catalyst into an oxygen carrier.

HARD · 9 SLOTS, 6 OF THEM FREE

2× IN THE DECK

BIOCATALYSIS

8 pts · tier 3

Selective Oxidation

#V65PU7

Build a production platform for ibuprofen with the help of Peroxygenase immobilised inside encapsulins.

CARGO

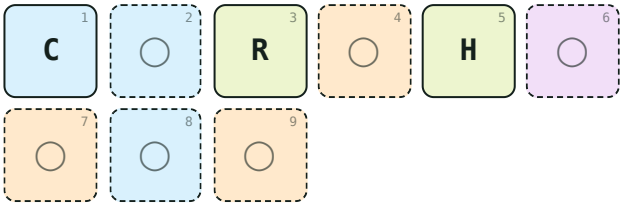
Unspecific Peroxygenase (UPO)

A haem enzyme that uses hydrogen peroxide as its oxygen source to carry out targeted oxidations, for example hydroxylations on carbon hydrogen bonds that are otherwise sluggish.

BACKGROUND

Drug production needs highly selective biocatalysts. A single hydroxyl group in the wrong place turns an active ingredient into a byproduct.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

The difference from the peroxidase sits in a single building block. Under the heme there is a **cysteine** here instead of a histidine. Exactly that swap turns the oxidation catalyst into an oxygen carrier.

HARD · 9 SLOTS, 6 OF THEM FREE

2× IN THE DECK

BIOCATALYSIS

8 pts · tier 3

Halogenation without Chlorine Chemistry

#C82CH2

Lock a Vanadium Chloroperoxidase inside an encapsulin and couple it with Glucose Oxidase. That is exactly the nanoreactor ENCORE is working on.

CARGO

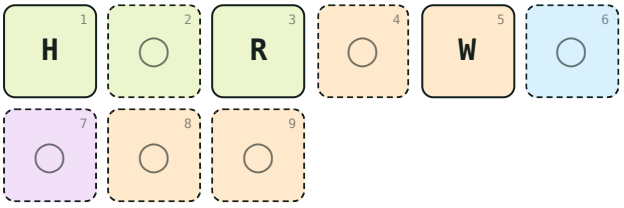
Vanadium Chloroperoxidase (VCPO)

The enzyme uses a redox stable vanadate cofactor and hydrogen peroxide to oxidise halide ions into hypohalous acids.

BACKGROUND

There is a problem. VCPO needs a lot of hydrogen peroxide, and H_2O_2 damages the host cell.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

A **histidine** binds the vanadate, and **arginine** and **tryptophan** shape the funnel that the halide comes in through.

HARD · 9 SLOTS, 6 OF THEM FREE

2× IN THE DECK

BIOCATALYSIS

8 pts · tier 3

Halogenation without Chlorine Chemistry

#C82CH2

Lock a Vanadium Chloroperoxidase inside an encapsulin and couple it with Glucose Oxidase. That is exactly the nanoreactor ENCORE is working on.

CARGO

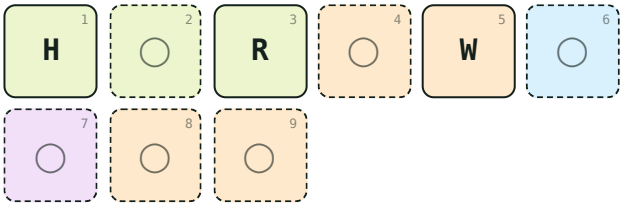
Vanadium Chloroperoxidase (VCPO)

The enzyme uses a redox stable vanadate cofactor and hydrogen peroxide to oxidise halide ions into hypohalous acids.

BACKGROUND

There is a problem. VCPO needs a lot of hydrogen peroxide, and H_2O_2 damages the host cell.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

A **histidine** binds the vanadate, and **arginine** and **tryptophan** shape the funnel that the halide comes in through.

HARD · 9 SLOTS, 6 OF THEM FREE

2× IN THE DECK

CLIMATE & CARBON

3 pts · tier 1

CO_2 from Flue Gas

#Q83VT8

Pack Carbonic Anhydrase into the encapsulin and speed up how CO_2 is captured in a flue gas scrubber.

CARGO

Carbonic Anhydrase

A zinc enzyme that turns CO_2 and water into bicarbonate, and back again. In your blood it makes sure CO_2 is carried away from the tissue and released again in the lungs.

BACKGROUND

When CO_2 is captured from power plant exhaust, the slow conversion of CO_2 into bicarbonate is the bottleneck. Enzymatic scrubbers could get by on far less energy than the amine processes used today.

It is one of the fastest enzymes known, up to a million reactions per second. Without this enzyme the same reaction would take minutes instead of microseconds.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

A **polar** and an **acidic** residue line the water molecule up so that the zinc can attack it. This fine tuning is the reason for the enormous speed.

EASY · 5 SLOTS, 5 OF THEM FREE

4× IN THE DECK

CLIMATE & CARBON

3 pts · tier 1

CO_2 from Flue Gas

#Q83VT8

Pack Carbonic Anhydrase into the encapsulin and speed up how CO_2 is captured in a flue gas scrubber.

CARGO

Carbonic Anhydrase

A zinc enzyme that turns CO_2 and water into bicarbonate, and back again. In your blood it makes sure CO_2 is carried away from the tissue and released again in the lungs.

BACKGROUND

When CO_2 is captured from power plant exhaust, the slow conversion of CO_2 into bicarbonate is the bottleneck. Enzymatic scrubbers could get by on far less energy than the amine processes used today.

It is one of the fastest enzymes known, up to a million reactions per second. Without this enzyme the same reaction would take minutes instead of microseconds.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

A **polar** and an **acidic** residue line the water molecule up so that the zinc can attack it. This fine tuning is the reason for the enormous speed.

EASY · 5 SLOTS, 5 OF THEM FREE

4× IN THE DECK

CLIMATE & CARBON

3 pts · tier 1

CO_2 from Flue Gas

#Q83VT8

Pack Carbonic Anhydrase into the encapsulin and speed up how CO_2 is captured in a flue gas scrubber.

CARGO

Carbonic Anhydrase

A zinc enzyme that turns CO_2 and water into bicarbonate, and back again. In your blood it makes sure CO_2 is carried away from the tissue and released again in the lungs.

BACKGROUND

When CO_2 is captured from power plant exhaust, the slow conversion of CO_2 into bicarbonate is the bottleneck. Enzymatic scrubbers could get by on far less energy than the amine processes used today.

It is one of the fastest enzymes known, up to a million reactions per second. Without this enzyme the same reaction would take minutes instead of microseconds.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

A **polar** and an **acidic** residue line the water molecule up so that the zinc can attack it. This fine tuning is the reason for the enormous speed.

EASY · 5 SLOTS, 5 OF THEM FREE

4× IN THE DECK

CLIMATE & CARBON

3 pts · tier 1

CO_2 from Flue Gas

#Q83VT8

Pack Carbonic Anhydrase into the encapsulin and speed up how CO_2 is captured in a flue gas scrubber.

CARGO

Carbonic Anhydrase

A zinc enzyme that turns CO_2 and water into bicarbonate, and back again. In your blood it makes sure CO_2 is carried away from the tissue and released again in the lungs.

BACKGROUND

When CO_2 is captured from power plant exhaust, the slow conversion of CO_2 into bicarbonate is the bottleneck. Enzymatic scrubbers could get by on far less energy than the amine processes used today.

It is one of the fastest enzymes known, up to a million reactions per second. Without this enzyme the same reaction would take minutes instead of microseconds.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

A **polar** and an **acidic** residue line the water molecule up so that the zinc can attack it. This fine tuning is the reason for the enormous speed.

EASY · 5 SLOTS, 5 OF THEM FREE

4× IN THE DECK

CLIMATE & CARBON

5 pts · tier 2

CO_2 Capture

#E88YM4

Use Rubisco inside the encapsulin to fix CO_2 efficiently and save the Earth.

CARGO

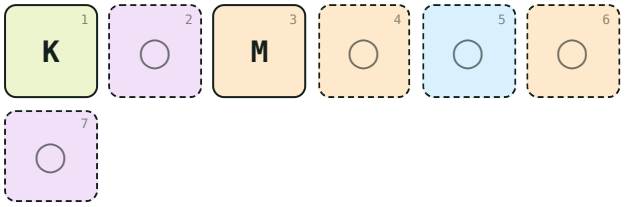
Rubisco

Ribulose-1,5-bisphosphate carboxylase/oxygenase is the key enzyme of photosynthesis.

BACKGROUND

Being able to bind CO_2 from the atmosphere is central to the fight against climate change. Plants, algae and some bacteria use the Calvin cycle for it.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

The **lysine** is carbamylated itself. It binds a CO_2 molecule first, before the enzyme can work at all. The **methionine** stabilizes the pocket beside it.

MEDIUM · 7 SLOTS, 5 OF THEM FREE

3× IN THE DECK

CLIMATE & CARBON

5 pts · tier 2

CO_2 Capture

#E88YM4

Use Rubisco inside the encapsulin to fix CO_2 efficiently and save the Earth.

CARGO

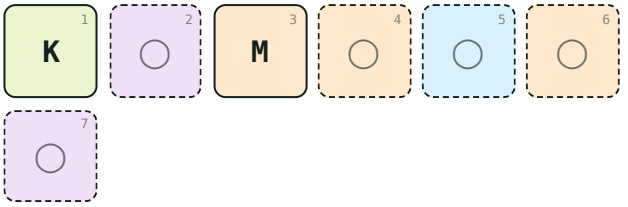
Rubisco

Ribulose-1,5-bisphosphate carboxylase/oxygenase is the key enzyme of photosynthesis.

BACKGROUND

Being able to bind CO_2 from the atmosphere is central to the fight against climate change. Plants, algae and some bacteria use the Calvin cycle for it.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

The **lysine** is carbamylated itself. It binds a CO_2 molecule first, before the enzyme can work at all. The **methionine** stabilizes the pocket beside it.

MEDIUM · 7 SLOTS, 5 OF THEM FREE

3× IN THE DECK

CLIMATE & CARBON

5 pts · tier 2

CO_2 Capture

#E88YM4

Use Rubisco inside the encapsulin to fix CO_2 efficiently and save the Earth.

CARGO

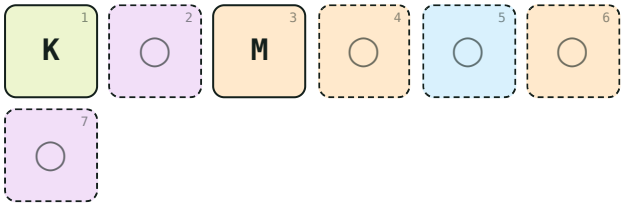
Rubisco

Ribulose-1,5-bisphosphate carboxylase/oxygenase is the key enzyme of photosynthesis.

BACKGROUND

Being able to bind CO_2 from the atmosphere is central to the fight against climate change. Plants, algae and some bacteria use the Calvin cycle for it.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

The **lysine** is carbamylated itself. It binds a CO_2 molecule first, before the enzyme can work at all. The **methionine** stabilizes the pocket beside it.

MEDIUM · 7 SLOTS, 5 OF THEM FREE

3× IN THE DECK

CLIMATE & CARBON

8 pts · tier 3

The Biological Haber Bosch

#D58NQ7

Develop the biological Haber Bosch process with the help of encapsulins. Nitrogenase needs an environment free of oxygen, and that is exactly what your cage can deliver.

CARGO

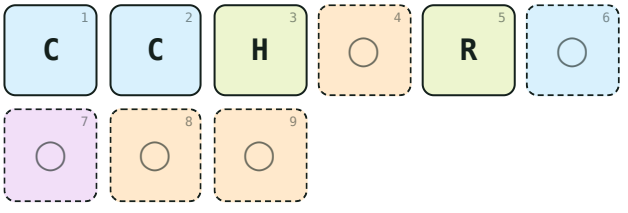
Nitrogenase

The enzyme that turns nitrogen from the air into ammonia.

BACKGROUND

Nitrogen is essential for all life. It sits in proteins and in DNA.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

The iron molybdenum cofactor hangs on two anchors, a **cysteine** and a **histidine**. The P cluster beside it is held by six more cysteines, which is why you need two of them right away.

HARD · 9 SLOTS, 5 OF THEM FREE

2× IN THE DECK

CLIMATE & CARBON

8 pts · tier 3

The Biological Haber Bosch

#D58NQ7

Develop the biological Haber Bosch process with the help of encapsulins. Nitrogenase needs an environment free of oxygen, and that is exactly what your cage can deliver.

CARGO

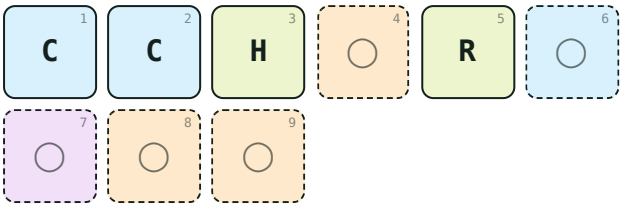
Nitrogenase

The enzyme that turns nitrogen from the air into ammonia.

BACKGROUND

Nitrogen is essential for all life. It sits in proteins and in DNA.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

The iron molybdenum cofactor hangs on two anchors, a **cysteine** and a **histidine**. The P cluster beside it is held by six more cysteines, which is why you need two of them right away.

HARD · 9 SLOTS, 5 OF THEM FREE

2× IN THE DECK

MEDICINE & DRUG DELIVERY

3 pts · tier 1

Fight Cancer

#Z52YA7

Help bring doxorubicin to exactly the right place in the body, and use encapsulins to do it.

CARGO

Binding Pocket for Doxorubicin

Doxorubicin is not a protein. You build the pocket that holds it inside the cage until it reaches the tumour.

BACKGROUND

Classical chemotherapy acts everywhere in the body, which causes hair loss, nausea and damage to the heart. Targeted transport is meant to bring the drug straight to the tumour and spare healthy tissue.

Doxorubicin comes from a soil bacterium (Streptomyces peucetius) and was discovered in the 1960s. Despite its age it is still one of the most widely used chemotherapy drugs in the world.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

Doxorubicin carries a positively charged sugar residue. Two **negatively charged** building blocks grab hold exactly there and keep the drug in the cage.

EASY · 5 SLOTS, 5 OF THEM FREE

4× IN THE DECK

MEDICINE & DRUG DELIVERY

3 pts · tier 1

Fight Cancer

#Z52YA7

Help bring doxorubicin to exactly the right place in the body, and use encapsulins to do it.

CARGO

Binding Pocket for Doxorubicin

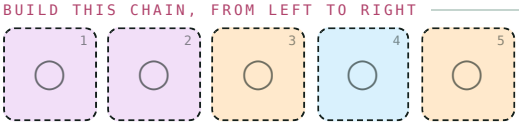
Doxorubicin is not a protein. You build the pocket that holds it inside the cage until it reaches the tumour.

BACKGROUND

Classical chemotherapy acts everywhere in the body, which causes hair loss, nausea and damage to the heart. Targeted transport is meant to bring the drug straight to the tumour and spare healthy tissue.

Doxorubicin comes from a soil bacterium (Streptomyces peucetius) and was discovered in the 1960s. Despite its age it is still one of the most widely used chemotherapy drugs in the world.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

Doxorubicin carries a positively charged sugar residue. Two **negatively charged** building blocks grab hold exactly there and keep the drug in the cage.

EASY · 5 SLOTS, 5 OF THEM FREE

4× IN THE DECK

MEDICINE & DRUG DELIVERY

3 pts · tier 1

Fight Cancer

#Z52YA7

Help bring doxorubicin to exactly the right place in the body, and use encapsulins to do it.

CARGO

Binding Pocket for Doxorubicin

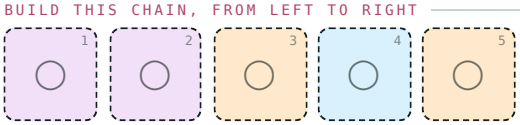
Doxorubicin is not a protein. You build the pocket that holds it inside the cage until it reaches the tumour.

BACKGROUND

Classical chemotherapy acts everywhere in the body, which causes hair loss, nausea and damage to the heart. Targeted transport is meant to bring the drug straight to the tumour and spare healthy tissue.

Doxorubicin comes from a soil bacterium (Streptomyces peucetius) and was discovered in the 1960s. Despite its age it is still one of the most widely used chemotherapy drugs in the world.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

Doxorubicin carries a positively charged sugar residue. Two **negatively charged** building blocks grab hold exactly there and keep the drug in the cage.

EASY · 5 SLOTS, 5 OF THEM FREE

4× IN THE DECK

MEDICINE & DRUG DELIVERY

3 pts · tier 1

Fight Cancer

#Z52YA7

Help bring doxorubicin to exactly the right place in the body, and use encapsulins to do it.

CARGO

Binding Pocket for Doxorubicin

Doxorubicin is not a protein. You build the pocket that holds it inside the cage until it reaches the tumour.

BACKGROUND

Classical chemotherapy acts everywhere in the body, which causes hair loss, nausea and damage to the heart. Targeted transport is meant to bring the drug straight to the tumour and spare healthy tissue.

Doxorubicin comes from a soil bacterium (Streptomyces peucetius) and was discovered in the 1960s. Despite its age it is still one of the most widely used chemotherapy drugs in the world.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

Doxorubicin carries a positively charged sugar residue. Two **negatively charged** building blocks grab hold exactly there and keep the drug in the cage.

EASY · 5 SLOTS, 5 OF THEM FREE

4× IN THE DECK

MEDICINE & DRUG DELIVERY

5 pts · tier 2

Gene Silencing Delivery

#V58CF4

Test the delivery of siRNA with encapsulins.

CARGO

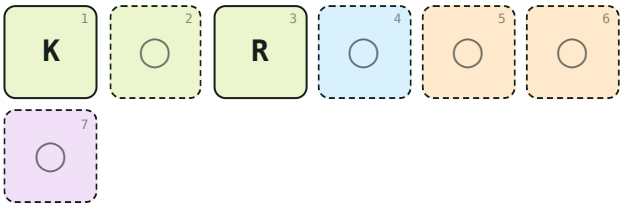
siRNA Binding Protein

siRNA is a short RNA molecule that silences single genes on purpose by blocking and destroying the matching mRNA.

BACKGROUND

Many diseases come from genes that are too active or faulty, from cancer to inherited metabolic disorders. Gene silencing could switch those off without changing the DNA itself.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

RNA is strongly negatively charged. **Lysine** and **arginine** pull it in electrostatically, and the **positively charged** surface beside them holds it tight.

MEDIUM · 7 SLOTS, 5 OF THEM FREE

3× IN THE DECK

MEDICINE & DRUG DELIVERY

5 pts · tier 2

Gene Silencing Delivery

#V58CF4

Test the delivery of siRNA with encapsulins.

CARGO

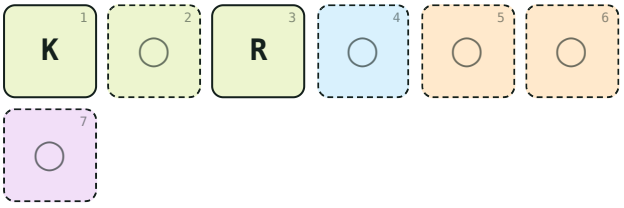
siRNA Binding Protein

siRNA is a short RNA molecule that silences single genes on purpose by blocking and destroying the matching mRNA.

BACKGROUND

Many diseases come from genes that are too active or faulty, from cancer to inherited metabolic disorders. Gene silencing could switch those off without changing the DNA itself.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

RNA is strongly negatively charged. **Lysine** and **arginine** pull it in electrostatically, and the **positively charged** surface beside them holds it tight.

MEDIUM · 7 SLOTS, 5 OF THEM FREE

3× IN THE DECK

MEDICINE & DRUG DELIVERY

5 pts · tier 2

Gene Silencing Delivery

#V58CF4

Test the delivery of siRNA with encapsulins.

CARGO

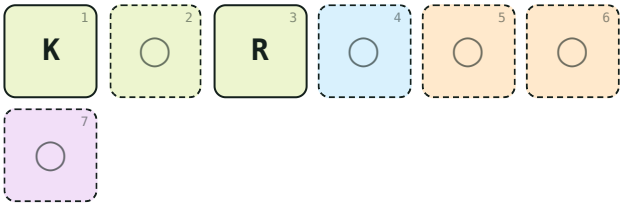
siRNA Binding Protein

siRNA is a short RNA molecule that silences single genes on purpose by blocking and destroying the matching mRNA.

BACKGROUND

Many diseases come from genes that are too active or faulty, from cancer to inherited metabolic disorders. Gene silencing could switch those off without changing the DNA itself.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

RNA is strongly negatively charged. **Lysine** and **arginine** pull it in electrostatically, and the **positively charged** surface beside them holds it tight.

MEDIUM · 7 SLOTS, 5 OF THEM FREE

3× IN THE DECK

MEDICINE & DRUG DELIVERY

8 pts · tier 3

An Alternative to Antibiotics

#R99BE2

Use vault proteins to put antimicrobial peptides to work against bacterial infections.

CARGO

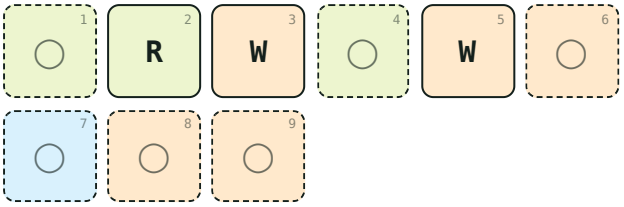
Antimicrobial Peptide (AMP)

AMPs are short proteins, either made by the body or synthetic, that punch holes in bacterial membranes and kill pathogens.

BACKGROUND

According to the WHO, resistance to antibiotics is one of the biggest global threats to health. More and more bacterial strains no longer respond to standard antibiotics.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

An AMP has to be two things at once, **positively charged** to find the bacterial membrane and fat loving to drill into it. That is what the **arginine** and the two **tryptophans** are for, and they sit right at the border between water and membrane.

HARD · 9 SLOTS, 6 OF THEM FREE

2× IN THE DECK

MEDICINE & DRUG DELIVERY

8 pts · tier 3

An Alternative to Antibiotics

#R99BE2

Use vault proteins to put antimicrobial peptides to work against bacterial infections.

CARGO

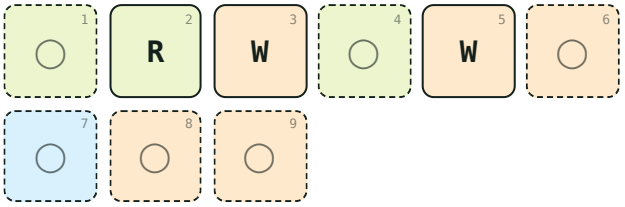
Antimicrobial Peptide (AMP)

AMPs are short proteins, either made by the body or synthetic, that punch holes in bacterial membranes and kill pathogens.

BACKGROUND

According to the WHO, resistance to antibiotics is one of the biggest global threats to health. More and more bacterial strains no longer respond to standard antibiotics.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

An AMP has to be two things at once, **positively charged** to find the bacterial membrane and fat loving to drill into it. That is what the **arginine** and the two **tryptophans** are for, and they sit right at the border between water and membrane.

HARD · 9 SLOTS, 6 OF THEM FREE

2× IN THE DECK

TRANSCRIPTOMICS & BIOPROCESSING

3 pts · tier 1

Time Machine

#F57VV5

Use Pab1p to catch a snapshot of the transcriptome while the yeast is under heat stress.

CARGO

Pab1p, Poly(A) Binding Protein

Pab1p binds to the poly(A) tail of mature mRNA. Fuse it to a targeting peptide and it pulls the mRNA into the protein cage as the cage assembles.

BACKGROUND

How microorganisms react to stress is hard to capture at industrial scale. The cell stays a black box, because the telltale mRNAs are long gone by the time anyone measures.

mRNA is fleeting and is broken down within minutes. Once it sits inside the compartment it is safe from the RNases of the cytoplasm, and it can still be read out hours later.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

The binding module is a sandwich of four β strands. Three **fat loving** building blocks form its core, and without them nothing folds at all.

EASY · 5 SLOTS, 5 OF THEM FREE

4× IN THE DECK

TRANSCRIPTOMICS & BIOPROCESSING

3 pts · tier 1

Time Machine

#F57VV5

Use Pab1p to catch a snapshot of the transcriptome while the yeast is under heat stress.

CARGO

Pab1p, Poly(A) Binding Protein

Pab1p binds to the poly(A) tail of mature mRNA. Fuse it to a targeting peptide and it pulls the mRNA into the protein cage as the cage assembles.

BACKGROUND

How microorganisms react to stress is hard to capture at industrial scale. The cell stays a black box, because the telltale mRNAs are long gone by the time anyone measures.

mRNA is fleeting and is broken down within minutes. Once it sits inside the compartment it is safe from the RNases of the cytoplasm, and it can still be read out hours later.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

The binding module is a sandwich of four β strands. Three **fat loving** building blocks form its core, and without them nothing folds at all.

EASY · 5 SLOTS, 5 OF THEM FREE

4× IN THE DECK

TRANSCRIPTOMICS & BIOPROCESSING

3 pts · tier 1

Time Machine

#F57VV5

Use Pab1p to catch a snapshot of the transcriptome while the yeast is under heat stress.

CARGO

Pab1p, Poly(A) Binding Protein

Pab1p binds to the poly(A) tail of mature mRNA. Fuse it to a targeting peptide and it pulls the mRNA into the protein cage as the cage assembles.

BACKGROUND

How microorganisms react to stress is hard to capture at industrial scale. The cell stays a black box, because the telltale mRNAs are long gone by the time anyone measures.

mRNA is fleeting and is broken down within minutes. Once it sits inside the compartment it is safe from the RNases of the cytoplasm, and it can still be read out hours later.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

The binding module is a sandwich of four β strands. Three **fat loving** building blocks form its core, and without them nothing folds at all.

EASY · 5 SLOTS, 5 OF THEM FREE

4× IN THE DECK

TRANSCRIPTOMICS & BIOPROCESSING

3 pts · tier 1

Time Machine

#F57VV5

Use Pab1p to catch a snapshot of the transcriptome while the yeast is under heat stress.

CARGO

Pab1p, Poly(A) Binding Protein

Pab1p binds to the poly(A) tail of mature mRNA. Fuse it to a targeting peptide and it pulls the mRNA into the protein cage as the cage assembles.

BACKGROUND

How microorganisms react to stress is hard to capture at industrial scale. The cell stays a black box, because the telltale mRNAs are long gone by the time anyone measures.

mRNA is fleeting and is broken down within minutes. Once it sits inside the compartment it is safe from the RNases of the cytoplasm, and it can still be read out hours later.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

The binding module is a sandwich of four β strands. Three **fat loving** building blocks form its core, and without them nothing folds at all.

EASY · 5 SLOTS, 5 OF THEM FREE

4× IN THE DECK

TRANSCRIPTOMICS & BIOPROCESSING

5 pts · tier 2

Better Baker's Yeast

#X59SF5

Use CRISPRi and the mRNA from your Time Machine to improve the fermentation of baker's yeast in a targeted way.

CARGO

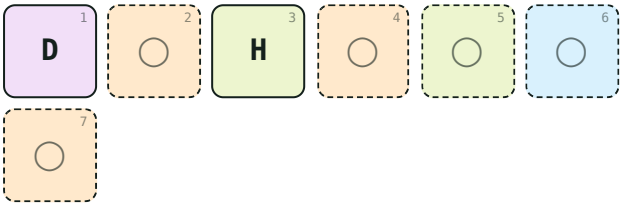
dCas9, CRISPR Interference

CRISPRi uses a "dead" Cas9 protein that cannot cut.

BACKGROUND

Baker's yeast is one of the best studied eukaryotic model organisms and the number one production strain in industry, from beer and bread to bioethanol and recombinant proteins such as insulin.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

D and **H** stand for the two residues that shut Cas9 down, namely D10A and H840A. Only these two point mutations turn the scissors into a blocker, in the game just as in the lab.

MEDIUM · 7 SLOTS, 5 OF THEM FREE

3× IN THE DECK

TRANSCRIPTOMICS & BIOPROCESSING

5 pts · tier 2

Better Baker's Yeast

#X59SF5

Use CRISPRi and the mRNA from your Time Machine to improve the fermentation of baker's yeast in a targeted way.

CARGO

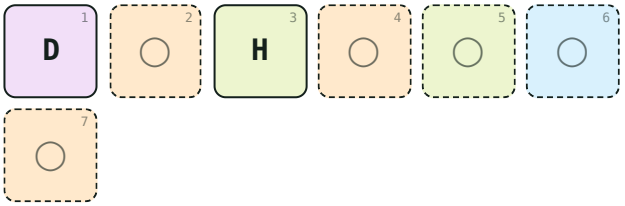
dCas9, CRISPR Interference

CRISPRi uses a "dead" Cas9 protein that cannot cut.

BACKGROUND

Baker's yeast is one of the best studied eukaryotic model organisms and the number one production strain in industry, from beer and bread to bioethanol and recombinant proteins such as insulin.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

D and **H** stand for the two residues that shut Cas9 down, namely D10A and H840A. Only these two point mutations turn the scissors into a blocker, in the game just as in the lab.

MEDIUM · 7 SLOTS, 5 OF THEM FREE

3× IN THE DECK

TRANSCRIPTOMICS & BIOPROCESSING

5 pts · tier 2

Better Baker's Yeast

#X59SF5

Use CRISPRi and the mRNA from your Time Machine to improve the fermentation of baker's yeast in a targeted way.

CARGO

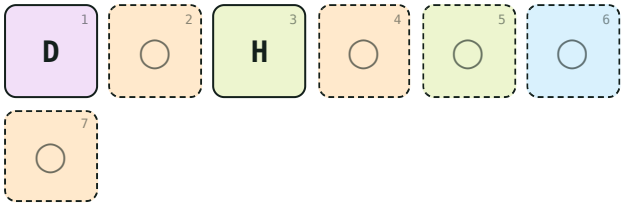
dCas9, CRISPR Interference

CRISPRi uses a "dead" Cas9 protein that cannot cut.

BACKGROUND

Baker's yeast is one of the best studied eukaryotic model organisms and the number one production strain in industry, from beer and bread to bioethanol and recombinant proteins such as insulin.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

D and **H** stand for the two residues that shut Cas9 down, namely D10A and H840A. Only these two point mutations turn the scissors into a blocker, in the game just as in the lab.

MEDIUM · 7 SLOTS, 5 OF THEM FREE

3× IN THE DECK

TRANSCRIPTOMICS & BIOPROCESSING

8 pts · tier 3

The Bigger Archive

#A23ER7

Encapsulins fill up fast. Build Pab1p into vault particles and multiply the capacity of your transcriptome archive by ten.

CARGO

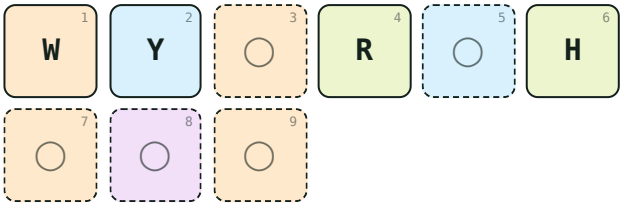
Pab1p with an INT Domain for Vaults

Vault particles are built from many copies of the Major Vault Protein and have a much larger inner volume than encapsulins.

BACKGROUND

The more mRNA a snapshot catches, the more reliable the picture. A larger compartment means more captured transcripts, and with them the rare, short lived signals that would otherwise drown in the noise.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

Nucleic acids are read by flat, ring shaped building blocks. **Tryptophan** and **tyrosine** stack onto the bases, and **arginine** and **histidine** grip the backbone. That is why this mission is expensive.

HARD · 9 SLOTS, 5 OF THEM FREE

2× IN THE DECK

TRANSCRIPTOMICS & BIOPROCESSING

8 pts · tier 3

The Bigger Archive

#A23ER7

Encapsulins fill up fast. Build Pab1p into vault particles and multiply the capacity of your transcriptome archive by ten.

CARGO

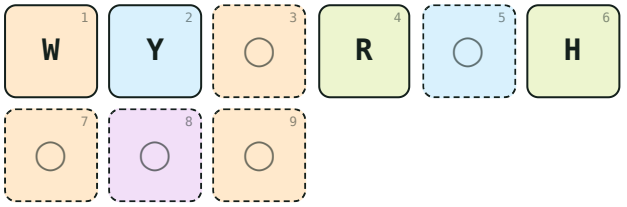
Pab1p with an INT Domain for Vaults

Vault particles are built from many copies of the Major Vault Protein and have a much larger inner volume than encapsulins.

BACKGROUND

The more mRNA a snapshot catches, the more reliable the picture. A larger compartment means more captured transcripts, and with them the rare, short lived signals that would otherwise drown in the noise.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

Nucleic acids are read by flat, ring shaped building blocks. **Tryptophan** and **tyrosine** stack onto the bases, and **arginine** and **histidine** grip the backbone. That is why this mission is expensive.

HARD · 9 SLOTS, 5 OF THEM FREE

2× IN THE DECK

NANOMATERIALS & BIOMINERALIZATION

3 pts · tier 1

The Iron Core

#M52QZ4

Build the ferroxidase centre into your encapsulin and grow an iron core of exactly defined size inside it.

CARGO

Encapsulin Associated Ferritin

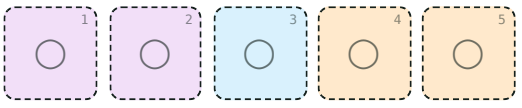
A protein that oxidises divalent iron to the trivalent form. The iron oxide that forms precipitates inside the cage, and the cage decides how big the grain can get.

BACKGROUND

Classical nanoparticle synthesis always gives you a spread of sizes. A protein cage gives you a mould instead. Every particle grows as big as the space inside, and not one nanometre bigger.

Ferritin is doing this in your body at this very moment. It stores iron in a form that neither rusts nor turns toxic.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

Two **negatively charged** building blocks form the pincer that holds two iron ions side by side while the oxygen oxidizes them. Glutamate and aspartate can both do it.

EASY · 5 SLOTS, 5 OF THEM FREE

4× IN THE DECK

NANOMATERIALS & BIOMINERALIZATION

3 pts · tier 1

The Iron Core

#M52QZ4

Build the ferroxidase centre into your encapsulin and grow an iron core of exactly defined size inside it.

CARGO

Encapsulin Associated Ferritin

A protein that oxidises divalent iron to the trivalent form. The iron oxide that forms precipitates inside the cage, and the cage decides how big the grain can get.

BACKGROUND

Classical nanoparticle synthesis always gives you a spread of sizes. A protein cage gives you a mould instead. Every particle grows as big as the space inside, and not one nanometre bigger.

Ferritin is doing this in your body at this very moment. It stores iron in a form that neither rusts nor turns toxic.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

Two **negatively charged** building blocks form the pincer that holds two iron ions side by side while the oxygen oxidizes them. Glutamate and aspartate can both do it.

EASY · 5 SLOTS, 5 OF THEM FREE

4× IN THE DECK

NANOMATERIALS & BIOMINERALIZATION

3 pts · tier 1

The Iron Core

#M52QZ4

Build the ferroxidase centre into your encapsulin and grow an iron core of exactly defined size inside it.

CARGO

Encapsulin Associated Ferritin

A protein that oxidises divalent iron to the trivalent form. The iron oxide that forms precipitates inside the cage, and the cage decides how big the grain can get.

BACKGROUND

Classical nanoparticle synthesis always gives you a spread of sizes. A protein cage gives you a mould instead. Every particle grows as big as the space inside, and not one nanometre bigger.

Ferritin is doing this in your body at this very moment. It stores iron in a form that neither rusts nor turns toxic.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

Two **negatively charged** building blocks form the pincer that holds two iron ions side by side while the oxygen oxidizes them. Glutamate and aspartate can both do it.

EASY · 5 SLOTS, 5 OF THEM FREE

4× IN THE DECK

NANOMATERIALS & BIOMINERALIZATION

3 pts · tier 1

The Iron Core

#M52QZ4

Build the ferroxidase centre into your encapsulin and grow an iron core of exactly defined size inside it.

CARGO

Encapsulin Associated Ferritin

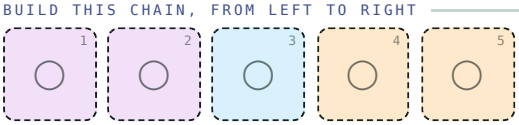
A protein that oxidises divalent iron to the trivalent form. The iron oxide that forms precipitates inside the cage, and the cage decides how big the grain can get.

BACKGROUND

Classical nanoparticle synthesis always gives you a spread of sizes. A protein cage gives you a mould instead. Every particle grows as big as the space inside, and not one nanometre bigger.

Ferritin is doing this in your body at this very moment. It stores iron in a form that neither rusts nor turns toxic.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

Two **negatively charged** building blocks form the pincer that holds two iron ions side by side while the oxygen oxidizes them. Glutamate and aspartate can both do it.

EASY · 5 SLOTS, 5 OF THEM FREE

4× IN THE DECK

NANOMATERIALS & BIOMINERALIZATION

5 pts · tier 2

Glass at Room Temperature

#A82WS3

Lock Silicatein inside an encapsulin and grow silica nanoparticles. No heat, no acid.

CARGO

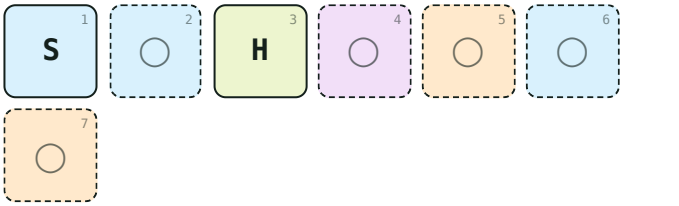
Silicatein

The enzyme glass sponges use to build their glass needles.

BACKGROUND

Silica nanoparticles sit in catalysts, in coatings and in carrier materials for medicines. So far they are made with aggressive chemistry.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

Silicatein is a rebuilt protease. Where its relative cathepsin L carries a cysteine, there is a **serine** here. This one swap turns a protein splitter into a glass builder. The **histidine** beside it belongs to the same triad.

MEDIUM · 7 SLOTS, 5 OF THEM FREE

3× IN THE DECK

NANOMATERIALS & BIOMINERALIZATION

5 pts · tier 2

Glass at Room Temperature

#A82WS3

Lock Silicatein inside an encapsulin and grow silica nanoparticles. No heat, no acid.

CARGO

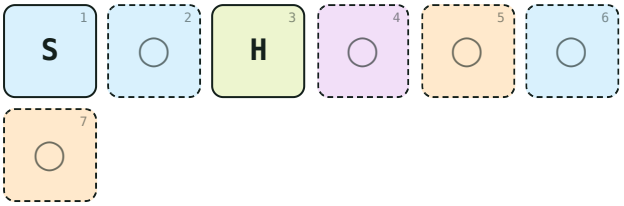
Silicatein

The enzyme glass sponges use to build their glass needles.

BACKGROUND

Silica nanoparticles sit in catalysts, in coatings and in carrier materials for medicines. So far they are made with aggressive chemistry.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

Silicatein is a rebuilt protease. Where its relative cathepsin L carries a cysteine, there is a **serine** here. This one swap turns a protein splitter into a glass builder. The **histidine** beside it belongs to the same triad.

MEDIUM · 7 SLOTS, 5 OF THEM FREE

3× IN THE DECK

NANOMATERIALS & BIOMINERALIZATION

5 pts · tier 2

Glass at Room Temperature

#A82WS3

Lock Silicatein inside an encapsulin and grow silica nanoparticles. No heat, no acid.

CARGO

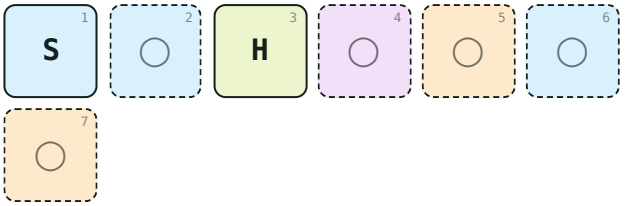
Silicatein

The enzyme glass sponges use to build their glass needles.

BACKGROUND

Silica nanoparticles sit in catalysts, in coatings and in carrier materials for medicines. So far they are made with aggressive chemistry.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

Silicatein is a rebuilt protease. Where its relative cathepsin L carries a cysteine, there is a **serine** here. This one swap turns a protein splitter into a glass builder. The **histidine** beside it belongs to the same triad.

MEDIUM · 7 SLOTS, 5 OF THEM FREE

3× IN THE DECK

NANOMATERIALS & BIOMINERALIZATION

8 pts · tier 3

Magnetite Made to Measure

#B24SM3

Build Mms6 into your encapsulin and grow magnetic nanocrystals inside it with exactly controlled size.

CARGO

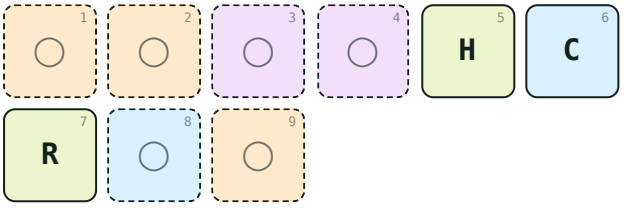
Mms6, Magnetosome Protein

The protein that magnetotactic bacteria use to shape their magnetite crystals.

BACKGROUND

Magnetic nanoparticles serve as contrast agents in MRI, as carriers in hyperthermia therapy and as the basis of magnetic data storage. In all three the exact grain size decides how well they perform.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

One part of the protein is **fat loving** and folds into the scaffold, the other is strongly **acidic**. **Histidine**, **cysteine** and **arginine** grip the iron ions and decide which crystal face they dock onto.

HARD · 9 SLOTS, 6 OF THEM FREE

2× IN THE DECK

NANOMATERIALS & BIOMINERALIZATION

8 pts · tier 3

Magnetite Made to Measure

#B24SM3

Build Mms6 into your encapsulin and grow magnetic nanocrystals inside it with exactly controlled size.

CARGO

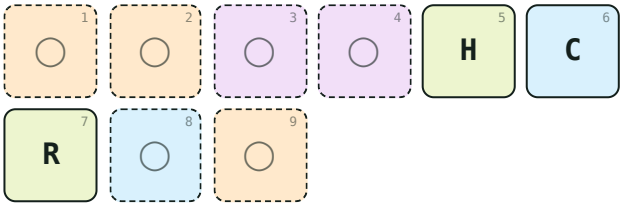
Mms6, Magnetosome Protein

The protein that magnetotactic bacteria use to shape their magnetite crystals.

BACKGROUND

Magnetic nanoparticles serve as contrast agents in MRI, as carriers in hyperthermia therapy and as the basis of magnetic data storage. In all three the exact grain size decides how well they perform.

BUILD THIS CHAIN, FROM LEFT TO RIGHT



○ = **any** amino acid of that colour · letter = exactly this one

One part of the protein is **fat loving** and folds into the scaffold, the other is strongly **acidic**. **Histidine**, **cysteine** and **arginine** grip the iron ions and decide which crystal face they dock onto.

HARD · 9 SLOTS, 6 OF THEM FREE

2× IN THE DECK