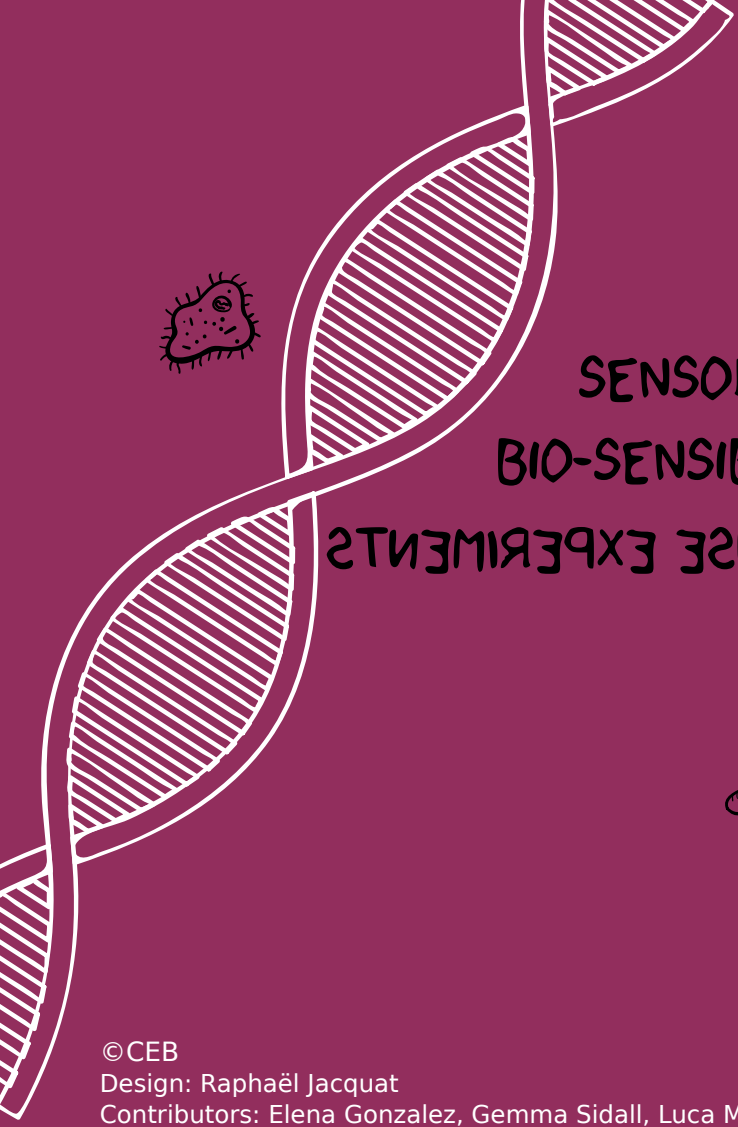
CEB
Sense Experiment Book

Student Name

School/Institution

UNIVERSITY OF CAMBRIDGE
Chemical Engineering and Biotechnology



SENSORS
BIO-SENSIBILITY
AND NO-SENSE EXPERIMENTS

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Draw under creative common created by freepik, xkcd.com, and R. Jacquat

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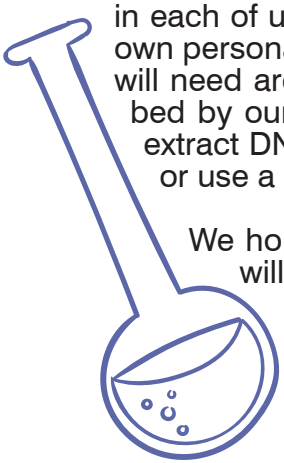
Dear Science Explorers,

The world is full of things to see, stories to hear and tell, experiences to collect, not to mention all those delicious cakes to try… But sometimes making sense of everything can be challenging. Luckily, Nature has equipped humans with a multitude of sensory organs, which help us adapt to and interact with our environment. Sometimes, however, these sensory organs are simply not sensitive enough or they stop working properly. This is why scientists and engineers around the world work hard to develop new technologies that can overcome the limitations of our senses. They have designed sensors that monitor different things, such as sugar or drug level in blood, air pollution, or behaviour of molecules in a single cell. They are looking for ways to repair damaged senses by using computer technology and new materials.

To challenge your senses and to inspire you to take a closer look at them, we are inviting you on a journey through the CEB Sense Experiment Book. In this book you will find lots of interesting facts about how our senses are built and how they work. You will also find instructions for a few do-it-yourself experiments-that give unexpected results. Some of these experiments are inspired by the work done by scientists in our Department.

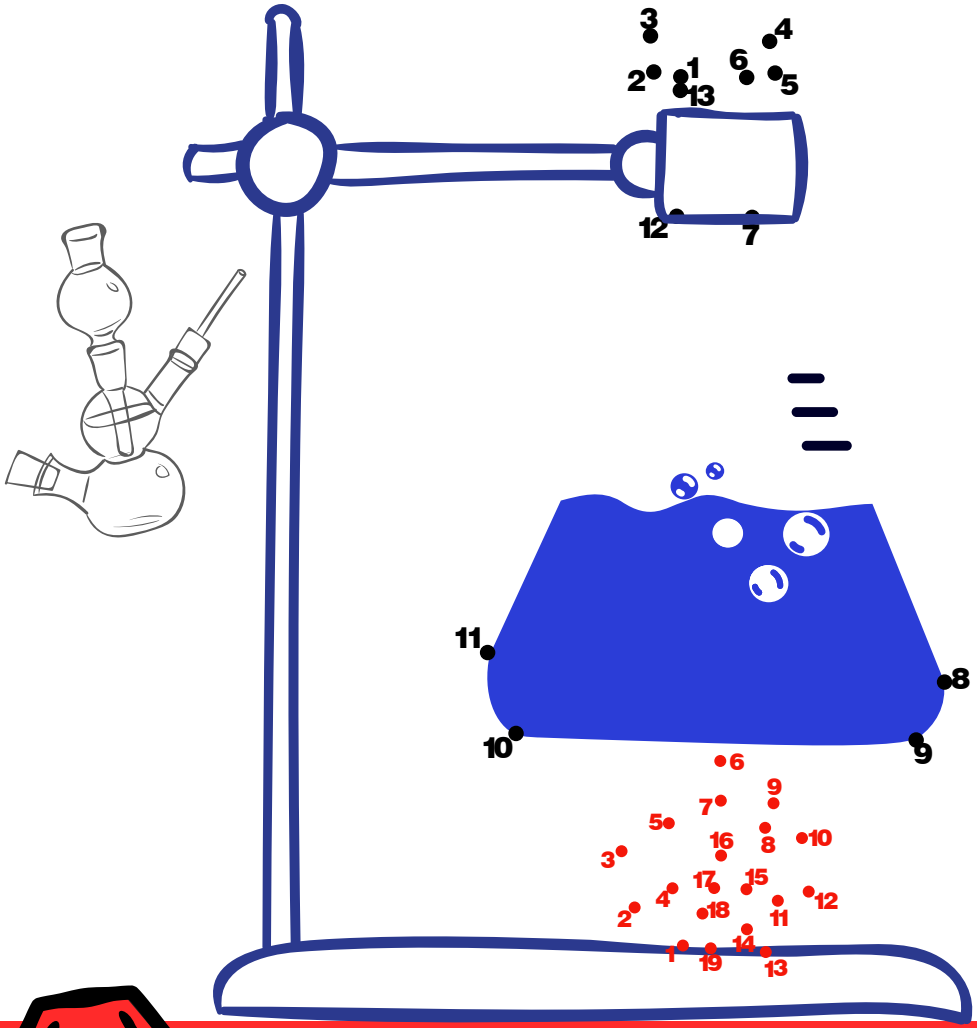
We have written this book with curious science lovers in mind, and for all of those who always wanted to turn their kitchens into laboratories. We believe there is a scientifically minded detective in each of us, so we've left some space for you to write your own personal experimental observations. The ingredients you will need are readily available. If you follow the steps described by our scientists and engineers, you will learn how to extract DNA from strawberries, create a volcano in a glass, or use a pineapple for biochemical reactions.



We hope that some of the information and experiments will challenge your senses (check that Albert Monroe image on page 15!) and show you how our natural senses (touch, sight, smell, taste, and hearing) can be affected and stimulated.

Connecting the Dots
WHAT IS THAT?

In this booklet the instructions are given in Italic
Connect the dots and find a very useful scientific instrument



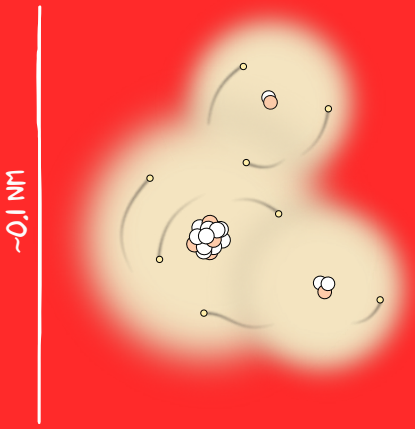
Answer : Test tube (Vital equipment for a scientist!)

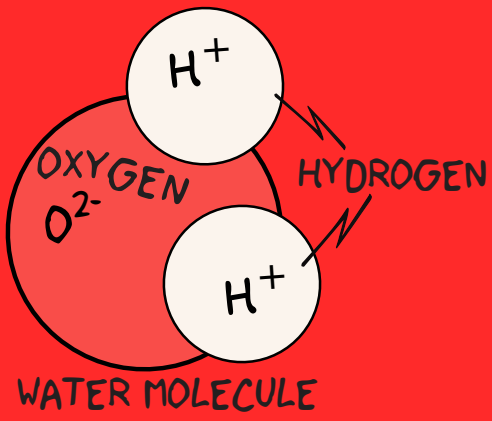
From Atoms to Amino Acids

ATOMS ARE FORMED OF 3 BASIC TINY PARTICLES

PROTON ELECTRON NEUTRON

ELECTRONS FLY AROUND A NUCLEUS MADE OF PROTONS AND NEUTRONS. ATOMS OF DIFFERENT ELEMENTS WILL HAVE DIFFERENT NUMBER OF THESE PARTICLES AND THIS WILL DETERMINE THEIR POSITION IN THE PERIODIC TABLE OF ELEMENTS. FOR EXAMPLE, HYDROGEN HAS ONE PROTON, OXYGEN 8 PROTONS, CARBON 12...

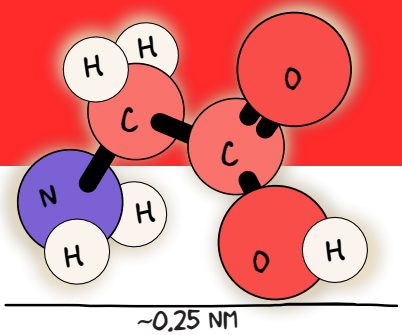




ATOMS CAN MAKE BONDS WITH EACH OTHER BY SHARING ELECTRONS AND FORM LARGER STRUCTURES, MOLECULES. WE ARE ALL MADE OF MOLECULES, SMALL AND BIG. FOR EXAMPLE, ALL OUR PROTEINS ARE MADE OF BASIC BUILDING BLOCKS CALLED AMINO ACIDS. THEY ARE REALLY SMALL, SMALLER THAN A NANOMETER (1 NM = 0.000000001 M) THE LARGEST KNOWN PROTEIN IN OUR BODY, TITIN, IS MADE OF ~30 000 AMINO ACIDS AND IT CAN BE FOUND IN MUSCLES.

DID YOU KNOW THAT ONLY 20 DIFFERENT AMINO ACIDS MAKE UP PROTEINS FOR 37,2 TRILLION CELLS IN OUR BODY?

GLYCINE MOLECULE
(AMINO ACID)



Experiment 1
Extract DNA Strawberries

MATERIALS

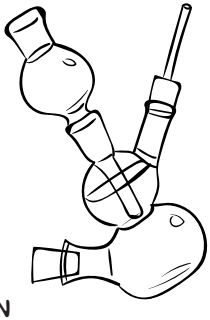
- RUBBING ALCOHOL
- MEASURING CUP
- MEASURING SPOONS
- SALT
- WATER
- DISHWASHING LIQUID (FOR HAND-WASHING DISHES)
- GLASS
- CHEESECLOTH
- FUNNEL
- TALL DRINKING GLASS
- THREE STRAWBERRIES
- RESEALABLE PLASTIC SANDWICH BAG
- SMALL GLASS JAR
- BAMBOO SKEWER, AVAILABLE AT MOST GROCERY STORES.

INSTRUCTION

1. CHILL THE RUBBING ALCOHOL IN THE FREEZER. (YOU'LL NEED IT LATER.)
2. MIX 1/2 TEASPOON OF SALT, 1/3 CUP OF WATER AND ONE TABLESPOON OF DISHWASHING LIQUID IN A GLASS OR SMALL BOWL. SET THE MIXTURE ASIDE. THIS IS YOUR EXTRACTION LIQUID.
3. COMPLETELY LINE THE FUNNEL WITH CHEESECLOTH. INSERT THE FUNNEL TUBE INTO THE TALL DRINKING GLASS (NOT THE GLASS WITH THE EXTRACTION LIQUID IN IT).
4. REMOVE AND DISCARD THE GREEN TOPS FROM THE STRAWBERRIES.
5. PUT THE STRAWBERRIES INTO A RESEALABLE PLASTIC SANDWICH BAG AND PUSH OUT ALL OF THE EXTRA AIR. SEAL THE BAG TIGHTLY.
6. WITH YOUR FINGERS, SQUEEZE AND SMASH THE STRAWBERRIES FOR TWO MINUTES.
7. ADD THREE TABLESPOONS OF THE EXTRACTION LIQUID YOU PREPARED TO THE STRAWBERRIES IN THE BAG. PUSH OUT ALL OF THE EXTRA AIR AND RESEAL THE BAG.
8. SQUEEZE THE STRAWBERRY MIXTURE WITH YOUR FINGERS FOR ONE MINUTE.
9. POUR THE STRAWBERRY MIXTURE FROM THE BAG INTO THE FUNNEL. LET IT DRIP THROUGH THE CHEESECLOTH AND INTO THE TALL GLASS UNTIL THERE IS VERY LITTLE LIQUID LEFT IN THE FUNNEL (ONLY WET PULP REMAINS).
10. POUR THE FILTERED STRAWBERRY LIQUID FROM THE TALL GLASS INTO THE SMALL GLASS JAR SO THAT THE JAR IS ONE QUARTER FULL.
11. MEASURE OUT 1/2 CUP OF COLD RUBBING ALCOHOL.
12. TILT THE JAR AND VERY SLOWLY POUR THE ALCOHOL DOWN ITS SIDE. POUR UNTIL THE ALCOHOL HAS FORMED APPROXIMATELY A ONE-INCH-DEEP LAYER ON TOP OF THE STRAWBERRY LIQUID. YOU MAY NOT NEED ALL OF THE 1/2 CUP OF ALCOHOL TO FORM THE ONE-INCH LAYER. DO NOT LET THE STRAWBERRY LIQUID AND ALCOHOL MIX.
13. STUDY THE MIXTURE INSIDE OF THE JAR. THE STRAWBERRY DNA WILL APPEAR AS GOOEY CLEAR/WHITE STRINGY STUFF. DO YOU SEE ANYTHING IN THE JAR THAT MIGHT BE STRAWBERRY DNA? IF SO, WHERE IN THE JAR IS IT?
14. DIP THE BAMBOO SKEWER INTO THE JAR WHERE THE STRAWBERRY LIQUID AND ALCOHOL LAYERS MEET AND THEN PULL UP THE SKEWER. DID YOU SEE ANYTHING STICK TO THE SKEWER THAT MIGHT BE DNA? CAN YOU SPOOL ANY DNA ONTO THE SKEWER?

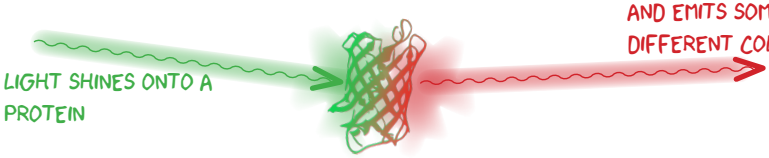
Source: Exctract DNA from strawberries
https://www.scientificamerican.com/article/squishy-science-extract-dna-from-smashed-strawberries/

Protein & DNA

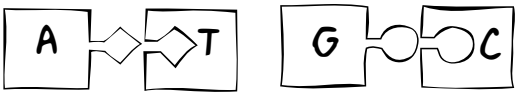


PROTEINS ARE LARGE MOLECULES MADE OF AMINO ACID CHAINS THAT PERFORM MANY DIFFERENT FUNCTIONS IN OUR CELLS. THEY CAN BE STRUCTURAL SCAFFOLDS, MOLECULAR CHEMISTS, INFORMATION TRANSFER OFFICERS OR CELL CLEANERS ... YOU NAME IT, THEY DO IT.

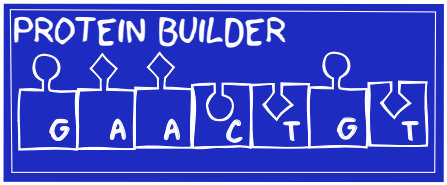
SOME PROTEINS ARE FLUORESCENT: WHEN YOU SHINE A LIGHT ONTO THEM, THEY GLOW WITH DIFFERENT COLOURS. THOSE CAN ACT AS LIGHTHOUSES FOR VARIOUS CELL PROCESSES, HELPING SCIENTISTS SEE OTHERWISE INVISIBLE PROCESSES.

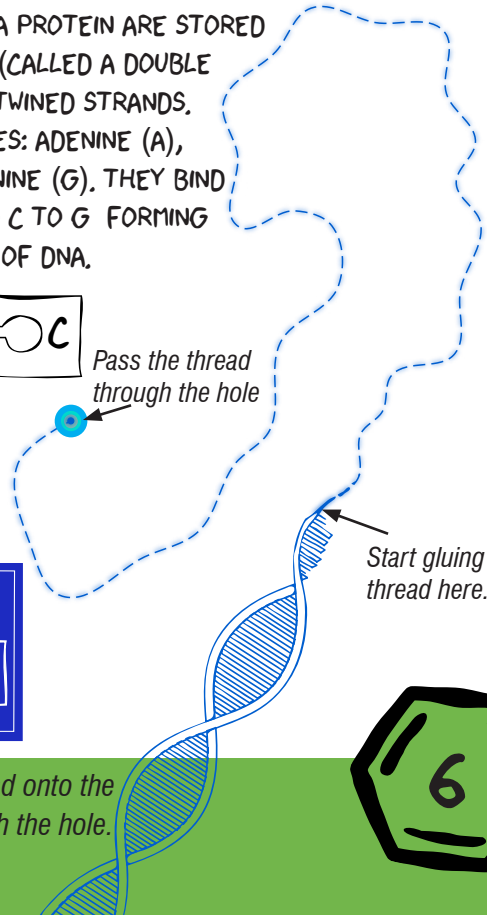


THE INSTRUCTIONS ON HOW TO MAKE A PROTEIN ARE STORED IN DNA, A SPIRAL SHAPED MOLECULE (CALLED A DOUBLE HELIX), WHICH IS MADE OF TWO INTERTWINED STRANDS. EACH STRAND IS COMPOSED OF 4 BASES: ADENINE (A), THYMINE (T), CYTOSINE (C) AND GUANINE (G). THEY BIND TO EACH OTHER IN PAIRS: A TO T AND C TO G FORMING LONG DOUBLE STRANDED SEQUENCES OF DNA.



IF STRETCHED, THE DNA FROM A SINGLE HUMAN CELL, WHICH CONTAINS ALL THE INFORMATION NEEDED TO MAKE A PERSON, WOULD BE 3 M LONG!



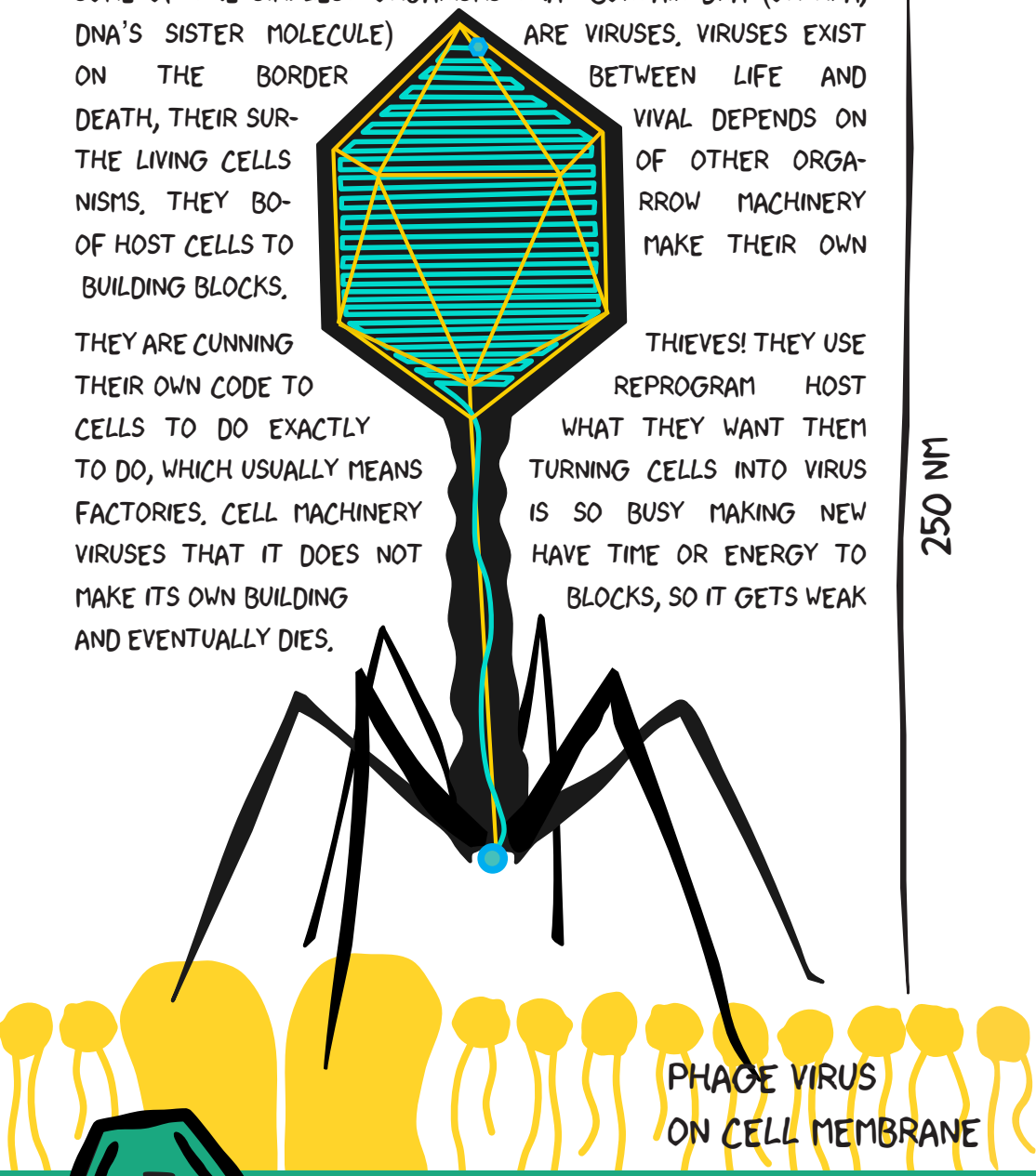


Complete the DNA by gluing a wool thread onto the paper and do not forget to pass it through the hole.

Viruses

SOME OF THE SIMPLEST ORGANISMS THAT CONTAIN DNA (OR RNA, DNA'S SISTER MOLECULE) ARE VIRUSES. VIRUSES EXIST ON THE BORDER BETWEEN LIFE AND DEATH, THEIR SURVIVAL DEPENDS ON THE LIVING CELLS OF OTHER ORGANISMS. THEY BORROW MACHINERY OF HOST CELLS TO MAKE THEIR OWN BUILDING BLOCKS.

THEY ARE CUNNING THIEVES! THEY USE THEIR OWN CODE TO REPROGRAM HOST CELLS TO DO EXACTLY WHAT THEY WANT THEM TO DO, WHICH USUALLY MEANS TURNING CELLS INTO VIRUS FACTORIES. CELL MACHINERY IS SO BUSY MAKING NEW VIRUSES THAT IT DOES NOT HAVE TIME OR ENERGY TO MAKE ITS OWN BUILDING BLOCKS, SO IT GETS WEAK AND EVENTUALLY DIES.



PHAGE VIRUS ON CELL MEMBRANE

7

Glue an end from DNA thread in the previous page on to the virus head.

Experiment 2
Hydrophobic Sand

⚠ PREPARE OUTDOORS WITH ADULT SUPERVISION ⚠

MATERIALS

- SAND FROM CRAFT STORE OR PET STORE
- WATER REPELLENT SPRAY
- ALUMINIUM TRAY OR NEWSPAPER
- CONTAINER AS BOTTLE FOR THE SAND

INSTRUCTION

SPREAD THE SAND ON TRAY/NEWSPAPER IN A THIN LAYER
SPRAY THE SAND WITH THE WATER REPELLENT SPRAY
WAIT UNTIL IT "DRIES"
MIX THE SAND AND REPEAT THE PROCEDURE 5 TIMES

HOW TO USE IT

TREATED SAND CAN BE PUT INTO THE GLASS OF WATER.
OBSERVE WHAT HAPPENS: DOES IT LOOK WET?
POUR THE WATER OUT. IS IT WET OR DRY?! MAGIC?

EXPLANATION

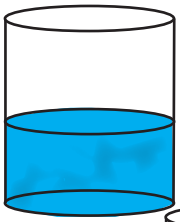
THE WATERPROOFING SPRAY COATS THE SAND AND CREATES A SHIELD THAT PROTECTS IT FROM WATER. SCIENTISTS CALL THIS SHIELD HYDROPHOBIC (AFRAID OF WATER).
HYDROPHOBIC LAYERS ARE IMPORTANT FOR OUR CELLS: THEY HELP FORM A MEMBRANE, WHICH SEPARATES THE INTERIOR OF THE CELL FROM ITS SURROUNDINGS.
IN BIOTECHNOLOGY SCIENTISTS TRY TO UNDERSTAND HYDROPHOBICITY OF PROTEINS AND VIRUS SURFACES TO IMPROVE DESIGN OF NEW MEDICAL TREATMENTS AND VACCINES ! [1,2]

[1] http://www.mtu.edu/news/stories/2017/march/virus-hydrophobicity-can-help-purify-vaccines.html
[2] Experimental and computational surface hydrophobicity analysis of a non-enveloped virus and proteins. Caryn L.Heldt,Amna Zahid,K. Saagar Vijayaragavan, Xue Mi

Experiment 3
What happens when yeast senses heat?

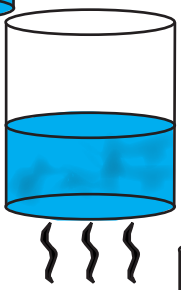
MATERIALS

-LUKEWARM WATER
-SUGAR OR HONEY
-LIVING YEAST, NOT THE CHEMICAL ONE
-HEAT SOURCE, AS A RADIATOR
-CONTAINER



STEP 1

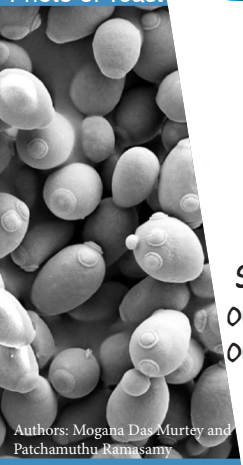
MIX THE SUGAR AND YEAST WITH WARM WATER IN A CONTAINER.



STEP 2

PUT THE CONTAINER IN A WARM PLACE (ON TOP OF THE RADIATOR), AND WAIT FOR FEW MINUTES. BE CAREFUL: DO NOT PLACE THE MIXTURE ON VERY HOT SURFACES LIKE A HOB , IF YOU DO THAT, THE EXPERIMENT WILL NOT WORK.

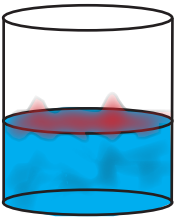
Photo of Yeast



Authors: Mogana Das Murtey and Patchamuthu Ramasamy

STEP 3

OBSERVE THE FORMATION OF THE FOAM



STEP 4

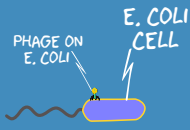
ADD THE MIXTURE TO THE FLOUR AND WATER (YOU MIGHT ADD A BIT OF OLIVE OIL TOO), MIX IT WELL, LEAVE IT TO RISE IN A WARM PLACE, BAKE IT AND YOU WILL GET A VERY AIRY DOUGH FULL OF BIG HOLES.

EXPLANATION

YEAST IS A SINGLE CELL ORGANISM (MICROORGANISM) FROM THE MUSHROOM KINGDOM. LIKE US, IT NEEDS TO BREATHE, EAT AND DISPOSE WASTE IN ORDER TO THRIVE.

THE FOAM IS PRODUCED AS THE YEAST STARTS TO GET BACK TO LIFE AFTER IT SENSES THAT THE TEMPERATURE IS INCREASED. YEAST STARTS TO BREATHE AND RELEASE CARBON DIOXIDE GAS (AS WE DO), THE BREATHING CONTINUES WITHIN THE DOUGH AND IT IS THE GAS THAT MAKES THE HOLES IN THE BREAD.

Cells



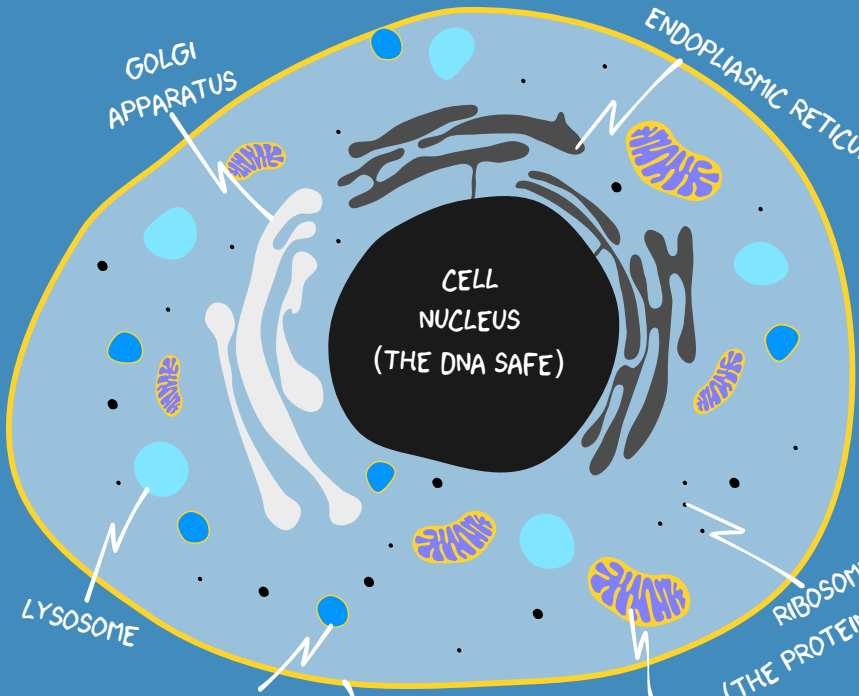
BACTERIUM E. COLI → 10 X BIGGER → PHAGE VIRUS

HUMAN CELL → 10 X BIGGER → BACTERIUM E. COLI

1 UM

ANIMAL AND PLANT CELLS HAVE A NUCLEUS, A SMALL COMPARTMENT SEPARATED FROM THE REST OF THE CELL, WHICH CONTAINS WELL PROTECTED INFORMATION CODE WITHIN DNA (SCIENTIS CALL IT A GENOME). THIS TYPE OF CELLS IS CALLED EUKARYOTIC CELL: TYPICAL ANIMAL CELL (AND HUMANS BELONG TO THE ANIMAL KINGDOM TOO) AS SHOWN BELOW:

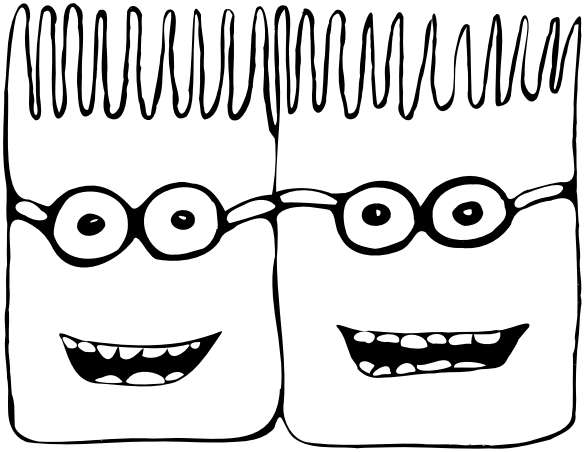
10 UM



Check the function of every cell part written above!
What do you think; how rough is their surface? Find different materials (paper, plastic, fabric, tissue, sand, etc...) and glue it on to each part.

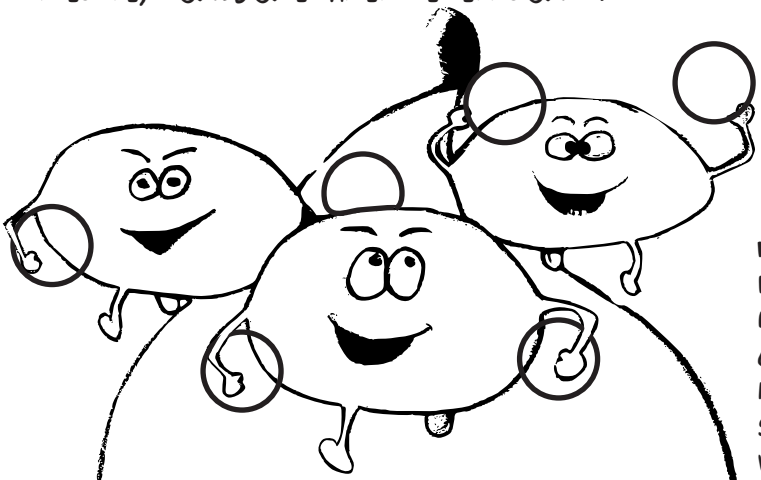
Colouring Cells

There are way more cells in your body than the people in the world! Get to know some of them and colour them.

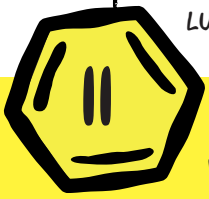


ENTEROCYTES: THEY LOVE FOOD! THEY CAN BE FOUND IN OUR INTESTINES. THE HAIR ON TOP OF THEIR HEADS MAKES THE SURFACE AREA LARGER SO THEY CAN ABSORB MORE FOOD. DID YOU KNOW THAT IF WE TOOK OUT AND UNFOLDED A HUMAN INTESTINE, IT COULD COVER AN ENTIRE TENNIS COURT?

NEURONS ARE OUR BODY'S MESSENGERS! THEY SEND INFORMATION TO OTHER CELLS WHEN WE ARE HURT, HUNGRY, WHEN WE SMELL SOMETHING NICE AND WHEN WE SEE SOMETHING BEAUTIFUL.
DID YOU KNOW THAT SOME NEURONS ARE AS LONG AS 1 METRE?



RED BLOOD CELLS TRANSPORT THE OXYGEN FROM YOUR LUNGS EVERYWHERE TO YOUR BODY. OXYGEN IS NEEDED TO POWER (OR FEED) ALL THE CELLS.
DID YOU KNOW THAT RED BLOOD CELLS CAN DO A COMPLETE JOURNEY THROUGH YOUR BODY WITHIN 1 MINUTE?



Credit: Anna-Maria Pappa & Cassandre Vuillaume

Human body

BRAIN:

FUNCTION: THE OPERATIONS CENTRE OF OUR BODY. IT CONTROLS EVERYTHING WE DO, EVEN WHEN WE SLEEP.

WEIGHT: 3 POUNDS (1.4 KG).

TRIVIA: IT USES 20% OF OUR TOTAL ENERGY CONSUMPTION. ALBERT EINSTEIN'S BRAIN WAS SMALLER THAN THE AVERAGE (1.2 KG). 80% OF IT IS WATER.

LUNGS:

FUNCTION: BREATHING, THAT IS, ABSORBING OXYGEN FROM THE AIR.

WEIGHT: 390-450 GR. THE LEFT ONE IS SMALLER THAN THE RIGHT ONE TO ACCOMMODATE THE HEART.

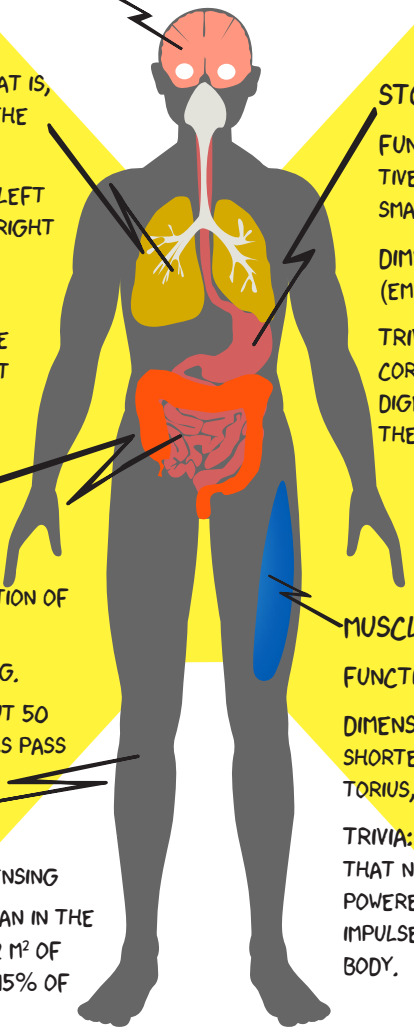
TRIVIA: THE TOTAL SURFACE AREA OF ONE LUNG IS ABOUT 75M^2, THE SIZE OF A TENNIS COURT!

STOMACH:

FUNCTION: PART OF THE DIGESTIVE SYSTEM, SPLITS FOOD IN SMALLER PARTS.

DIMENSIONS: 75 MILLILITRES (EMPTY) TO 1 LITRE (FULL).

TRIVIA: IT CONTAINS VERY CORROSIVE ACID FOR FOOD DIGESTION. THE STOMACH PH IS 1, THE SAME AS BATTERY ACID!



INTESTINE

FUNCTION: PART OF THE DIGESTIVE SYSTEM, ABSORPTION OF FOOD

DIMENSIONS: 8 METRES LONG.

TRIVIA: IN A LIFETIME, ABOUT 50 TONNES OF FOOD AND DRINKS PASS THROUGH YOU INTESTINE!

MUSCLE:

FUNCTION: MOVEMENT

DIMENSIONS: FROM 1 MM (STAPEDIUS, SHORTEST MUSCLE) TO 60 CM (SARTORIUS, LONGEST MUSCLE).

TRIVIA: THE HEART IS A MUSCLE THAT NEVER STOPS MOVING. IT IS POWERED BY REGULAR ELECTRIC IMPULSES GENERATED BY OUR OWN BODY.

SKIN

FUNCTION: PROTECTION, SENSING

DIMENSIONS: LARGEST ORGAN IN THE BODY. ADULT HUMAN HAS ~2 M^2 OF SKIN. SKIN ACCOUNTS FOR ~15% OF YOUR BODY WEIGHT.

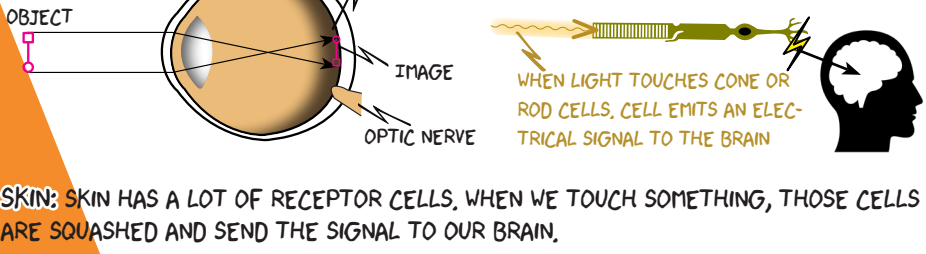
TRIVIA: IN SKIN THERE ARE AT LEAST 5 DIFFERENT TYPES OF NERVE ENDINGS: HEAT SENSITIVE, COLD SENSITIVE, PAIN SENSITIVE, ITCH SENSITIVE, PRESSURE SENSITIVE. THE AVERAGE PERSON HAS ~300 MILLION SKIN CELLS. THE SKIN RENEWS ITSELF EVERY 28 DAYS.

Credit: Luca Mascheroni

Human Senses

SENSORY CELLS CAN TRANSFORM THE INFORMATION FROM OUR ENVIRONMENT INTO ELECTRICAL SIGNALS. NEURONS TRANSMIT THESE SIGNALS INTO THE BRAIN WHERE THEY ARE PROCESSED AND CONVERTED INTO PICTURES, SMELLS, TASTES OR FEELINGS.

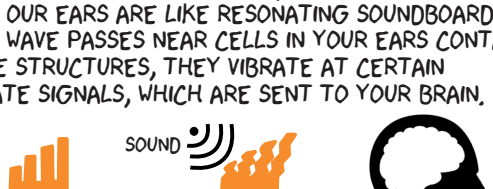
EYE: THE IMAGE IS FORMED ON THE RETINA, BUT IT IS UPSIDE DOWN AND CONVERTED AGAIN WITHIN THE BRAIN. THERE ARE TWO TYPES OF CELLS WHICH DETECT LIGHT: CONE AND RODS. CONES DETECT COLOUR. COLOUR BLINDNESS IS A CONSEQUENCE OF SOME MISSING CONES. RODS CANNOT DISTINGUISH COLOUR BUT ARE VERY GOOD IN DETECTING LIGHT OF DIFFERENT INTENSITIES. WE CAN USE THEM TO SEE DURING THE NIGHT



SKIN: SKIN HAS A LOT OF RECEPTOR CELLS. WHEN WE TOUCH SOMETHING, THOSE CELLS ARE SQUASHED AND SEND THE SIGNAL TO OUR BRAIN.

NOSE & TONGUE: SMELL AND TASTE ARE VERY SIMILAR AND RELATED. NOSE DETECTS "ODORANT" PARTICLES FLOWING IN THE AIR THROUGH SPECIFIC RECEPTORS, ADAPTED TO THE SHAPE OF THE ODOUR MOLECULES THE PARTICLE IS MADE OF. WHEN A MOLECULE MEETS THE RECEPTOR, IT GENERATES A SIGNAL. TASTE BUDS ON YOUR TONGUE WORK IN A SIMILAR WAY AND CAN DISTINGUISH BETWEEN SWEET, SOUR, SALTY, BITTER AND UMAMI (WHAT TASTES LIKE UMAMI?). AS THEY WORK IN A SIMILAR WAY, SOMETIMES IT HELPS TO BLOCK YOUR NOSE WHEN EATING SOMETHING THAT DOES NOT TASTE SO GOOD. TRY IT OUT NEXT TIME YOU REALLY DISLIKE SOMETHING YOU HAVE ON YOUR PLATE.

EAR: SOUND IS A CONSEQUENCE OF VIBRATION TRAVELLING THROUGH DIFFERENT MEDIA SUCH AS AIR AND WATER. THESE VIBRATIONS ARE INVISIBLE WAVES, SIMILAR TO THOSE MADE BY A ROCK THROWN INTO WATER. OUR EARS ARE LIKE RESONATING SOUNDBOARDS AND AMPLIFY THESE WAVES. WHEN THE WAVE PASSES NEAR CELLS IN YOUR EARS CONTAINING LOTS OF TINY HAIR-LIKE STRUCTURES, THEY VIBRATE AT CERTAIN FREQUENCY AND GENERATE SIGNALS, WHICH ARE SENT TO YOUR BRAIN.



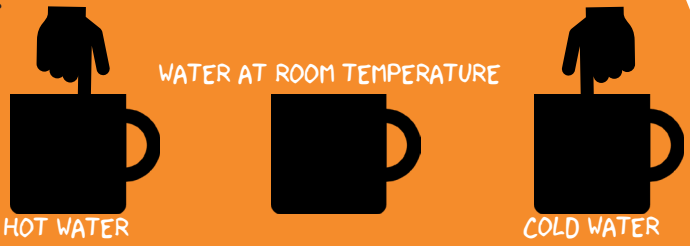
Experiment 4
Feeling Hot or Cold?

MATERIAL

3 CUPS OF WATER AT DIFFERENT TEMPERATURE

STEP 1

PUT A CUP OF WATER INTO THE FRIDGE FOR 1 HOUR. ONCE IT IS DONE, HEAT THE OTHER CUP IN THE MICROWAVE. ⚠ THE WATER SHOULD NOT BE TOO HOT. THE THIRD CUP SHOULD BE FILLED WITH WATER AT ROOM TEMPERATURE.

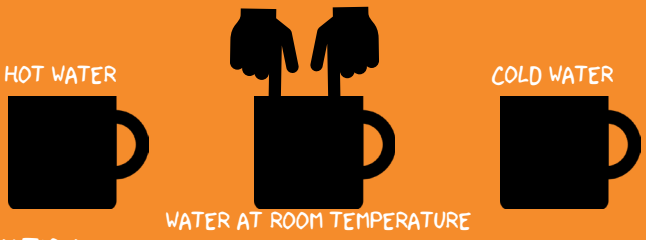


STEP 2

WHEN THREE CUPS ARE READY, PUT ONE OF YOUR LEFT FINGERS INTO THE HOT WATER AND ONE OF YOUR RIGHT FINGERS INTO THE COLD WATER FOR 10-30 SECONDS.

STEP 3

MOVE YOUR BOTH FINGERS TO THE CUP IN THE MIDDLE CONTAINING WATER AT ROOM TEMPERATURE. HOW DOES THE WATER FEEL? WARM OR COLD?

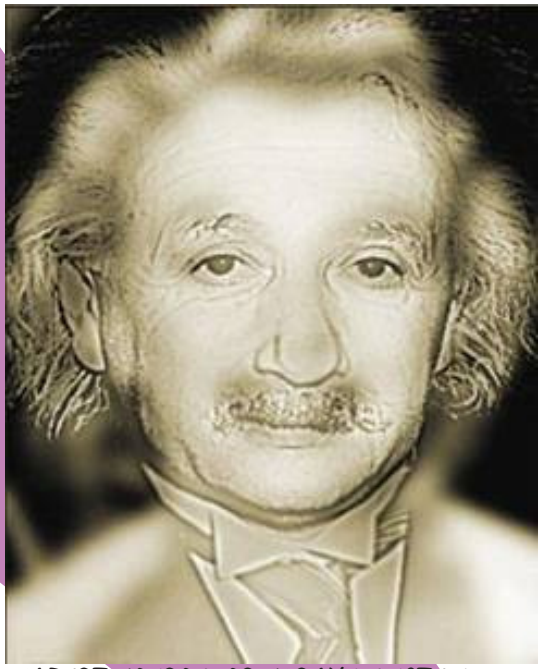


EXPLANATION:

YOUR RIGHT FINGER SHOULD BE FEELING HOT AND THE LEFT COLD, EVEN THOUGH THEY ARE BOTH IN THE CUP WITH THE SAME TEMPERATURE. OUR SENSES ARE NOT ENTIRELY RELIABLE, OUR BRAIN CAN BE FOOLED. THE TEMPERATURE SENSOR IN OUR SKIN IS VERY GOOD AT DETECTING THE DIFFERENCE IN TEMPERATURE TO DETERMINE IF SOMETHING IS HOT OR COLD, BUT IT IS NOT SO GOOD AT ESTIMATING THE EXACT TEMPERATURE.

Optical illusion

OUR SENSES ARE QUITE GOOD FOR THEIR INTENDED USE. WE CAN RECOGNISE FACES OR DETECT DIFFERENT SHAPES IN CLOUD, BUT OPTICAL ILLUSIONS CAN STILL TRICK THE MIND.



Credit: Aude Oliva,
The Art of Hybrid Images: Two for the View of One

ALBERT MONROE OR MARILYN EINSTEIN

TWO FAMOUS PERSONALITIES ARE SHOWN ON THE ABOVE IMAGE. CAN YOU SEE THEM? TRY TO LOOK AT THE IMAGE FROM FAR AWAY OR SQUINT.
OUR BRAIN IS USED TO DEALING WITH DIFFERENT LEVEL OF DETAIL. WHEN WE LOOK AT SOMETHING FROM FAR AWAY, DETAILS ARE NOT SO IMPORTANT AND WE CAN RECOGNISE THE BLURRED IMAGES SUCH AS THE IMAGE OF A FAMOUS ACTRESS.
AS YOU LOOK AT THE IMAGE WITHOUT CHANGING THE DISTANCE OR SQUINTING, YOU CAN SEE A FAMOUS SCIENTIST.

PONZO ILLUSION

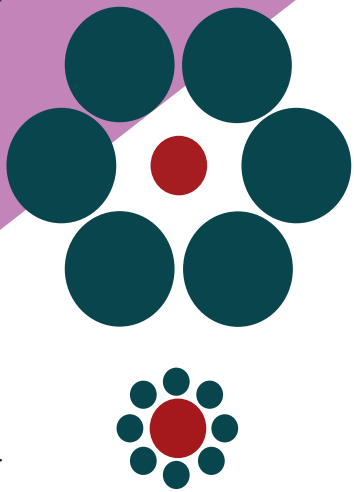
WHICH OF THE TWO RED LINES IS BIGGER?
WHY DO THESE RED LINES LOOK LIKE THEY ARE INSTEAD DIFFERENT SIZES?

HUMAN EYE IS USED TO PERSPECTIVE AND THE RAIL PATTERN LOOKS LIKE IT GOES AWAY FROM US. THE RED LINES HAVE THE SAME SIZE, BUT THEIR POSITION WITHIN THE PATTERN MAKES THEM LOOK DIFFERENT.

WHICH ONE OF THE RED DOTS IS BIGGER?
WHY DOES ONE RED DOT SEEMS BIGGER THAN THE OTHER?

THIS WEIRD EFFECT COMES FROM THE WAY WE JUDGE THE SIZE OF AN OBJECT BASED ON ITS SURROUNDING ENVIRONMENT. THE ILLUSION OCCURS AS A CONSEQUENCE OF HOW WE PERCEIVE PERSPECTIVE, OR DISTANCE; A FAR AWAY OBJECT ALWAYS LOOKS SMALLER. IF AN OBJECT IS SURROUNDED BY SMALLER OBJECTS, IT COULD APPEAR AS THOUGH IT IS FAR AWAY AND THEREFORE BIGGER THAN IT ACTUALLY IS. ON THE OTHER HAND, IF IT IS SURROUNDED BY LARGE OBJECTS, IT APPEARS SMALLER BECAUSE IT SEEMS CLOSER.

EBBINGHAUS ILLUSION



Experiment 5
Inverted reality experiment
Volcano in the cup

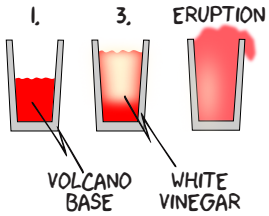
WHAT YOU NEED:

- 2 CLEAR PLASTIC CUPS (AS MANY AS YOU WANT, THESE ARE WHERE THE REACTION WILL HAPPEN)
- 1 TSP DISH SOAP
- 1/2 CUP COLD WATER
- 1/2 CUP WHITE VINEGAR
- FOOD COLOURING
- BAKING SODA SLURRY, FILL CUP WITH HALF BAKING SODA, AND REST OF WATER

NOTE: THE BUBBLES WILL OVER FLOW, SO BE SURE TO DO THIS EXPERIMENT ON A WASHABLE SURFACE, OR PLACE THE BOTTLE ON A TRAY OR IN THE SINK.

WHAT TO DO:

1. MAKE YOUR VOLCANO BASE, COMBINE WATER, BAKING SODA, FOOD COLOURING AND DISH SOAP IN ONE CUP, FILLED HALF WAY, MAKING SURE EVERYTHING IS WELL MIXED, AND THE COLOURS ARE NICE.
2. PLACE THAT CUP IN THE SINK OR TRAY AND GET READY FOR THE BUBBLES!
3. POUR HALF CUP OF VINEGAR INTO THE BASE CUP AND OBSERVE THE VOLCANO.

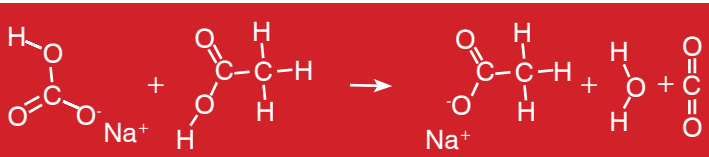


WHAT DO YOU NOTICE? WHAT COULD YOU EXPERIMENT WITH?

1. WHAT DOES ADDING MORE SOAP DO?
2. WHAT ABOUT MORE BAKING SODA, OR VINEGAR?
3. WHAT ABOUT THE HOLDER OF THE REACTION? WHAT IF YOU USED A POP BOTTLE?
4. WHAT IS YOUR FAVORITE COLOUR? WHAT ABOUT YOUR FRIEND'S?
5. WHAT HAPPENS TO THE TEMPERATURE OF THE SOLUTION? THE BUBBLES?

WHAT IS GOING ON?

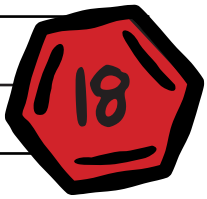
THE BUBBLES YOU SEE ARE CARBON DIOXIDE (THE SAME GAS THAT YOU EXHALE). BAKING SODA IS A WEAK BASE (SODIUM CARBONATE) AND VINEGAR A WEAK ACID (ACETIC ACID). WHEN THEY ARE MIXED, SODIUM ACETATE AND CARBONIC ACID ARE MADE.CARBONIC ACID IS UNSTABLE AND FALLS APART INTO CARBON DIOXIDE AND WATER. THIS CAUSES THE RAPID RELEASE OF THE GAS.



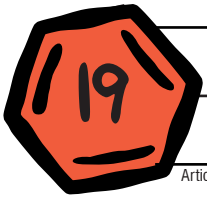
Volcano created by Joris Hoogendoorn from Noun Project

Observation Personal Note

DRAW YOUR VOLCANO



Observation Personal Note



Artichoke created by Clockwise from Noun Project

Experiment 6
Taste Perversion with Artichokes

THINGS YOU WILL NEED:

- ○ AN ARTICHOKE
- ○ SAUCE PAN
- ○ KITCHEN TONGS
- ○ AN ADULT
- ○ WATER
- ○ GLASS OF WATER, JUICE, OR SWEETS
- ○ POSSIBLY JUST CANNED ARTICHOKE (IT IS DEBATED WHETHER THIS WORKS OR NOT)

WHAT TO DO:

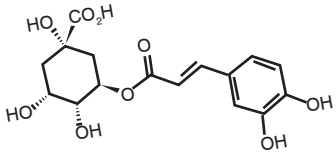
1. HAVE AN ADULT STEAM THE ARTICHOKE UNTIL HEART IS TENDER, 20-30 MINS
2. REMOVE FROM STEAMER WITH TONGS AND LET COOL FOR 3 MIN
3. REMOVE PEDALS AND EAT, YOU DO NOT EAT THE WHOLE PEDAL, BUT SCRAP THE INSIDE OF IT OFF
4. AFTER THAT TRY VARIOUS OTHER FOODS, OBSERVE HOW THE FLAVOURS CHANGE

MORE WAYS TO EXPLORE

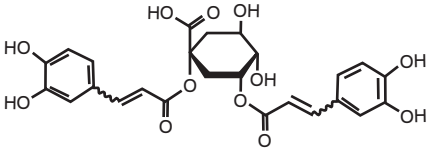
1. CAN YOU FIND OTHER FOODS THAT DO THIS?
2. WHAT FOODS TASTE GOOD WITH ARTICHOKE, WHAT TASTE BAD?
3. DOES IT CHANGE THE TASTE IN ANY OTHER WAY, MAKING IT SALTY, UMAMI, OR SOUR?
4. WHAT ARE SOME SIMILARITIES WITH THE STRUCTURES OF THE COMPOUNDS

HOW DID IT WORK?

THE EXACT MECHANISM IS NOT COMPLETELY UNDERSTOOD, BUT ARTICHOKES CONTAIN TWO COMPOUNDS, CYNARIN AND CHLOREGENIC ACID. BOTH OF THESE COMPOUNDS CAUSE FOODS AND DRINKS CONSUMED AFTER EATING AN ARTICHOKE TO TASTE SWEET. THESE COMPOUNDS BIND TO SWEET RECEPTORS, AND THEN WHEN SOMETHING NEW IS CONSUMED THEY ARE WASHED OFF, AND YOU PERCEIVE THAT AS SWEET!



CHLOREGENIC ACID



CYNARIN

Observation
Personal Note

Experiment 7
Elephant Toothpaste (Imaginary)

THINGS YOU WILL NEED:

- LIQUID DISH WASHING SOAP
- SMALL CUP
- A CLEAN 2L PLASTIC DRINK BOTTLE
- 1 TABLESPOON (ONE PACKET) OF DRY YEAST
- 100-200 ML OF 20-VOLUME HYDROGEN PEROXIDE LIQUID (20-VOLUME IS A 6% SOLUTION, ASK AN ADULT TO GET THIS FROM A BEAUTY SUPPLY STORE OR HAIR SALON)
- FOOD COLOURING
- SAFETY GOGGLES
- 3 TABLESPOONS OF WARM WATER

NOTE: THE FOAM WILL OVERFLOW FROM THE BOTTLE, SO BE SURE TO DO THIS EXPERIMENT ON A WASHABLE SURFACE, OR PLACE THE BOTTLE ON A TRAY.

WHAT TO DO:

1. HYDROGEN PEROXIDE CAN IRRITATE SKIN AND EYES, SO PUT ON THOSE SAFETY GOGGLES AND ASK AN ADULT TO CAREFULLY POUR THE HYDROGEN PEROXIDE SOLUTION INTO THE BOTTLE.
2. ADD 8 DROPS OF YOUR FAVOURITE FOOD COLOURING INTO THE BOTTLE.
3. ADD ABOUT 1 TABLESPOON OF WASHING UP LIQUID INTO THE BOTTLE AND MIX.
4. IN A SEPARATE SMALL CUP, COMBINE THE WARM WATER AND THE YEAST TOGETHER AND MIX FOR ABOUT 30 SECONDS.
5. FINALLY, POUR THE YEAST WATER MIXTURE INTO THE BOTTLE (A FUNNEL HELPS HERE) AND LET THE FOAMINESS BEGIN!

HOW DID IT WORK?

THE FOAM YOU MADE IS FILLED WITH OXYGEN DUE TO THE YEAST ACTING AS A CATALYST (A HELPER) TO REMOVE THE OXYGEN FROM THE HYDROGEN PEROXIDE. SINCE IT DID THIS VERY FAST, IT CREATED LOTS AND LOTS OF BUBBLES!
DID YOU NOTICE THE BOTTLE GOT WARM? YOUR EXPERIMENT CREATED A REACTION CALLED AN EXOTHERMIC REACTION – THAT MEANS IT NOT ONLY CREATED FOAM, IT CREATED HEAT!
THE FOAM PRODUCED IS JUST WATER, SOAP, AND OXYGEN SO YOU CAN CLEAN IT UP WITH A SPONGE AND POUR ANY EXTRA LIQUID LEFT IN THE BOTTLE DOWN THE DRAIN.

$$2\,H_2O_2 \longrightarrow 2\,H_2O + O_2$$

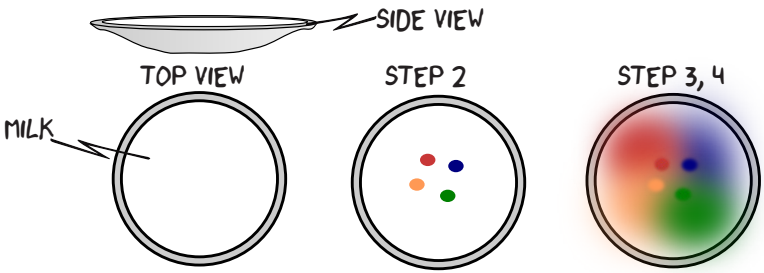
Experiment 8
Observe Kitchen Kaleidoscope

WHAT YOU NEED :

- MILK
- SAUCER
- FOOD COLOURING COTTON BUD
- WASHING UP LIQUID / DISH SOAP

WHAT TO DO

1. POUR SOME MILK INTO THE SAUCER, SO IT NEARLY REACHES THE BRIM.
2. CAREFULLY DRIP SOME FOOD COLOURING INTO THE CENTRE OF THE MILK, BEING CAREFUL NOT TO MIX IT. THE COLOURING SHOULD FLOAT ON THE SURFACE IN LITTLE BLOBS.
3. DIP THE TIP OF THE COTTON BUD IN THE WASHING UP LIQUID, AND THEN SLOWLY TOUCH THE SURFACE OF THE MILK NEAR THE FOOD COLOURING
4. WOW!



WHAT'S GOING ON?

MILK IS MADE OF MILLIONS OF TINY DROPLETS OF FAT SUSPENDED IN WATER. AT THE SURFACE, THERE IS A VERY THIN LAYER OF MOLECULES CREATING A 'SURFACE TENSION'. IT'S A BIT LIKE THE STRETCHED RUBBER AT THE SURFACE OF A BALLOON. WHEN YOU ADD THE SOAP, IT INTERACTS WITH THE FAT MOLECULES, DECREASING THE SURFACE TENSION, AND ACTS LIKE A PIN PRICKED INTO THE BALLOON. THE SURFACE WITHDRAWS TO THE EDGES OF THE SAUCER, AND AS THE SOAP SPREADS THE SURFACE TENSION KEEPS DECREASING, PULLING THE FOOD COLOURING INTO AMAZING NEW SHAPES!

Observation
Personal Note

Observation Personal Note

Experiment 9
Really? You can make Pharaoh's snake?

THINGS YOU WILL NEED:

- 2-4 EMSER PASTILLES
- ASHES
- 1 PORCELAIN TRAY
- LIGHTER
- 10 ML ETHANOL
- SAND
- PIPETTE
- SAFETY GOGGLES

WHAT TO DO:

1. ETHANOL CAN IRRITATE SKIN AND EYES, SO PUT ON THOSE SAFETY GOGGLES AND ASK AN ADULT TO CAREFULLY POUR IT ON THE PASTILLES AND LIGHT IT UP.
2. PLACE SAND-ASHES (1:1) MIXTURE IN A PORCELAIN TRAY
3. PLACE THE EMSER PASTILLES ON TOP OF THE SAND-ASHES MIXTURE
4. POUR ETHANOL OVER THE PASTILLES AND LIGHT IT UP

HOW DID IT WORK?

SOON AFTER LIGHTING THE ETHANOL UP, THE PASTILLES TURN BLACK AND START TO GROW SNAKE-LIKE OUT OF THE TRAY. EMSER PASTILLES ARE MADE OF SODIUM BICARBONATE ($NaHCO_3$) AND SUGAR. THE SUGAR IN PASTILLES STARTS TO BURN AS SOON AS YOU LIGHT IT UP TO FORM CARBON (BLACK COLOUR) AND THE GAS CO_2, WHICH FROTHS UP THE PASTILLES. MOREOVER, THE PASTILLES CONTAIN $NaHCO_3$. WHEN $NaHCO_3$ IS HEATED UP, IT STARTS TO DECOMPOSE AND FORM EVEN MORE CO_2. THIS IS SIMILAR TO BAKING A CAKE AT HOME, WHERE YOU ADD BAKING SODA TO THE DOUGH TO GET A NICE AND FLUFFY CAKE.

$$2\ NaHCO_{3(s)} \longrightarrow Na_2CO_{3(s)} + CO_{2(g)} + H_2O$$

$$C_{12}H_{22}O_{11(s)} + 9\ ½\ O_{2(g)} \longrightarrow 12\ CO_{2(g)} + 6\ H_2O_{(g)}$$

$$C_{12}H_{22}O_{11(g)} \longrightarrow 12\ C_{(s)} + 11\ H_2O_{(g)}$$

Experiment 10
Pineapple Enzyme and Gelatin

THINGS YOU WILL NEED:

- ○ A LARGE GLASS CONTAINER/CUP
- ○ BOILING WATER (ASK AN ADULT TO HELP YOU WITH THE BOILING WATER)
- ○ GELATIN SACHETS (ASK AN ADULT TO HELP YOU BUY IT FROM A SUPERMARKET)
- ○ FRESHLY CUT PINEAPPLES (ASK AN ADULT TO HELP YOU WITH THE CUTTING)
- ○ A POT
- ○ A MIXING SPOON
- ○ SAFETY GOGGLES AND A LAB COAT (FOR SAFETY PURPOSES)

WHAT TO DO:

1. EVERY SCIENTIST STARTS THEIR EXPERIMENT BY PUTTING ON THEIR SAFETY GOGGLES AND LAB COAT!
2. ADD 2 PACKAGES OF GELATIN TO YOUR CONTAINER.
3. BRING A POT FULL OF WATER TO A BOIL.
4. POUR IN 700ML OF BOILING WATER INTO THE CONTAINER WITH GELATIN.
5. STIR THE SOLUTION UNTIL ALL THE GELATIN IS DISSOLVED.
6. PLACE IN FRIDGE UNTIL THE GELATIN BECOMES A SEMI-SOLID.
7. REPEAT THE LAST FIVE STEPS IN A DIFFERENT CONTAINER TO BE USED AS A CONTROL FOR YOUR EXPERIMENT.
8. ONCE THE GELATIN HAS COOLED, TAKE BOTH CONTAINERS OUT OF THE FRIDGE.
9. PLACE A FRESH PIECE OF PINEAPPLE ON TOP OF THE GELATIN IN ONE OF THE CONTAINERS AND LEAVE THE OTHER ONE AS IS.
10. OVER TIME, YOU CAN SEE THE GELATIN IN THE CONTAINER WITH THE PINEAPPLE RETURN TO LIQUID, WHILE THE CONTROL CONTAINER WITH NO PINEAPPLE STAYS SOLID!

HOW DID IT WORK?

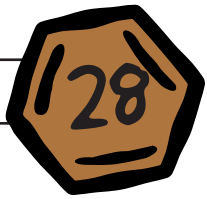
GELATIN IS MADE FROM A PROTEIN CALLED "COLLAGEN" – A PROTEIN FOUND IN ANIMAL CONNECTIVE TISSUE AND HELPS WITH SKIN ELASTICITY. WHEN THE COLLAGEN IS HEATED, THE PROTEIN BREAKS DOWN. WHEN IT IS COOLED AGAIN IN WATER, THE COLLAGEN TRIES TO REASSEMBLE BUT IS DISORGANISED AND TRAPS WATER IN THE MIDDLE OF ITS STRUCTURE. THAT'S HOW YOU GET THE WIGGLY GELATIN! IT STAYS IN THAT FORM AT ROOM TEMPERATURE.

PINEAPPLES HAVE A MIXTURE OF ENZYMES CALLED BROMELAIN THAT CAN DIGEST (BREAK DOWN) PROTEINS LIKE COLLAGEN. WHEN IN CONTACT WITH THE GELATIN, THE BROMELAIN STARTS TO BREAK IT DOWN SLOWLY TURNING IT BACK TO LIQUID IN FRONT OF YOUR VERY EYE!

THAT IS WHY IT CAN SOMETIMES HURT YOUR TONGUE AND MOUTH WHEN YOU EAT RAW PINEAPPLES. THE BROMELAIN IS SLOWLY BREAKING DOWN PROTEINS IN YOUR MOUTH!

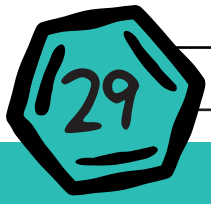
ANOTHER COOL EXPERIMENT WOULD BE TO BOIL THE PINEAPPLE BEFORE PUTTING IT ON THE GELATIN. THE BROMELAIN IS SENSITIVE TO HIGH TEMPERATURES. BOILING THE NEAPPLE DESTROYS THE BROMELAIN. YOUR GELATIN SHOULD NOT BE AFFECTED BOILED PINEAPPLE SLICE!

Observation / Personal Note



Observation / Personal Note

DRAW YOUR CRYSTALS



Experiment 11
Salty Crystals

WHAT YOU NEED:

- TABLE SALT – SODIUM CHLORIDE
- DISTILLED WATER
- A CLEAN, CLEAR GLASS CONTAINER – A JAM JAR IS PERFECT
- STRING
- A SPOON FOR STIRRING

WHAT TO DO:

1. STIR SALT INTO BOILING HOT WATER UNTIL NO MORE SALT WILL DISSOLVE (CRYSTALS START TO APPEAR AT THE BOTTOM OF THE CONTAINER). BE SURE THE WATER IS AS CLOSE TO BOILING AS POSSIBLE.

2. CAREFULLY POUR THE SOLUTION INTO YOUR JAR. (PUTTING A SPOON INTO THE JAR BEFORE ADDING THE WATER SHOULD PREVENT THE JAR BREAKING.)

3. SUSPEND YOUR STRING INTO THE JAR FROM THE SPOON LAID ACROSS THE TOP OF THE JAR.

4. LEAVE YOUR JAR SOMEWHERE IT WILL NOT BE DISTURBED AND WAIT FOR YOUR CRYSTAL TO GROW!

OBSERVE

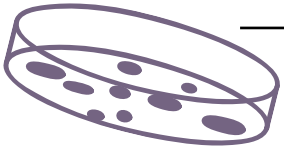
ONCE YOUR CRYSTALS HAVE GROWN, HERE ARE SOME THINGS FOR YOU TO LOOK FOR IN THEM:

-ANY IMPURITIES IN THE SALT OR THE WATER WILL CHANGE THE SHAPE AND COLOUR OF THE CRYSTALS YOU GROW. WHAT SHAPE AND COLOUR ARE YOURS? CAN YOU MAKE SOME COLORFUL CRYSTALS BY ADDING FOOD COLORING?

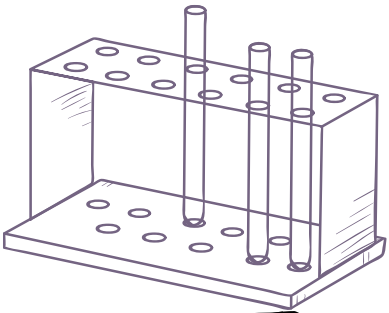
-TRY USING DIFFERENT TYPES OF TABLE SALT – TRY IODISED SALT, UN-IODISED SALT, SEA SALT, OR EVEN SALT SUBSTITUTES. IS THERE ANY DIFFERENCE IN THE APPEARENCE OF THE CRYSTALS?

-TRY USING DIFFERENT TYPES OF WATER, SUCH AS TAP WATER COMPARED WITH DISTILLED WATER. IS THERE ANY DIFFERENCE IN THE APPEARANCE OF THE CRYSTALS?

Note



Note



Note

About CEB

The Department of Chemical Engineering and Biotechnology (CEB) state of the art building is situated in the University's science and engineering hub on the West Cambridge site and perfectly placed to maximise links with neighbouring faculties like Physics at the Cavendish Laboratory, the Computer Science Laboratory, the Institute for Manufacturing and Cambridge Enterprise. Such an environment gives our academic and business leaders the facilities, resources, and inspiration to accelerate solutions to the world's most pressing challenges, bringing tangible benefits to society, and acting as a powerful catalyst to boost the economy locally and nationally, assisting employment and wealth creation in the UK and beyond.
Our goal is to increase our visibility as a global beacon for advances in chemical engineering and biotechnology, which in turn will enable the cross-fertilisation of ideas and their transfer into the marketplace.

CEB, one of the UK's leading research departments, ranks highly in both national and international University league tables and conducts internationally-leading research and creating a unique multidisciplinary research environment within the University of Cambridge, where collaborations with academic and industrial organisations flourish. CEB has an inclusive approach and proactive international outlook, making it an attractive place for the very best global talent.

We perform experiments to explore sustainable reaction engineering, chemical product and process design, healthcare, measurement, and materials science. The fusion of leading biotechnology research with chemical engineering skills, helping to solve commercial, industrial problems, supports our continuing development and discovery at the science-engineering interface. The Department's research strategy responds to the global drive for 'sustainability', addressing the need for novel chemical engineering and biotechnology processes and materials.

The Department's research strategy responds to the global drive for 'sustainability', addressing the need for novel chemical engineering and biotechnology processes and materials. Research across CEB adopts a whole system approach, taking innovation from concept to exploitation (C2X) with a focus on **Health and Energy**.

One of the strategic goals is to strengthen outcomes in key areas of **Materials, Sensors, Reaction and Process Engineering and Big Data**, while also positioning the department to contribute to strategic initiatives in the University.

Working effectively with industry is a core strength of the CEB teaching and research, as is progressing novel technologies through spinout companies and licensing agreements to ultimate launch of marketed products.

SENSING, SENSORS, SENSE AND NO-SENSE EXPERIMENTS
SENSING, SENSORS, SENSE AND NO-SENSE EXPERIMENTS
SENSING, SENSORS, SENSE AND NO-SENSE EXPERIMENTS
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SENSING, SENSORS, SENSE AND NO-SENSE EXPERIMENTS
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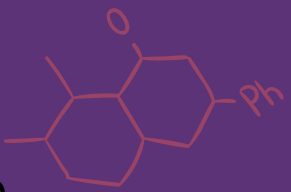

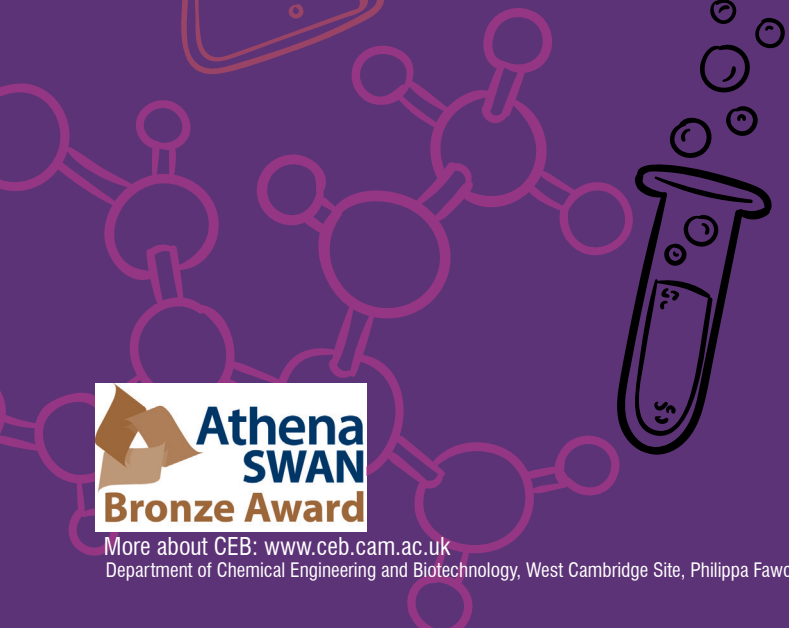

Athena SWAN Bronze Award

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