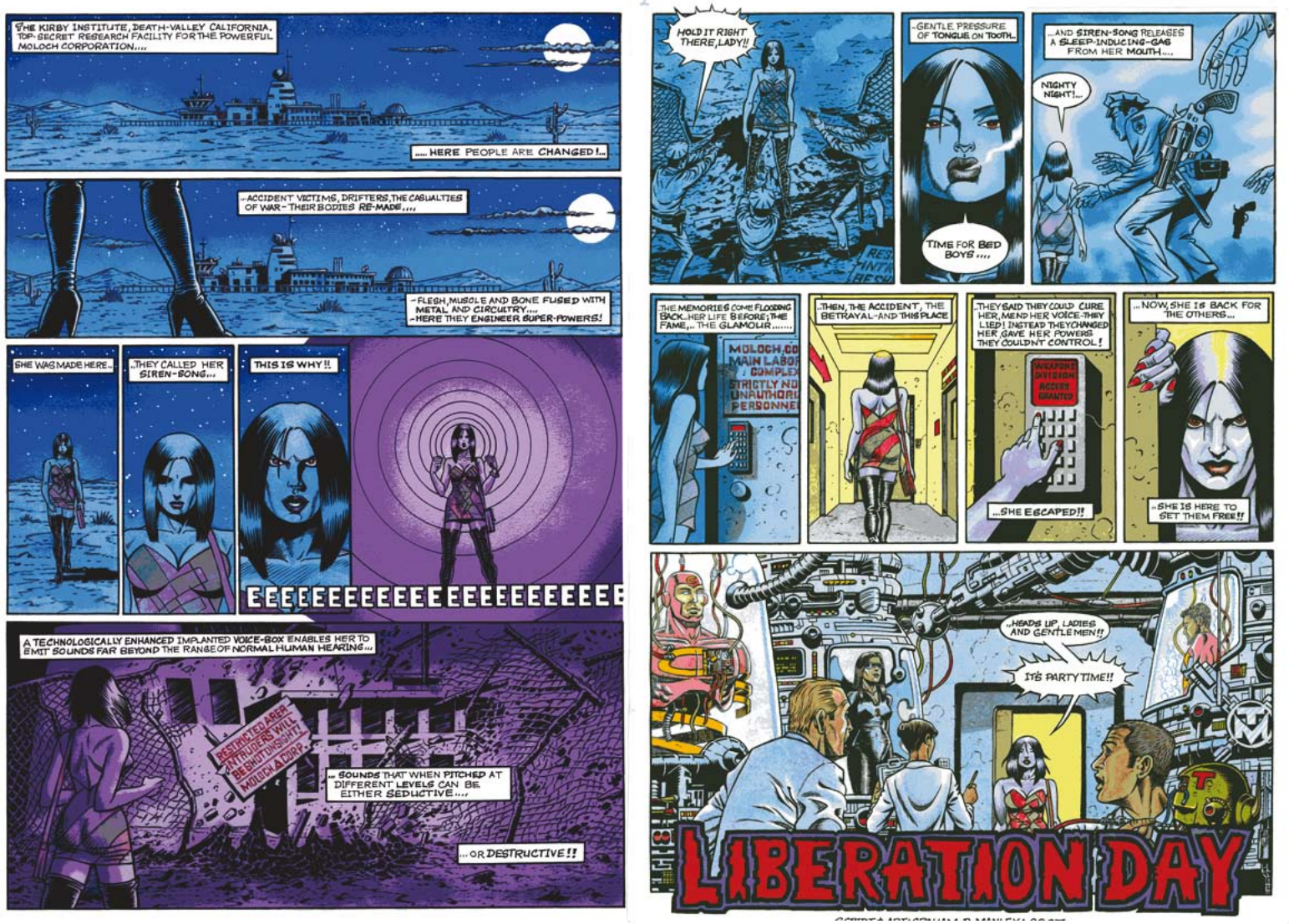

ESP!
ENGINEERING SUPER POWERS
ENGINEERING SUPER POWERS: SUPERHEROES AND THEIR NEMESES !
USE SCIENCE AND ENGINEERING TO INVENT YOUR OWN SUPERHERO OR VILLAIN!
University of Strathclyde Glasgow


THE KIRBY INSTITUTE, DEATH-VALLEY CALIFORNIA. TOP-SECRET RESEARCH FACILITY FOR THE POWERFUL MOLOCH CORPORATION....
.... HERE PEOPLE ARE CHANGED!..
..ACCIDENT VICTIMS, DRIFTERS, THE CASUALTIES OF WAR - THEIR BODIES RE-MADE....
- FLESH, MUSCLE AND BONE FUSED WITH METAL AND CIRCUITRY....
- HERE THEY ENGINEER SUPER-POWERS!
SHE WAS MADE HERE..
..THEY CALLED HER SIREN-SONG...
THIS IS WHY!!
EEEEEEEEEEEEEEEEEEEEEEEE
A TECHNOLOGICALLY ENHANCED IMPLANTED VOICE-BOX ENABLES HER TO EMIT SOUNDS FAR BEYOND THE RANGE OF NORMAL HUMAN HEARING...
RESTRICTED AREA INTRUDERS WILL BE SHOT ON SIGHT! MOLOCH CORP.
... SOUNDS THAT WHEN PITCHED AT DIFFERENT LEVELS CAN BE EITHER SEDUCTIVE....
...OR DESTRUCTIVE!!

HOLD IT RIGHT THERE, LADY!!
..GENTLE PRESSURE OF TONGUE ON TOOTH..
TIME FOR BED BOYS....
...AND SIREN-SONG RELEASES A SLEEP-INDUCING-GAS FROM HER MOUTH....
NIGHTY NIGHT!...
..THE MEMORIES COME FLOODING BACK..HER LIFE BEFORE; THE FAME,.. THE GLAMOUR.....
MOLOCH CO MAIN LABO COMPLEX STRICTLY NO UNAUTHORI PERSONNE
..THEN, THE ACCIDENT, THE BETRAYAL - AND THIS PLACE
..THEY SAID THEY COULD CURE HER, MEND HER VOICE - THEY LIED! INSTEAD THEY CHANGED HER, GAVE HER POWERS THEY COULDN'T CONTROL!
WEAPONS DIVISION ACCESS GRANTED
...SHE ESCAPED!!
... NOW, SHE IS BACK FOR THE OTHERS...
..SHE IS HERE TO SET THEM FREE!!
..HEADS UP, LADIES AND GENTLEMEN!!
IT'S PARTY TIME!!
LIBERATION DAY


MERIDIAN CITY: ONE YEAR LATER...
...SIR?...
...I'M PICKING SOMETHING UP, SIR.....
...SOMESORT OF, UH, SUPER-BEING...
COMMUNICATIONS & SURVEILLANCE CENTRE: MOLOCH CORPORATION H.Q....
...SHALL I CONTINUE TRACKING, SIR?...
..IT'S PROBABLY KILLCAT! SHE'S OF NO INTEREST TO US....SHE'S A FREAK, A VIGILANTE! - SHE'S NOT ONE OF THE PROGRAM...
...BUT, ..ON THE OTHER HAND.... SHE MAY LEAD US TO ONE OF THE OTHERS..
KEEP WATCHING HER!!...
.. THESE TYPES MIGHT HAVE A TENDENCY TO SEEK EACH OTHER OUT."
KILLCAT!!.. WE NEED TO TALK.
WHA-?!!
WHO?-WHAT THE HELL ARE YOU?!!
... I AM CALLED COILER... ...THIS IS MIDNIGHT BLUE... — KILLCAT, WE NEED YOUR HELP!...THERE IS A GREAT DANGER COMING TO ALL OF US THAT ARE,.... "DIFFERENT!!"...
"... DIFFERENT?!!?-" -LOOK, I DON'T KNOW YOU AND I DON'T CARE ABOUT YOUR "DANGER" — I WORK ALONE AND I LIKE IT THAT WAY....


...WAIT!!— YOU DON'T UNDERSTAND...
-I CAN TAKE CARE OF MYSELF!!!...
-KILLCAT— PLEASE... COME WITH US— WE HAVE SOMETHING TO SHOW YOU!!
..DO I HAVE TO SPELL IT OUT..
....I'M NOT INTERESTED!!!
NOW, WHAT HAVE WE GOT HERE ?!? IT SEEMS YOU CAN'T TURN AROUND IN THIS TOWN WITHOUT BUMPING INTO A BUNCH OF WEIRDOS' !!??!!
..WELL, WELL, ..IF IT ISN'T TINKERBELL AND THE HUMAN-SPRING!!—AND I SEE YOU'VE PICKED UP A LITTLE FRIEND!!
...ANYWAY, I'M HERE TO OFFER YOU A CHOICE - IT'S QUITE SIMPLE REALLY.. EITHER JOIN MY LITTLE GROUP— OR DIE!!
...AND AS FOR YOU, KITTY-KAT... YOU'D BETTER DECIDE WHOSE SIDE YOU'RE ON 'COS THINGS 'ROUND HERE ARE ABOUT TO GET MESSY!!!
TO BE CONTINUED!!

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THE COMIC STRIP ART WAS SPONSORED BY
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ENGINEERING SUPER POWERS RESOURCE PACK CONTENTS

PART 1: USING THIS RESOURCE PACK AND THE LEARNING CONTEXT

"INSTEAD OF POURING KNOWLEDGE INTO PEOPLE'S HEADS, WE NEED TO HELP THEM GRIND A NEW SET OF EYEGLASSES SO THAT WE CAN SEE THE WORLD IN A NEW WAY." -- J S BROWN.

THE AIM OF THE ENGINEERING SUPER POWERS RESOURCE PACK IS TO:

- PROVIDE INFORMATION AND ACTIVITIES THAT WILL ENGAGE PUPILS TO LEARN ABOUT SCIENCE AND ENGINEERING
- ENABLE PUPILS TO USE THEIR SCIENCE AND ENGINEERING KNOWLEDGE TO BIOENGINEER THEIR OWN FUTURISTIC SUPER POWERS AND COMIC STRIP CHARACTER
- RAISE AWARENESS OF NEW TECHNOLOGIES IN SCIENCE, ENGINEERING AND THE BIOMEDICAL FIELD

BACKGROUND TO THE RESOURCE

THE IDEA

The idea for the project came from reading an article on Dr James Kakalios at the University of Minnesota, who uses comic book superheroes to teach introductory physics. Instead of just using the superhero topic to teach wouldn't it be even better if students could invent their own comic strip character?

COMIC STRIP CHARACTERS

Superheroes have been a part of popular culture from as early as the 1930s. Originally in comic books, they have been developed for other media. Through the ages the characters have evolved and new ones, such as The Incredibles, have been introduced. The science of superheroes is usually determined by artists and writers. Only a few have super powers that are actually conceivable today, even with the huge advances that have been made in science since superheroes first emerged.

USING POPULAR TOPICS TO TEACH SCIENCE

Children regularly play with, read and talk about superheroes but do they have any concept that some powers are based on science while others are scientifically impossible? Through the concept of superheroes and villains this resource engages pupils with science and engineering enabling them to create their own futuristic super powers and 22nd century comic strip character based on current science and engineering developments.

WHAT THE PEOPLE INVOLVED IN THE PROJECT HAVE TO SAY...

"..EVERYTHING WE DONE, I HAD A SMILE ON MY FACE" [PRIMARY PUPIL]

"..I COULD FIND OUT THINGS I DIDN'T THINK WERE REAL" [PRIMARY PUPIL]

"..IT WAS FUN AND WE LEARNED LOADS" [SECONDARY PUPIL]

"..SOMETHING NEW, MORE EXCITING, COULD DO IT AGAIN [SECONDARY PUPIL]

"..EXCELLENT CONTEXT FOR LEARNING" [PRIMARY TEACHER]

"..A GREAT PROJECT" "..BRINGS SOME REALITY INTO SCIENCE" [SECONDARY TEACHER]

SCIENCE AND ENGINEERING ROLE MODELS

THE BENEFITS OF USING ROLE MODELS

The Royal Society commissioned a study "to develop an understanding of how effective role models are in changing young people's perceptions about scientists and engineers, encouraging them to aspire to careers in science, engineering or technology (SET) and pursue courses in SET". The discussion groups with young people supported many of the points already highlighted in literature.

THE PRESENCE OF YOUNG ROLE MODELS AND OF ROLE MODELS FROM INDUSTRY OR BUSINESS HELPS TO PLACE SCHOOL WORK IN THE CONTEXT OF THE REAL WORLD, BRINGING SCHOOL INVESTIGATIONS TO LIFE AND SHOWING THEIR RELEVANCE.

We strongly encourage you to use role models to help deliver this topic. One of our bioengeering role models had this to say "… *A GREAT EXPERIENCE, I WOULD DO IT AGAIN" "IT WAS INVALUABLE...I REALLY ENJOYED IT... IT WAS REALLY GOOD FUN*

FINDING A ROLE MODEL

The Science, Technology, Engineering and Mathematics Network runs the Science and Engineering Ambassadors (SEAs) Programme through the SETPOINTS. SEAs come from a wide variety of science, technology and engineering backgrounds and all share enthusiasm and commitment, along with a passion for what they do. Before visiting any school the SEAs are disclosure checked and receive training. To find out more contact your local SETPOINT **(www.stemnet.org.uk/setpoints/setpoint_map.cfm).**

The Researchers in Residence scheme places PhD and post doctoral students in secondary schools across the UK. Young researchers from a diverse range of subjects (including all the sciences, social sciences, arts and humanities) contribute their ideas, fascination for their subject, skills and time to a project. Placements are

between 14 and 24 hours long. Visit the Researchers in Residence website to find out more **(http://www.researchersinresidence.ac.uk/).**

LEARNING OUTCOMES

While designing their character children are taken through various stages of an engineering design process: identifying a need (new superhero or villain with scientific powers), conducting research on the problem, brainstorming different designs that fit the criteria based on their knowledge and understanding, selecting the most promising design, producing a prototype of the idea, and finally communicating and selling the product (their superhero or villain).

THROUGH THESE ACTIVITIES CHILDREN CAN LEARN:

- A RANGE OF RESEARCH SKILLS
- TO WORK COLLABORATIVELY
- ABOUT DIFFERENT SCIENCE AND ENGINEERING TECHNOLOGIES
- ABOUT BIOENGINEERING
- TO USE THEIR KNOWLEDGE TO DEVELOP NEW TECHNOLOGIES
- ABOUT THE REAL SCIENCE AND ENGINEERING BEHIND SUPERHEROES AND VILLAINS

LEARNING TASKS

GROUP WORKING AND FOLDERS

We suggest people work in small groups of roughly four to develop their character. Pupils who took part in the pilot project, despite not being enthusiastic about group work at the start of the project, found working in groups beneficial. It meant that they all had to work together even when initially they had different opinions of what super powers to have or whether to have a villain(ess) or a hero(ine) to create their character.

Each group should have their own folder to:

- store their worksheets,
- collect articles on bioengineering, new technologies, superheroes and villains,
- and collate ideas for their super powers and character design.

PRACTICAL ACTIVITIES

You probably don't have time to carry out all the activities in the resource pack so pick the activities that are the most suitable in each section. We recommend you use the short quizzes to introduce the two topics. The superhero and villain quiz should get people thinking about the science behind super powers. The bioengineering quiz introduces new technologies and people should start to think about what could be possible in future.

If you prepare the resources in advance all the practical activities (without optional activities and extensions) can be done in 45 minutes. We recommend you try the activities yourself first then decide the best way to run them. At the start of each activity there is a list of the resources you will need to carry out the investigation. Below for each activity we have identified optional internet (website links should be investigated in advance to judge their suitability) and extension activities, the key concept(s) and suggested ways of working.

SUPERHEROES AND VILLAINS ACTIVITIES

SUPERMAN This activity is best done in pairs. Key concept(s) – memory

POISON IVY This activity works well in small groups or pairs. Lipstick might need more time at the end of the session to set. Optional internet and 'hands-on' extension activity. Key concept(s) – material properties (solid, liquid and melting) and toxins.

DR OCTOPUS' HARNESS This activity can be done as a challenge in small groups or pairs. Key concept(s) – building stable structures (shapes, forces, loads and materials) and artificial arms.

BIOENGINEERING ACTIVITIES

HOW DO YOUR MUSCLES WORK? This activity can be done individually or in pairs. Can be related to fair testing. Optional extension activity. Key concept(s) – forces, loads, muscles and adrenaline.

BUILD AN ARTIFICIAL MUSCLE This activity works well in pairs. Optional internet activity. Key concept(s) – electric circuits and smart wire.

SHAPE MEMORY ALLOY SPRINGS This activity works well in pairs with small group discussions on the answers. Can be related to fair testing. Optional internet activity. Key concept(s) – material properties, shape memory alloy materials and transition temperature.

GAIT CYCLE STUDY FOR EXOSKELETON This activity works well in pairs. Optional internet activity and extension activity. Key concept(s) – gait cycle and exoskeleton.

MOTION CAPTURE This activity contains two parts and is best done in two sessions. We suggest you do part one and prepare the box in the first session. Then film the hand in the second session and show the clip at the end. Part one is best done individually and part two in pairs or small groups. Optional internet activity. Key concept(s) – properties of light (reflection) and motion capture.

ARTIFICIAL BLOOD SUBSTITUTES This activity works well in pairs or small groups. Can be related to fair testing. Optional extension activity. Key concept(s) – liquid

properties, velocity, viscosity and blood vessels.

BONE STRENGTH This activity works well in pairs. If you have groups of four designing a superhero or villain split each group and get half to make the bone without play dough and the other half with it. To make the bones we suggest setting a 20 minute challenge. Optional internet activity. Key concept(s) – building stable structures (shapes, forces, loads and materials) and bone structure.

POLYMORPH PLASTIC This activity works well individually with small group discussions on the answers. Key concept(s) – material properties and melting point.

TISSUE ENGINEER A FINGER This activity works well in pairs or individually. Key concept(s) – anatomy of the finger and tissue engineering.

DESIGNING YOUR CHARACTER

Start designing your superhero or villain by looking at the science behind current superheroes and villains using the quiz and practical activities. Next use the bioengineering quiz and practical activities to learn about current and future bioengineering technologies. To get some ideas about the type of super powers you could design have a look at the answers on the worksheets and the materials you have collected. For further inspiration look at the superhero(in)es and villain(esse)s on the Engineering Super Powers website (www.engineeringsuperpowers.org). Don't forget that your futuristic super powers should be scientifically possible, if not now, then in 50 years time!

If possible involve an artist in the bringing the characters to life stage to help the groups draw their characters. **"***THE ARTIST CAME ROUND AND HE ASKED US ABOUT OUR CHARACTER AND THEN HE ASKED US ABOUT THE BACKGROUND OF THE CHARACTER AND WE JUST SORT OF BUILT UP A STORY BEHIND IT ...IT WAS QUITE GOOD...IT MADE YOU THINK ABOUT WHAT THE CHARACTER WAS ALL ABOUT..."* [pupil].

PRESENTING YOUR CHARACTER

Get each group to present their engineered superhero or villain to the other groups, and where possible, their peers and families. They must explain why their character is the best one to either save the world from the forces of evil or triumph over the forces of good. They should draw their character and prepare a pitch outlining their super powers and why their character should win. Get the audience to ask questions and either give each group a score or get them to vote for their favourite (not including their own character).

CURRICULAR LINKS

Instead of giving detailed links for each practical activity we have included the main areas of the Scottish and English curriculum that the activities in this pack can relate to. Inventing your superhero or villain and creating comic strips can also have curricular links with Art and English.

SCOTLAND

SKILLS IN SCIENCE - Preparing for Tasks, Carrying out Tasks, Reviewing and Reporting on Tasks

EARTH AND SPACE - Materials From Earth (Level B & C), Changing Materials (Level B)

ENERGY AND FORCES - Properties and Uses of Energy (Level C & D), Conversion and Transfer of Energy (Level C & E), Forces and their Effects (Level B)

LIVING THINGS AND THE PROCESSES OF LIFE - The Processes of Life (Level B, C & D)

TECHNOLOGY - Needs and How They are Met, Resources and How They are Managed, Processes and How They are Applied

SKILLS IN TECHNOLOGY - Preparing for Tasks, Carrying Out Tasks, Reviewing and Reporting on Tasks

ENGLAND

SC1 SCIENTIFIC ENQUIRY – Key Stage 2 and 3

SC2 LIFE PROCESSES AND LIVING THINGS – Humans and other animals (Key Stage 2), Humans as organisms (Key Stage 3)

SC3 MATERIALS AND THEIR PROPERTIES – Grouping and classifying materials (Key Stage 2), Changing materials (Key Stage 2), Classifying materials (Key Stage 3)

SC4 PHYSICAL PROCESSES – Electricity and magnetism (Key Stage 2), Forces and motion (Key Stage 2), Light and Sound (Key Stage 2), Electricity (Key Stage 3), Forces and Motion (Key Stage 3) and Light and Sound (Key Stage 3).

CLASSROOM REQUIREMENTS AND SAFETY

While we have minimised the risk involved in the activities it is important that you conduct your own risk assessment. A useful resource is **Be Safe!** published by the ASE. Where a risk has been identified safety precautions are given in the activity. If you are unsure about the safety of any activity then please consult your Education Authority (Health and Safety) Guidelines.

SUPERHEROES AND VILLAINS

THE SCIENCE AND ENGINEERING BEHIND SUPERHEROES AND VILLAINS

We suggest you start thinking about engineering your super powers by looking at some of the science behind the powers of current superheroes and villains. What super powers do they have and are they scientifically possible or impossible? A useful place to start is the BBC website “The Science of Superheroes” (see useful websites at the end of this pack.) If you have time we recommend reading “The Science of Superheroes” and “The Science of Supervillains” by Lois Gresh and Robert Weinberg.

HOW WELL DO YOU KNOW YOUR SUPERHEROES AND VILLAINS?

Before trying the superhero and villain quiz why not play a matching game? Photocopy the quiz sheet and cut out each of the super powers and the names of the superheroes/villains (or you could print out an image of each of them). Now match the super power to the superhero or villain.

SCIENCE MISSION – POSSIBLE OR IMPOSSIBLE?

Three ‘hands-on’ activities that investigate the science behind Superman’s memory, Poison Ivy’s lipstick and Dr Octopus’ harness.

PRACTICAL ACTIVITIES:

SUPERHERO AND VILLAIN QUIZ

SUPERMAN

Super Powers	Possible?	
incapable of being injured or damaged	yes	no
vision powers (telescopic, infra-red and microscopic vision)	yes	no
accurately remembers images sounds and objects	yes	no
super hearing	yes	no

ELASTIGIRL

Super Powers	Possible?	
very flexible and able to stretch	yes	no
super strength	yes	no

BATMAN

Super Powers	Possible?	
superior human ability in martial arts, acrobatics and escape artistry	yes	no
large selection of specialized gadgets e.g. the Batmobile	yes	no
a belt that contains explosives, infra-red flash light, smoke capsule, fingerprint equipment, miniature camera, pass keys, tiny oxyacetylene torch, gas capsule	yes	no

POISON IVY

Super Powers	Possible?	
skin poisons that kill	yes	no
toxic lipstick	yes	no
killer plants	yes	no

DR OCTOPUS

Super Powers	Possible?	
A harness with arms that are:		
controlled by the brain	yes	no
can lift up to nine tons or two African elephants each	yes	no
allow him to move rapidly (50 miles per hour) over any ground	yes	no

SPIDER-MAN

Super Powers	Possible?	
able to cling to walls / stick to most surfaces	yes	no
fast and nimble with perfect balance and stability	yes	no
night vision	yes	no
ability to shoot / spin webs	yes	no

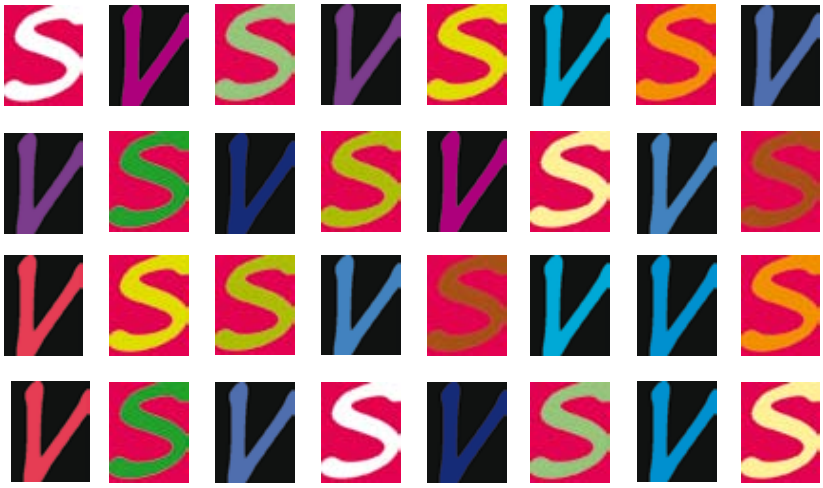
SUPERMAN–HE ACCURATELY REMEMBERS IMAGES. HOW LIKELY IS THAT?

Resource list to test your memory

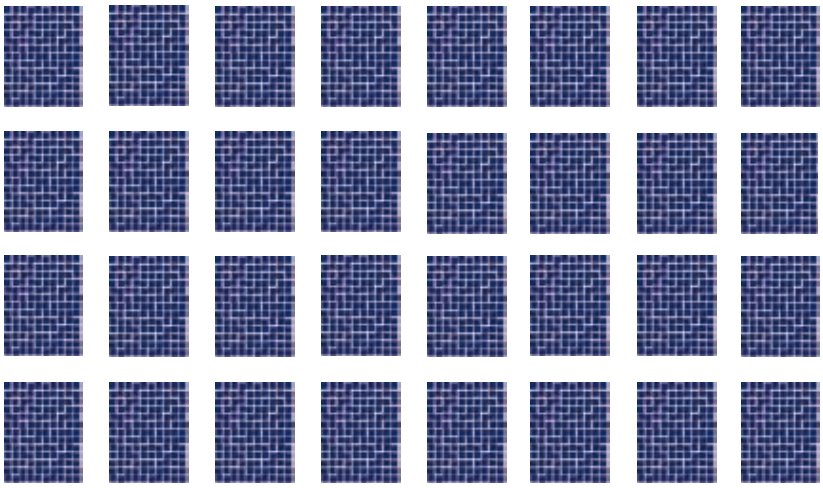
1. **32 paired cards (or make your own superhero and villain pairs)**

2. **a stopwatch**

1. Shuffle the cards and place them in four rows of eight (or try four rows of five...then six...then seven...then eight) with the superhero face up as shown.

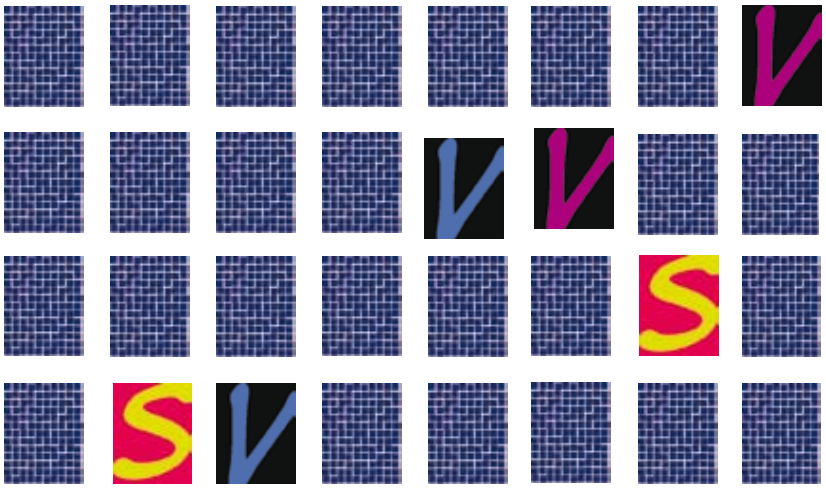


You have one minute to memorise where each card is. Now turn all the cards over but don't move them.



2. Start the timer and match the cards by turning over two cards at a time. Each time you turn over a pair (two cards) is one move.

3. If the pair do not match turn them back over and try another pair. When you match a pair leave them sitting face up and try another pair.



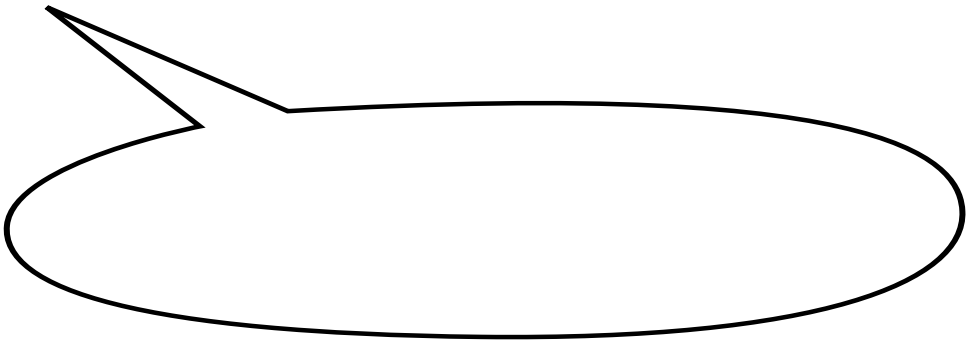
4. Count the number of moves you make and the time it takes you to match all 16 pairs.

5. Decide how you are going to record your results. What do you need to record?

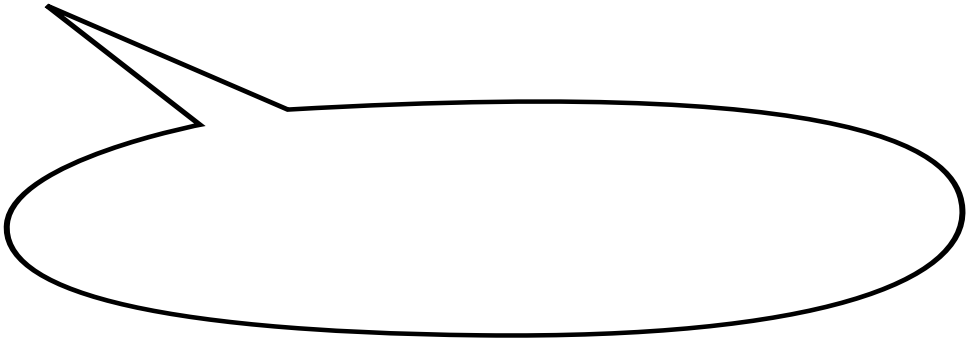
   [name, turn, number of moves and the time it took]

6. Have another turn.

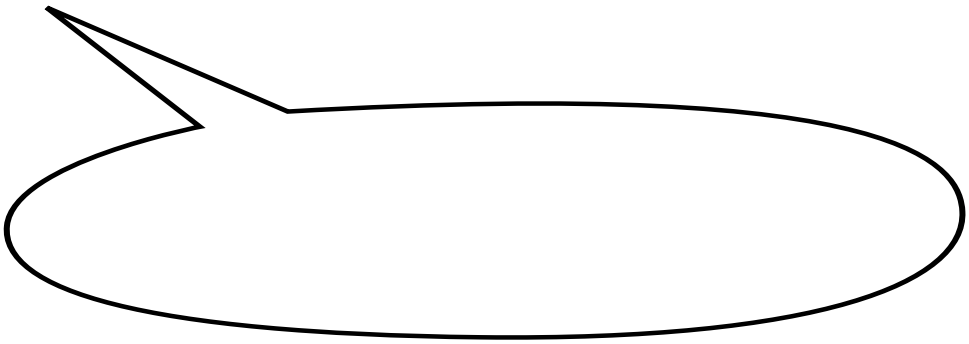
How accurately did you remember where the cards where?



Did you improve?



Did you remember where the pairs were each time and match them in 16 moves?



Do you think its possible to match each pair first time like Superman?

MEMORY

Memory is the ability of an organism to store, retain, and subsequently recall (remember) information. There are three main stages in forming and recalling memories:

Encoding – when you process and modify the information you have received through your senses (touch, sight, smell, sound, taste)

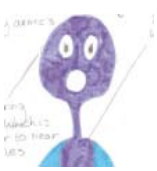
Storage - creating a record in the brain of the encoded information

Recall - responding to a stimulus by calling back the information

Some people are better at processing, storing and recalling memories than others. You can improve your memory. It is easier to remember a string of numbers 1752948036 by bunching them together i.e. 17 52 94 80 36 or connecting them to other things e.g. 175 white cups, 294 paper plates, 80 blue napkins and 36 red

balloons. You can also use rhymes or phrases e.g. Richard Of York Gave Battle In Vain for the colours of the Rainbow – Red, Orange, Yellow, Green, Blue, Indigo and Violet.

EXTENSION ACTIVITY - Test your memory (see useful websites at the end of this pack).



POISON IVY – SHE NEVER LEAVES HOME WITHOUT HER LIPSTICK. BUT HOW DOES SHE MAKE IT?

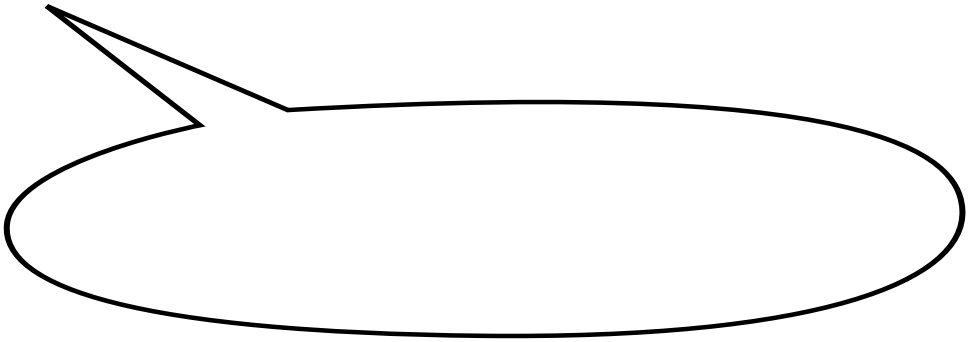
Resource list to make poison ivy's lipstick

- **15 tbsp grapeseed oil**
- **1 tbsp honey**
- **45g beeswax**
- **food colouring**
- **measuring spoons**
- **microwave**
- **large microwave safe bowl**
- **small portable plastic container or tin**
- **long heat proof gloves**

SAFETY TIPS: BE VERY CAREFUL WHEN HANDLING THE HOT OIL AND WAX WHICH CAN CAUSE BURNS. WEAR LONG HEAT PROOF GLOVES AND COVER ANY EXPOSED SKIN (E.G. ARMS AND HANDS) WHILE THE MIXTURE IS BEING HEATED AND COOLED. DO NOT OVERHEAT THE MIXTURE: STOP HEATING AS SOON AS THE WAX HAS MELTED. IF YOU NEED TO CARRY THE HOT MIXTURE MAKE SURE THE ROUTE IS CLEAR AND COVER THE TOP OF THE CONTAINER WITH TINFOIL OR CLING FILM TO PREVENT SPILLS. DO NOT PLACE AN AIRTIGHT LID ON THE MIXTURE WHEN HOT. TO PROTECT CLOTHES FROM POSSIBLE FOOD COLOURING SPILLS WEAR AN APRON.

1. **Measure out 15 tablespoons of grapeseed oil into the bowl.**
2. **Add the 45g block of beeswax.**
3. **Microwave for a maximum of 30 seconds at a time, stirring in-between in the microwave, until the beeswax has melted (this should take approximately two minutes).**
4. **Add 1 tablespoon of honey.**
5. **Add a couple of drops of food colouring.**
6. **Mix all the ingredients together.**
7. **Let the mixture cool.**
8. **Stir every second minute. (To cool quickly put it in the fridge.)**
9. **Once the mixture is cool transfer to your container and leave to set.**

Ooops forgot the poison! Which deadly plant toxin would you put in your lip gloss? Why not have a look on the internet for a suitable plant toxin while your lip gloss cools?



Do you think it's possible for Poison Ivy to make toxic lipstick?

TOXINS

A toxin must enter the body to kill someone. It can be inhaled (through the nose and mouth), eaten or in the case of a toxic lipstick enter the body through the skin. Poisons can also be injected into the body e.g. bee stings and snake bites.

Why is Poison Ivy's lipstick not toxic to her? Perhaps she puts a 'barrier lipstick' underneath that stops the poison passing through. Or her lipstick may contain a substance that is toxic to other people but not to her. For example nuts are only toxic for some people.

There are animals who use poisons on their skin. Poison Dart frogs produce toxins in their skin. The Hooded Pitohui bird also produces a toxin on its skin and feathers. They use their toxins to stop other animals eating them. The Slow Loris has poison secreting patches on the inside of its elbows. It puts the poison on its young to stop them being eaten.

EXTENSION ACTIVITY – Make your own edible lipstick (see useful websites at the end of this pack).

DR OCTOPUS – YOU PUT YOUR LEFT ARM IN, YOU PUT YOUR RIGHT ARM IN, YOUR PUT YOUR FIRST TENTACLE IN, YOU PUT YOUR SECOND TENTACLE IN..... CAN YOU SHAKE THE PIECES ALL ABOUT AND BUILD DR OCTOPUS' HARNESS?

Resource list to make Dr Octopus' harness

K'nex or Meccano set (the more pieces you have the better the harness!)

The challenge is to build two tentacles (arms) with pincers (hands) on the end.

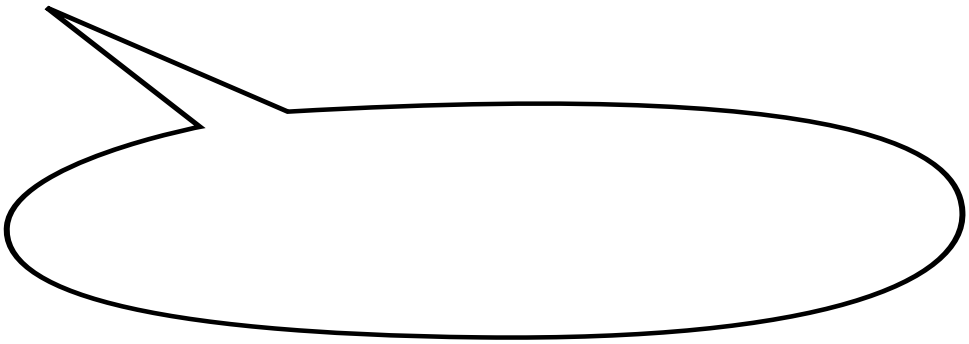
1. The tentacles should be attached to a harness.

2. The tentacles should have at least two sections that can move.

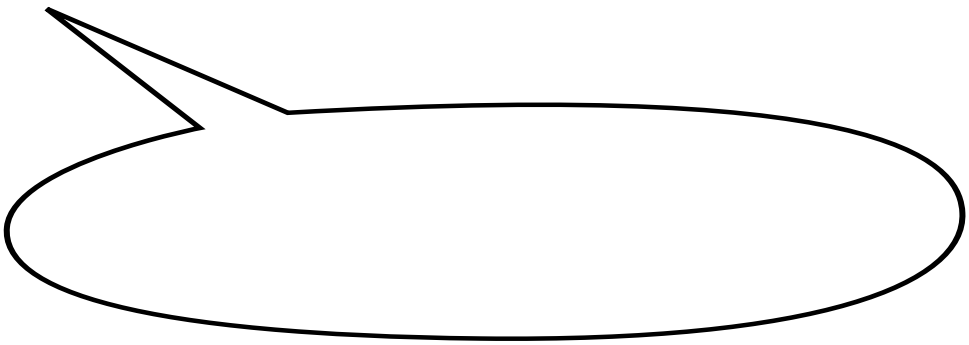
3. One of the pincers (three finger-like limbs) should be able to lift up a pencil

4. The other pincer should be able to turn round like a fan.

How would your harness attach to the body?



Can you move the tentacles on your harness using your brain like you do your arms?

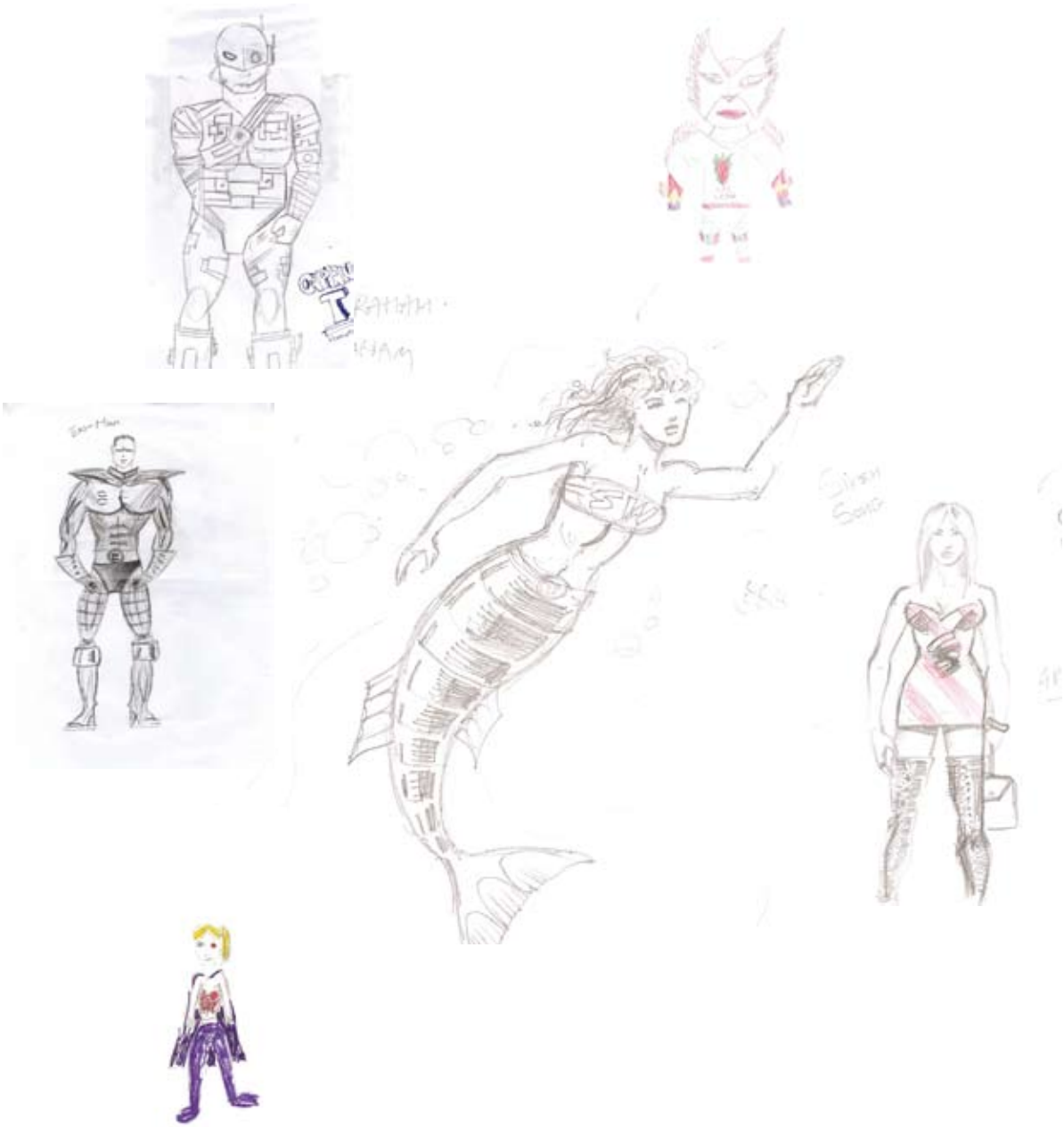


Do you think it's possible to engineer Dr Octopus' harness?

ARTIFICIAL LIMBS

Artificial limbs are not science fiction. In fact they've been around for many years. You might know that early artificial legs were made from wood and hands were replaced by hooks. But did you know the Egyptians made artificial toes? Over the years artificial limbs have become more advanced.

Today the world's most advanced artificial arm can be moved by thoughts alone, just like a real arm. The wearer no longer needs to use their body to press switches that move the limb. Now the four nerves that were once connected to the arm can be connected to move the chest muscles. When brain signals pass down the nerves to tell the arm which movement to make the movement of the chest muscle is converted by a computer to move the artificial arm.



BIOENGINEERING
WHAT IS BIOENGINEERING?

Bioengineering / Biomedical engineering
- the application of engineering principles and techniques to problems in medicine and biology.

It's not a new subject. In fact one of the first examples of bioengineering dates back to the ancient Egyptians. A mummy was found with a carved wooden prosthesis, complete with toenail. The wooden prosthesis (an artificial device used to replace a body part) replaced the big toe, which carries a lot of weight when walking and provides stability. You could say that bioengineering has been around for over 3000 years!

Have you not heard the one about the pirate with a wooden leg, a hook instead of a hand and a patch over his right eye? When asked how it happened the pirate replies, "a shark bit me leg off, lost me hand in battle and salt water got in me eye." Confused his mate says, "You lost your eye when salt water got in it?" The pirate responds, "Well it was me first day with the hook." Thanks to bioengineers the pirate had artificial devices (prostheses) to replace some of the functions of his leg and hand. These days artificial limbs are more elaborate, designed for function and look.

What about the eye the pirate lost? Right, aye. That's a bit more complicated. To restore sight bioengineers are working on artificial eyes that use computer chips to link the device to your brain. It's no longer science fiction. Bionic arms controlled by the brain already exist. Another possibility is tissue engineering. Tissue engineering uses living cells and temporary structures (scaffolds) to grow new tissue and eventually organs in the lab.

TISSUE ENGINEERING

Tissue engineers use cells, materials, chemicals and their engineering, biology, chemistry and physics knowledge to improve or replace biological functions and tissues (e.g. bone, blood vessels, liver, etc). For example artificial skin can be grown from cells called fibroblasts found in the lower dermal layer of your skin. To grow artificial skin the living cells are placed on collagen structures in a warm environment at 37°C and fed regularly. The skin cells make themselves at home and start to divide and multiply forming skin tissue. To stay healthy and continue growing the cells need a supply of food and to be able to get rid of their waste products. Currently bioengineers can grow skin, tissue, bones, blood vessels, even bladders and are working on other organs.

BIOMECHANICS

Biomechanics is the study of external and internal forces on the living body. It covers the development of mechanical substitutes for body parts, e.g. artificial limbs and prosthesis,

assistive tools and rehabilitation aids. As well as studying the mechanics of muscle movement and other biological processes. For example, studying your body movements during a range of activities including sports (they can even suggest ways of improving your sporting ability).

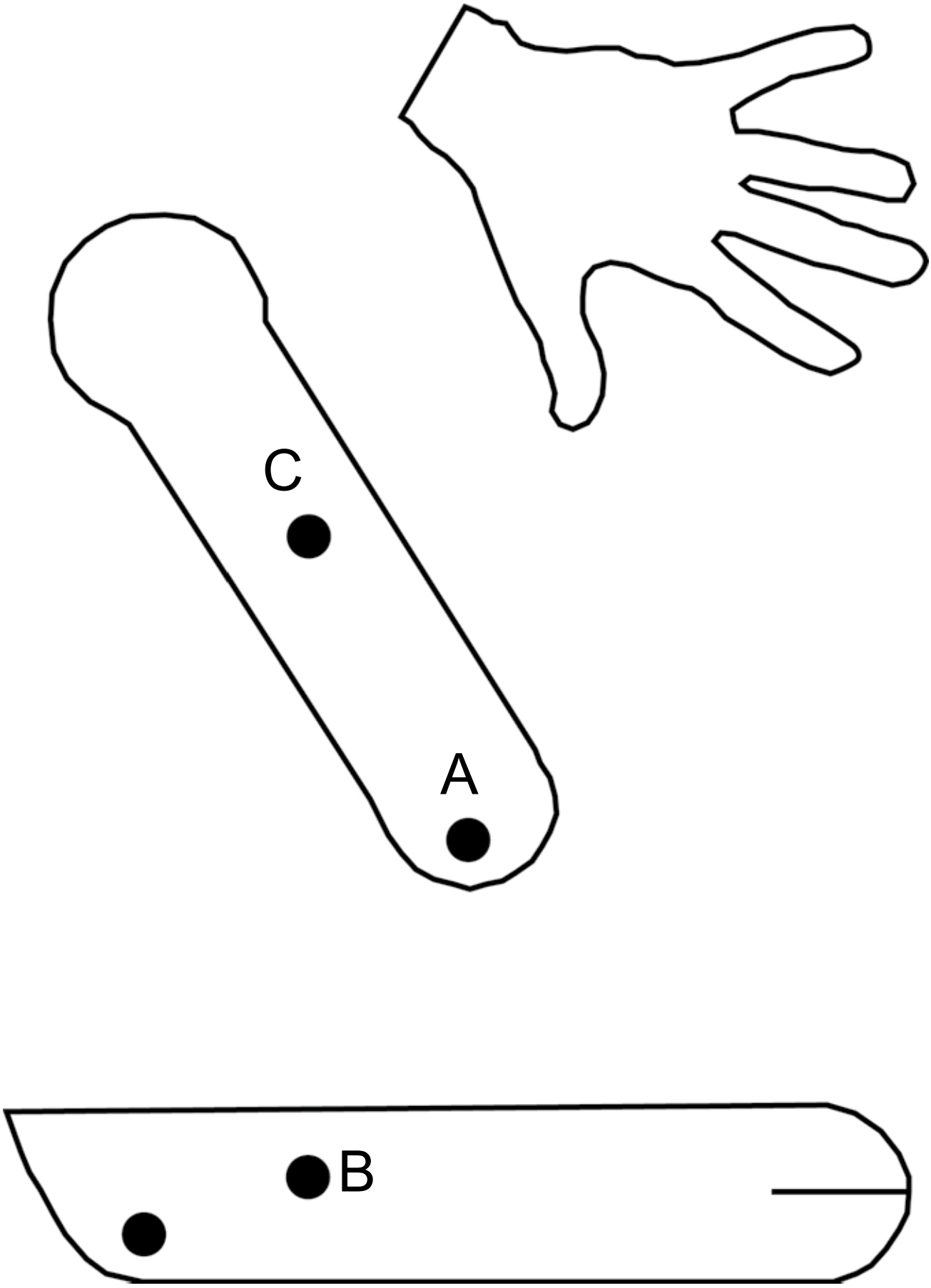
PRACTICAL ACTIVITIES:

BIOENGINEERING QUIZ

If you are running this activity with a group of people we recommend you split them into small groups, print out an image of each technology (it's easier to identify an artificial eye as bionic if the picture shows the silicone implant) and ask the groups to identify the technologies, which part of the body it replaces and if the technology is in use or still being developed.

Do an image search on the internet for the technologies and circle "in use" if you think people are routinely fitted with the device or "still being developed" if it is not routinely used yet.

TECHNOLOGY	IT IS.....
BIONIC EYE	IN USE / STILL BEING DEVELOPED
ARTIFICIAL HEART	IN USE / STILL BEING DEVELOPED
ARTIFICIAL ARTERIES	IN USE / STILL BEING DEVELOPED
ARTIFICIAL LUNG	IN USE / STILL BEING DEVELOPED
HIP JOINT PROSTHESIS	IN USE / STILL BEING DEVELOPED
ARTIFICIAL LEG	IN USE / STILL BEING DEVELOPED


C
A
B

Biomechanics - How do your muscles work?

Resource list for how do your muscles work

- **strong cardboard or plywood / correx -2 lengths about 20x4 cm long and a small piece 10x10 cm for the hand.**
- **3 split pins**
- **string approx 20 cm long**
- **small weights up to 200g**

SAFETY TIP: BE CAREFUL WHEN PLACING THE WEIGHTS ON THE HAND. CHECK THE SURFACE BELOW THE HAND AS FALLING WEIGHTS CAN CAUSE DAMAGE. DO NOT INCREASE THE WEIGHT ABOVE 200G.

1. Cut out of the cardboard the three pieces shown in the pattern (see diagram 1). Make holes where the black marks are and cut out a slot where the black line is.

2. Next line up the two holes marked A (at the ends of the two lengths of board) and push a split pin through both holes to make the elbow pivot.

3. Push a split pin through the hole marked B, making sure it is pointing in the same direction as the pin at A, and fix the string to the split pin.

4. Now push the string through the hole marked C and loosely fix it in place by sticking a split pin through the hole (making sure it is pointing in the same direction as the other pins) so that when the string is tight the two halves of the arm are roughly at 90˚ to each other (see diagram 2).

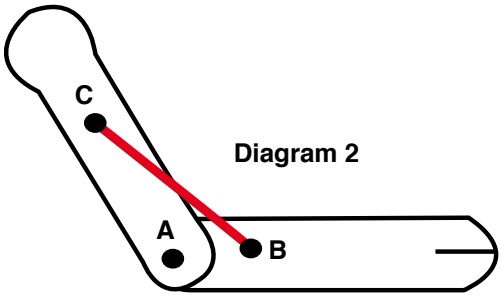


Diagram 2

5. Push the smaller piece of board into the slot, to make a hand.

6. Hold the ‘upper arm’ so that it is vertical and put a small weight (100g or less) onto the hand.

What do you have to do to the string to lift the mass?

Does anything change when you increase the weight (up to a maximum of 200g) on the hand?

What is going on?

We exert force through changes of length in our muscles. To raise the arm and the load you need to shorten the string. When we raise a load in a real arm the biceps muscle at the top of your arm shortens in length (contracts) and also bulges. When the load is lowered the triceps muscle contracts. When the mass of the load is increased it becomes more difficult to lift and lower the arm. The muscles must work harder and use up more enengy.

When we are afraid, excited or nervous adrenaline (a substance produced by the body) is released into the bloodstream. Adrenaline increases the heart rate and prepares us to fight or run known as the 'fight or flight' response. This increase in heart rate speeds up the supply of oxygen and glucose to the brain and muscles which can then work harder than you'd ever thought possible!

Extension Activity - Try feeling the changes in your bicep when you lift and lower your arm. Place one hand on the opposite arm's biceps (the front muscle on your upper arm) so that your wrist is on the inner side of your arm and your fingers on the outer arm. Bend the arm and observe the change in the length of the muscle. The changes that you should have observed are that a contracting muscle gets harder, shorter, and thicker.

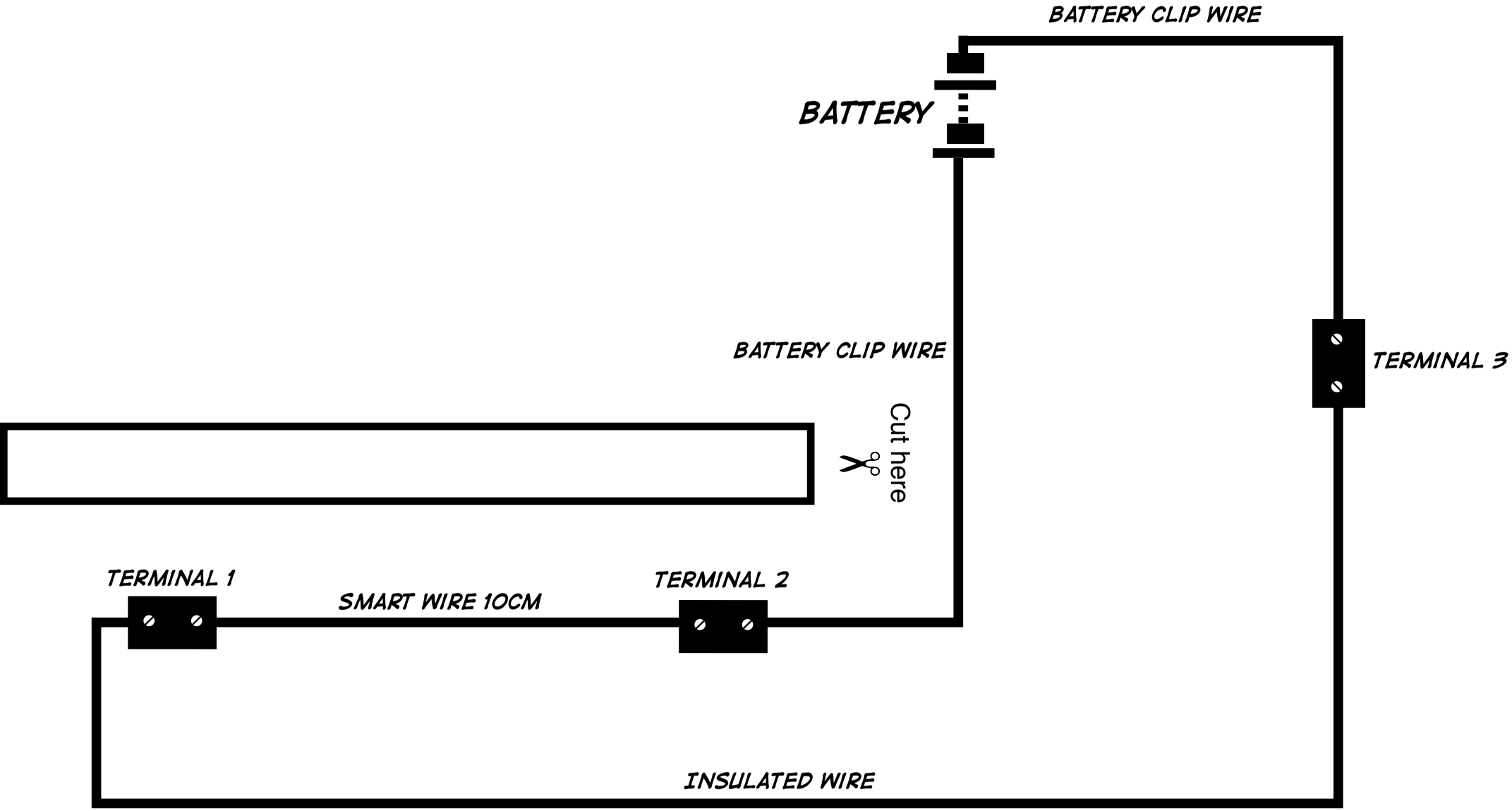
DR OCTOPUS – HIS HARNESS HAS FOUR POWERFUL METAL ARMS THAT ALLOW HIM TO WALK UP SHEER CONCRETE WALLS, MOVE QUICKLY ABOUT AND GRAB ITEMS. HOW DO THE ARTIFICIAL MUSCLES IN HIS HARNESS WORK?

Biomechanics- build an artificial muscle

- **A4 sheet of card**
- **scissors**
- **double-sided tape**
- **3 screw terminal blocks**
- **screwdriver to fit terminal block screws**
- **10 cm length of smart wire (can be obtained from www.mutr.co.uk)**
- **two small crimping fastners for smart wire (can be obtained from www.mutr.co.uk)**
- **insulated wire (approx 20 cm in length)**
- **battery clip**
- **battery case for 2 A4 batteries (preferably with a switch)**
- **2 A4 batteries**

SAFETY TIPS: AVOID RECHARGEABLE BATTERIES. EXPLAIN ABOUT THE DANGERS OF ELECTRICITY AND THAT LOW VOLTAGE BATTERIES ARE A LESS DANGEROUS SOURCE OF ELECTRICITY. DO NOT TOUCH THE WIRES WHEN THE CIRCUITED IS CONNECTED. IDEALLY SWITCH THE CIRCUIT ON AND OFF WITH A SWITCHED BATTERY HOLDER. THERE IS A SMALL RISK OF BURNING IF THE SMART WIRE IS OVERHEATED.

1. First cut out the thin strip on the card as indicated on the template (see diagram).


BATTERY CLIP WIRE
BATTERY
BATTERY CLIP WIRE
TERMINAL 3
Cut here
TERMINAL 1
SMART WIRE 10CM
TERMINAL 2
INSULATED WIRE

2. Now stick your terminal blocks on the card in the places indicated with double sided sticky tape.

3. Place one end of the smart wire in a crimping fastner, put the crimping fastener in terminal block 1 and tighten the screw to press down on the crimping fastener and smart wire. Repeat this process at the other end of the smart wire in terminal block 2. The smart wire between the screw terminal blocks should be tight when the card is flat.

4. Next join one end of the smart wire to a length of the insulated wire in screw terminal block 1. Place the end of the insulated wire in the other side of the screw terminal block and fix in place using the screwdriver.

5. Place the other end of this piece of insulated wire in terminal block 3 and use the screwdriver to fix in place.

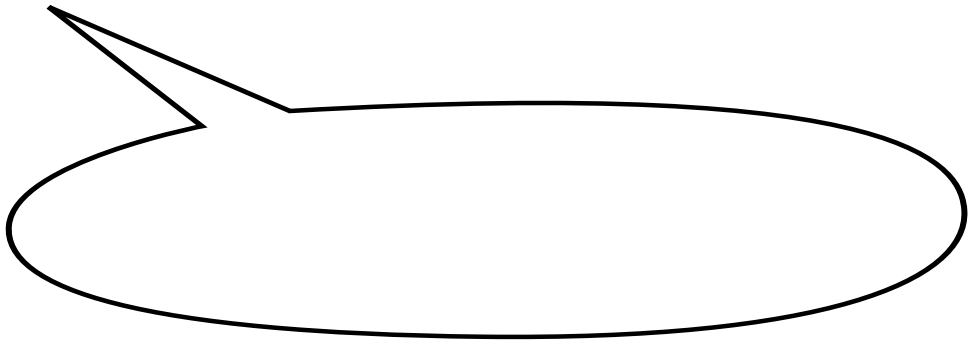
6. Place one of the battery clip leads in the other end of screw terminal block 3 and fix in place using the screwdriver.

7. Join the other battery clip lead to the end of the smart wire by placing in screw terminal block 1 and fixing in place using the screwdriver.

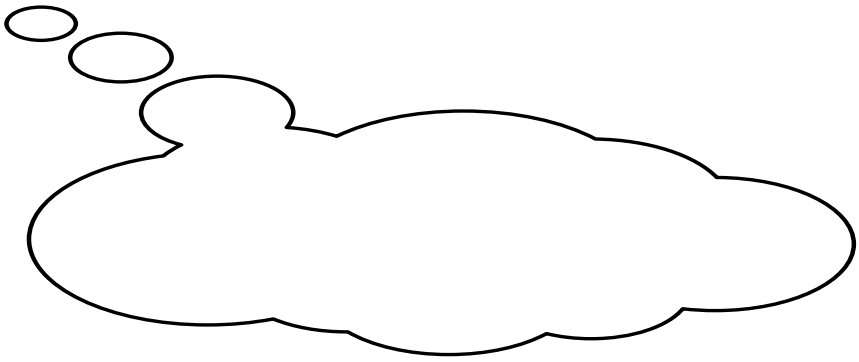
8. Put the batteries in the holder and connect the battery clip to it.

9. Turn the switch on the battery holder on for no more than 5 seconds. **Do not leave the circuit connected and on. The shape memory wire may overheat loosing its memory properties and the batteries will run down very quickly.**

What happens to the the card below the smart wire?

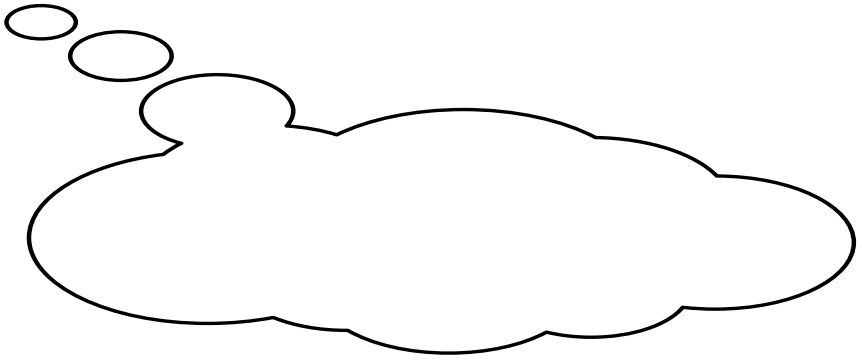


What do you think happens to the smart wire to make this happen?

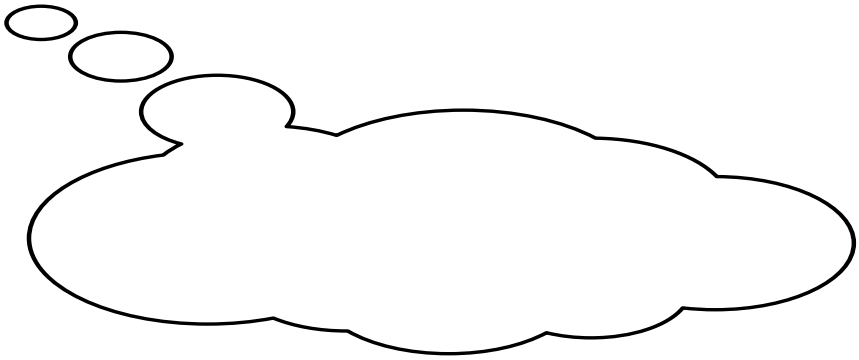


To repeat the experiment you need to flatten the card again by holding it and pulling down at both ends at terminal blocks 1 and 2.

How do you think an artificial muscle would straighten an arm?



Can you think of any weaknesses artificial muscles might have?



What is going on?

When the wire is connected to the battery, the free end of the card should rise up vertically by about 30mm. Moving the switch completes the circuit and electricity flows from the battery through the smart wire. When electricity passes through the smart wire, the wire shortens and is heated in the process. The card moves because the smart wire is anchored at two points. The shorter wire pulls on the card curling the card and raising the free end.

An artificial arm is a prosthesis (a device that substitutes for a missing or damaged part). Artificial muscles are used to move the arm. Today it is possible for people wearing artificial arms to move the arm using only their thoughts - just like a real arm. Have look yourself by searching on the internet for 'neural prosthetic arm'.

ANACONDA–SHE HAS THE SUPERHUMAN ABILITY TO EXTEND HER ARMS AND LEGS TO ABOUT ONE AND A HALF TIMES THEIR NORMAL LENGTH AND CONSTRICT HER OPPONENTS LIKE A SNAKE. WHAT COULD THE ALLOY-BASED SUBSTANCE IN HER SKELETON BE?

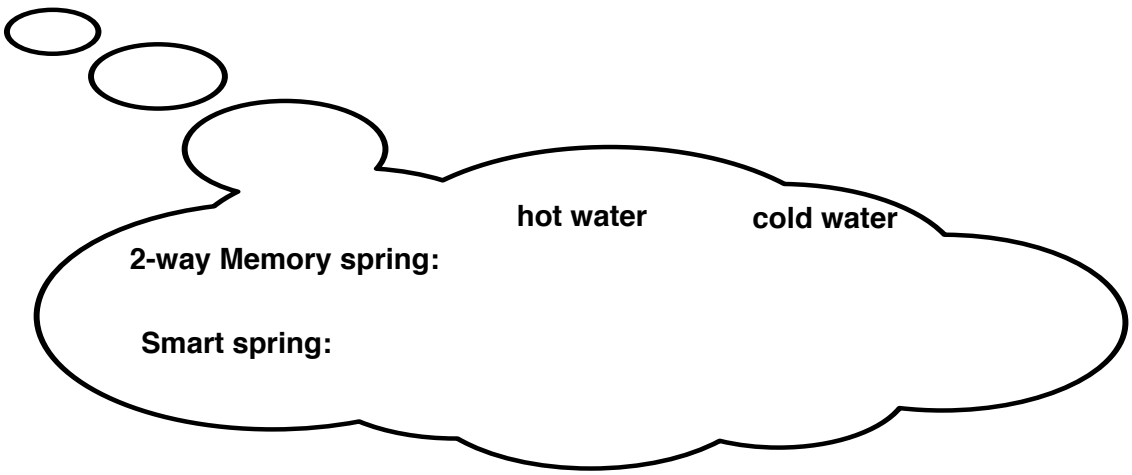
Biomechanics - shape memory alloy springs

Resource list for shape memory alloy springs

- **2-way Memory spring (can be obtained from www.mutr.co.uk)**
- **Smart spring (can be obtained from www.mutr.co.uk)**
- **2 small deep heatproof watertight containers**
- **hot water at 90°C**
- **cold water**
- **tweezers**

SAFETY TIPS: NICKEL ALLOYS CAN IRRITATE THE SKIN–THIS IS THE SAME RISK AS HANDLING 'COPPER' COINS THAT CONTAIN NICKEL. BE CAREFUL WITH HOT WATER AND IF APPROPRIATE WEAR GLOVES. TO PREVENT SPILLS ONLY PLACE A SMALL AMOUNT OF HOT WATER IN THE CONTAINER (JUST ENOUGH TO COVER THE SPRING). USE A DEEP CONTAINER TO MINIMISE THE SMALL RISK OF THE SPRINGS FLYING OUT OF THE CONTAINER. DO NOT OVERHEAT THE SPRINGS BY PLACING THEM IN WATER ABOVE 90°C. ALWAYS USE TWEEZERS TO LIFT THE SPRINGS IN AND OUT THE HOT AND COLD WATER. NEVER TOUCH THE SPRINGS WHEN THEY ARE HEATING OR COOLING (THERE IS A SMALL RISK OF SKIN BEING TRAPPED).

Write down what you think will happen when you place the 2-way Memory and Smart springs in the hot water and what will happen in the cold water?



1. Now place the 2-way Memory and then the Smart spring in the hot water and then the cold water. What happens?

hot water **cold water**

2-way Memory spring:

Smart spring:

2. Open up the Smart spring by about 1 cm by gently pulling the ends apart. Place it in the hot water and record what happens.

What is going on?

A shape memory alloy (SMA) is a material that has a memory. It can be made to remember shapes by using a special process to heat it. The process of changing from one shape back to its original shape can be repeated millions of times. The temperature at which SMA remembers its original form is called the transition temperature and when this temperature is reached, the SMA changes shape. A transition is a change in state from one form into another, just like when water freezes it turns into ice. The most common SMA is an alloy (mixture of metals) called nitinol (nickel and titanium).

Scientists and engineers have been developing shape memory alloys for robotics projects and to simulate human muscle motion. Perhaps in the future amputees will be fitted with fully functional artificial limbs made from shape memory alloys, or robots will be able to move and walk just like us because their components are based on SMA actuators (a device that performs a mechanical motion). To find out more about humanoid robots have a look on the internet for the robot called ASIMO produced by Honda.

IRON MAN-HIS ARMOUR PROVIDES SUPERHUMAN STRENGTH, PROTECTION FROM ATTACKS, A SEALED ENVIRONMENT WITH ITS OWN LIFE SUPPORT, AN ASSORTED WEAPONS SYSTEMS, JET BOOT FLIGHT, COMMUNICATION DEVICES AND SENSORS (E.G. RADAR AND RADIO) AND IS CONTROLLED BY HIS BRAIN. TO DESIGN ARMOUR TO ALLOW THE IRON MAN TO WALK EASILY WHAT WOULD YOU NEED TO KNOW?

Resource list for gait cycle study for exoskeleton

- **2 metre length of string marked at 25cm intervals with pen, tape, etc.**
- **masking tape**

1. First make sure the measuring string is straight and fixed to the floor with masking tape at both ends.

2. Now stand with your left foot at the start of the string and your weight on your left leg.

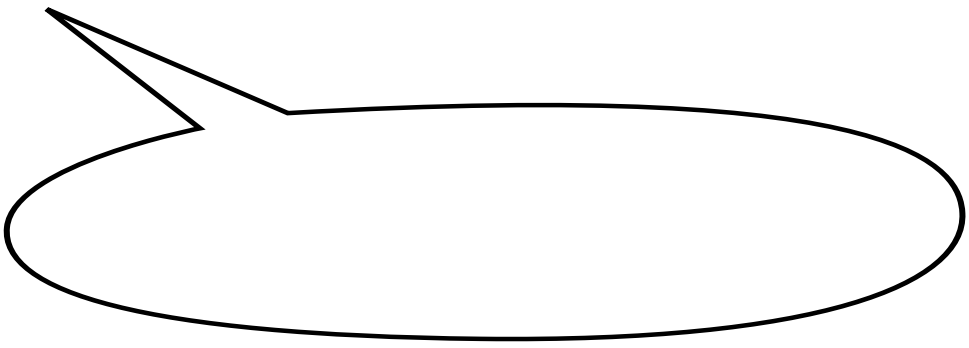
3. Lift your right foot and take a step placing it in front of our left foot just like you would do when walking normally.

4. Now take another step forward onto your left leg and stop moving forward when your right foot is on the ground in front of your left foot.

5. Place a piece of masking tape where the front of your right foot lands. You have just completed one gait cycle.
   Gait cycle is another word for continuous walking movement.

6. Measure the length of your gait cycle. From the start of the string to where the front of your right foot landed.

What is the length of your half gait cycle



If you can compare the length of your half gait cycle with other people. Are there any differences?

What is going on?
In the olden days knights used to wear armour for protection but it stopped them moving easily and naturally. If we want to design an exoskeleton (hard protective outer covering) that allows us to move naturally we have to know which muscles we use to walk and when they contract (shorten and pull), so that we can make the exoskeleton move in the same way. We can learn this from studying gait cycles.

We usually do not think about how we walk - it seems to happen automatically. This is because you learned how to walk when you were younger and your nervous system has remembered how to walk. The nervous system gathers information and responds to changes in the environment either inside or outside the body. Powered human exoskeletons previously seen in science fiction movies and books have been developed by engineers. Don't believe us? Why not do an internet image search for exoskeleton?

Extension Activity - All sorts of walking aids, for example an orthosis (a device that is applied externally to the body to correct problems, improve function or relieve symptoms by supporting or assisting the muscular skeletal system), prosthesis (an artificial device that replaces a missing body part such as a limb) and even a walking stick can alter the way you walk. The way you walk often loses its smoothness and people need to develop a new way of walking. Try repeating the exercise above using a walking stick to lean on. How does it affect your gait cycle?

Biomechanics-motion capture

Resource list for motion capture

- **16 light reflecting markers (we used 3M reflective tape www.3mselect.co.uk)**
- **a pair of black gloves**
- **large cardboard box (taped shut with three small holes-see instructions below)**
- **torch (preferably with small focused beam)**
- **tape**
- **video camera**
- **a dark cloth that covers the ends of the cardboard box**

MOTION CAPTURE PART 1

Motion capture is a special filming technique that allows us to show exactly how body parts move. Markers that reflect light are placed on the subject (person or moving object) and cameras film the position of the reflecting markers. A computer then recreates the movement showing only the reflective markers which appear as dots.

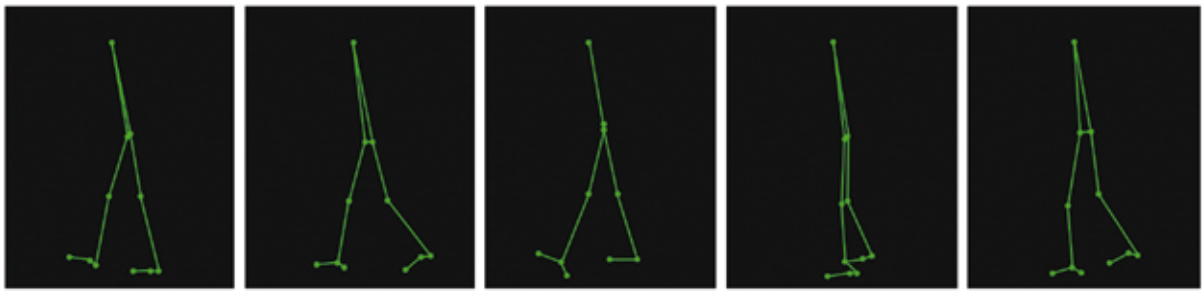
1. The five pictures of the person walking below are in the right order. The green 'stick figure' pictures are motion capture images. They are computerised images of the same person walking produced from the camera images.

2. Can you match the body parts to the first stick figure image? Draw a line from the word to the body part of the stick figure.

3. Now put the number of the photo in the box below the motion capture image you think is correct.

1 2 3 4 5

chest
hip
knee
heel
ankle
toes



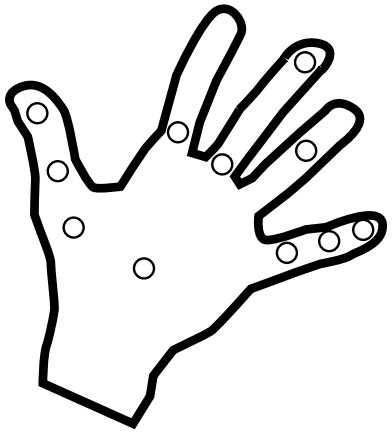
A ☐ B ☐ C ☐ D ☐ E ☐

(to find out the answer see the Useful Website section)

MOTION CAPTURE PART 2

SAFETY TIPS: YOU WILL NEED AT LEAST TWO PEOPLE TO CARRY OUT THIS EXPERIMENT–ONE TO HOLD AND OPERATE THE VIDEO CAMERA AND THE OTHER TO WEAR THE GLOVES. BE VERY CAREFUL CUTTING OUT THE HOLES IN THE CARDBOARD BOX. DO NOT PLACE YOUR HAND ON THE OTHER SIDE OF THE BOX WHEN YOU ARE CUTTING THROUGH THE CARDBOARD. CHECK THE ELECTRICAL SAFETY OF THE VIDEO CAMERA AND FOLLOW THE MANUFACTURERS INSTRUCTIONS.

1. The picture shows a right hand with white dots where the reflective markers should be placed. To make all the hand segments visible, you will need to stick on 16 reflective markers.



2. Draw the five missing reflective markers on the hand in the picture (to find out the answer see the Useful Website section).

3. Now put the markers on the right hand glove in the same locations as they are on the hand in the picture.

4. Cut a small hole in one end of the cardboard box half way between the top and the middle of the box, to fit the video camera lens. About 10cm below the video camera hole cut a second hole that just fits the torch.

5. Now cut a third hole in the opposite side of the cardboard box that you can just fit your hand through.

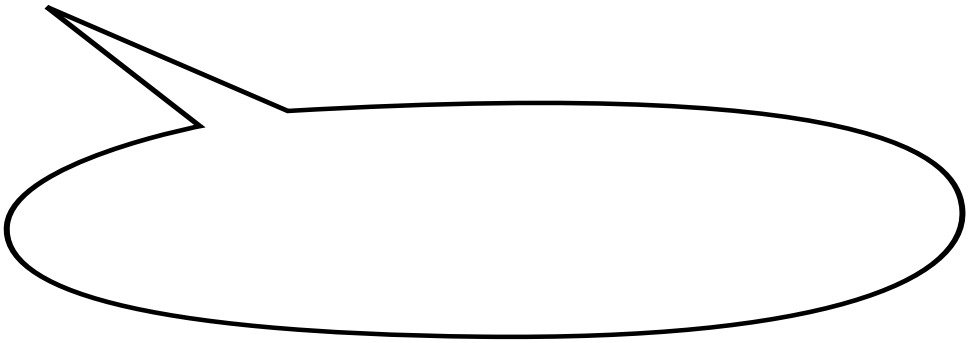
6. Place the dark cloth over the top of the box. It should cover the hole you put your hand through and if possible hang down the other side covering the video camera and torch holes.

7. The person filming should place the video camera lens in the hole, switch it on and check the box is completely dark without the torch turned on. If the box is not completely dark seal up any gaps where light is coming in.

8. The second person should put on the black gloves and place their left hand (without any reflective markers) in the box under the dark cloth. Check no light is entering the box and film the hand moving in the dark. Now switch on the torch and make sure that **the light from the torch is pointing at the middle of the hand.** [If the torch is lighting up the box as well as the hand try putting black card over the beam and cutting out a small hole in the middle to focus the beam.] Film the hand moving.

9. Then place the right hand (with the reflective markers) in the box under the dark cloth. As before check no light is entering the box and film the hand moving in the dark. Now switch on the torch, check that the light from the torch is pointing at the middle of the hand and film the hand moving.

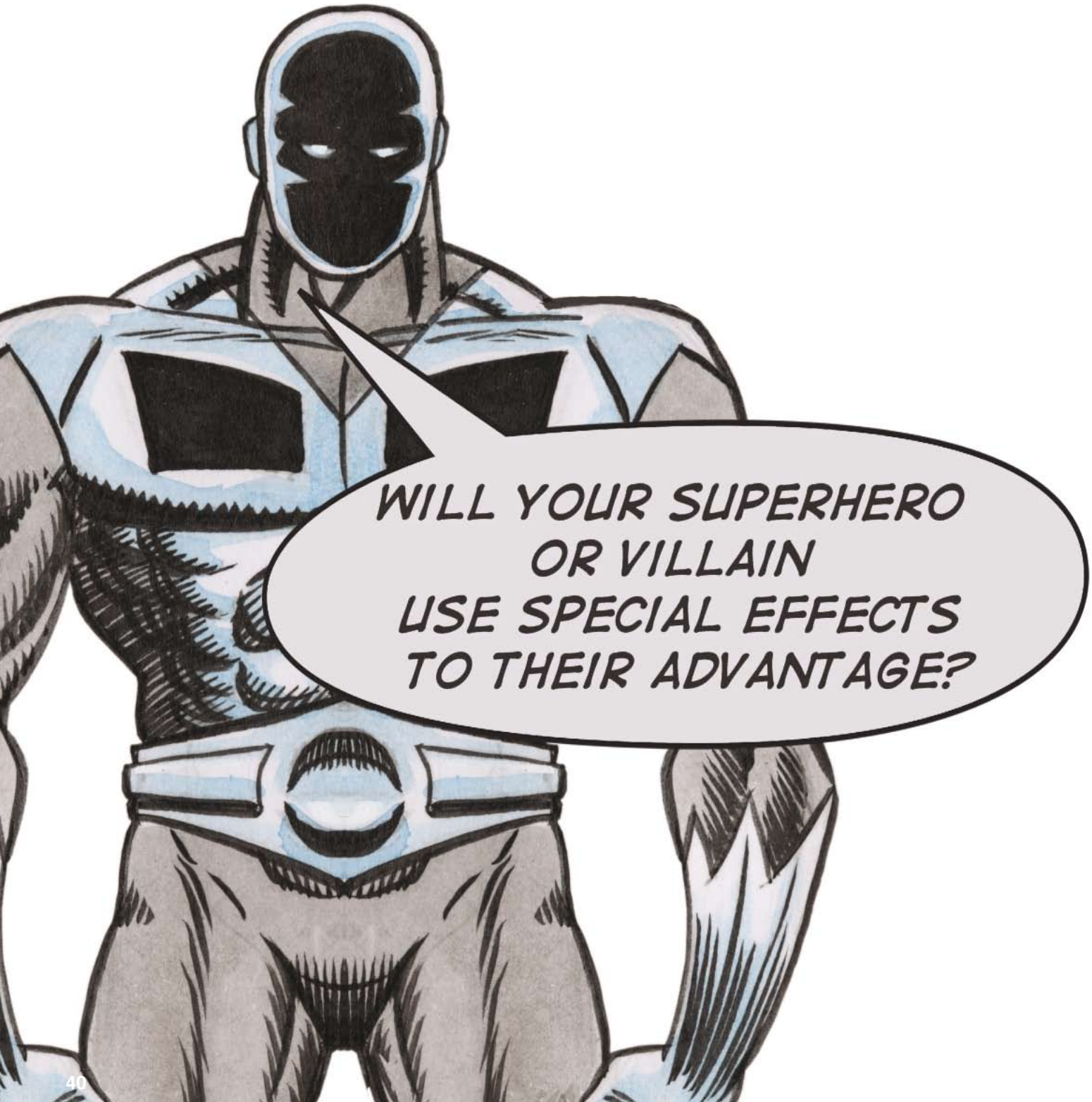
Finally have a look at the film footage on the video camera. Is it easier to see the moving parts of the hand in the black glove or the glove with the reflective markers?



What is going on?

It's easier to see the different parts of the hand moving on the glove with the reflective markers. The reflective tape on the glove is highly visible because most of the torch light is bounced back (reflected) towards the camera. The black glove is less visible because nearly all of the white light from the torch is absorbed. The black glove will become hotter as the energy from the light is changed into heat.

Motion capture systems use cameras that have been changed to only pick up the bright light from the markers. The film footage is usually converted by a computer to show the reflective markers as dots. Using the positions of the markers a computer programme can then draw body parts around the dots. For example, Gollum in the film 'The Lord of the Rings' was produced using motion capture. A real man's movements were filmed and then Gollum's features were added after. To find out more see useful websites.



CAPTAIN AMERICA- *AFTER TAKING SUPER-SOLDIER SERUM HE CHANGED INTO THE "PERFECT" HUMAN - INTELLIGENT, STRONG, FAST, AGILE, IMMUNE TO MANY DISEASES AND AS DURABLE AS IT'S POSSIBLE FOR A HUMAN TO BE. THE FORMULA ENHANCES ALL OF HIS METABOLIC FUNCTIONS AND PREVENTS THE BUILD-UP OF TOXINS IN HIS MUSCLES. TO FLOW ROUND HIS BODY QUICKLY WHAT PROPERTIES SHOULD THE SUPER-SOLDIER SERUM HAVE?*

Resource list for artificial blood substitutes

- **clear tubing approximately 30 cm long (we used tubing with a diameter of approx 0.5 cm)**
- **a syringe (or funnel small enough to fit in the tubing)**
- **a bucket**
- **a measuring beaker or jug**
- **a stop watch**
- **a ruler**
- **10 ml of water**
- **10 ml of washing up liquid**
- **10 ml of tomato ketchup**

SAFETY TIPS: MAKE SURE THE END OF THE TUBING IS IN THE BUCKET BEFORE POURING THE LIQUID. CLEAN UP ANY SPILLAGES IMMEDIATELY.

1. Set up the equipment as shown in the picture. Hold the tubing in the bucket with the end just touching the bottom of the bucket.

2. Place the small end of the barrel of the syringe (or funnel) in the top of the tubing.

3. Measure out 10 ml of water.

4. Start the timer at the same time as you start to pour the water into the syringe.

5. Stop the timer as soon as the last drop of water comes out of the end of the tube.

6. Record the time in a table like the one below.

7. Repeat the experiment with the 10 ml of washing up liquid and finally the 10ml of tomato ketchup. Don't forget to write the time it takes for the substance to flow through the tube in your table.

   Now calculate the velocity (speed at which the fluid moves through the tube) of the fluid.

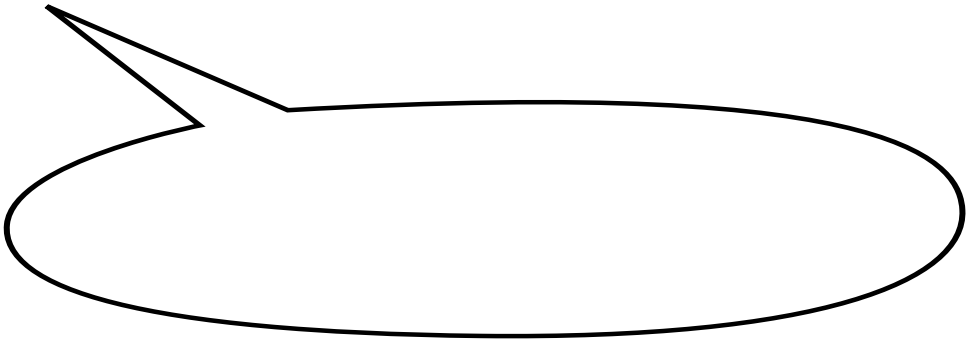
8. First measure the length of your tubing in centimetres and convert to meters by dividing by 100 e.g. a tubing length of 30 cm = 0.3 m

9. To calculate the velocity of the water divide this length by the time it took the liquid to flow through the tube.

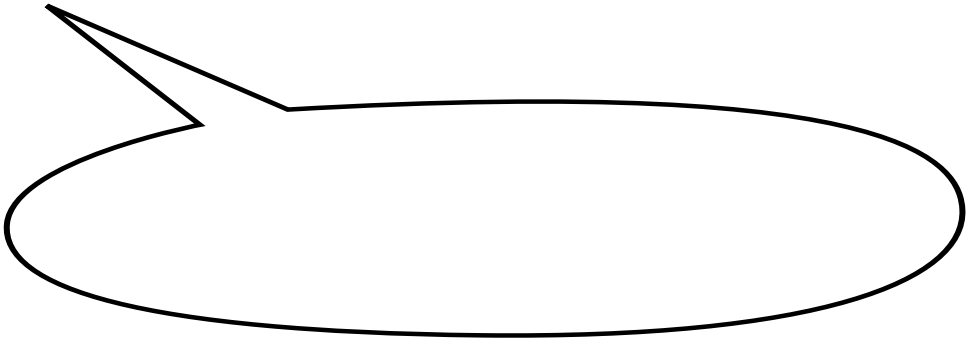
$$\text{Velocity (v)} = \frac{\text{Distance (d)}}{\text{Time (s)}}$$

BLOOD SUBSTITUTE	TIME (SECONDS)	VELOCITY (M/S)
WATER		
WASHING UP LIQUID		
TOMATO KETCHUP		

Which 'blood substitute' had the slowest velocity flowing through the tube?



Compare the blood substitute with the slowest velocity with the blood substitute with the fastest velocity. What differences do you notice in the properties of the liquid?



What is going on?

The particles in a liquid are close together, not arranged in order and move around each other. This is why liquids are able to flow and take the shape of their container. How easily the particles move over each other is a measure of viscosity (the resistance of a liquid to flow). Viscosity depends on the force holding the liquid particles together and the shape of the liquid particles. The greater the viscosity the more slowly the liquid flows. Ketchup is a viscous (thick) liquid.

Arteries and veins are flexible tubes called blood vessels. Arteries carry blood from the heart delivering oxygen and nutrients to body tissue. Veins return blood to the heart removing carbon dioxide and other waste products from the tissue. They also carry the cells of the immune system. Thick blood tends to coagulate (stick together) and form unwanted blood clots (lumps) that can block the blood flow to the heart or brain, causing a heart attack, stroke or death. Artificial blood substitutes are used to increase the volume of blood (if a person has had major blood loss) or to increase the amount of oxygen in the blood.

Extension Activity – if you have tubing with different diameters (hole sizes) try repeating the experiment only using water and changing the size of the tube. What happens to the velocity of the water when you increase the tube size?

WOLVERINE- HE HAS A NEARLY UNBREAKABLE METAL ALLOY ADAMANTIUM BONDED TO HIS SKELETON AND HIS BONES ARE ALMOST UNBREAKABLE WHICH INCREASES HIS STRENGTH. WHAT MAKES HIS BONES SUPER STRONG?

Tissue Engineering-bone strength

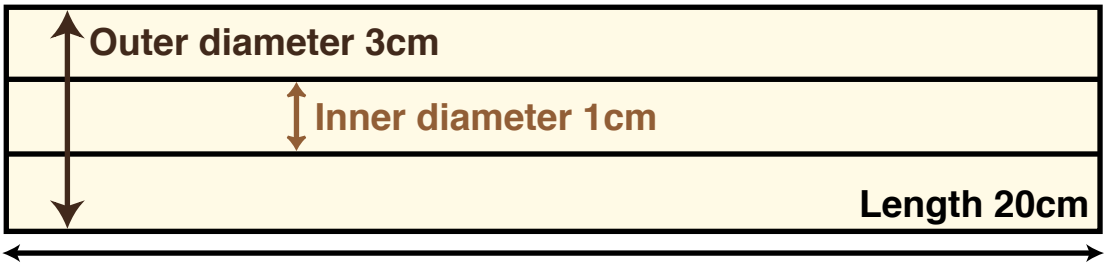
Resource list for bone strength

- **newspaper**
- **cardboard (tubes and flat sheets)**
- **play dough**
- **scissors**
- **rulers**
- **sellotape**
- **small bucket**
- **two clamps and support stands**
- **weights, sand or pennies (to act as the load)**

SAFETY TIPS: MAKE SURE THE THREE POINT LOAD TEST EQUIPMENT IS STRONG AND STABLE ENOUGH TO WITHSTAND THE MAXIMUM LOAD. WE RECOMMEND USING A MAXIMUM LOAD OF 2 KG AND INCREASING THE LOAD BY 50 G AT A TIME. SET UP THE TEST RIG WELL WAY FROM PEOPLE AND PLACE SOMETHING SOFT (E.G. A CUSHION) UNDERNEATH FOR THE BUCKET TO LAND ON IF IT FALLS.

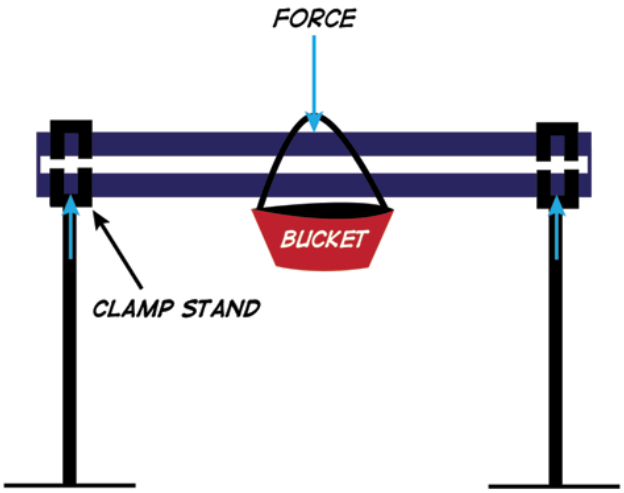
DESIGN TWO BONES THAT ARE AS STRONG AS POSSIBLE USING THE MATERIALS PROVIDED.

1. The first bone should be approximately 20 cm x 3 cm x 3 cm with a hole in the middle 1 cm x 1 cm. The overall diameter (width from one side to the other) should be roughly 7 cm.



2. The second bone should be the same size but fill the centre with play dough.

3. Set up the equipment as shown in the picture. Hold the bone to be tested in one clamp and slide the bucket over the free end of the bone. Secure the bone by clamping the free end.



4. Place the first load (50 g weight) in the bucket

5. Keep increasing the load by 50 g until the bone breaks or you reach 2 kg. Write down the weight in the bucket.

6. Replace the bone with the one with play dough in the middle

7. Repeat the experiment and take a note of the weight.

BONE	WEIGHT (G)
WITHOUT PLAY DOUGH	
WITH PLAY DOUGH	

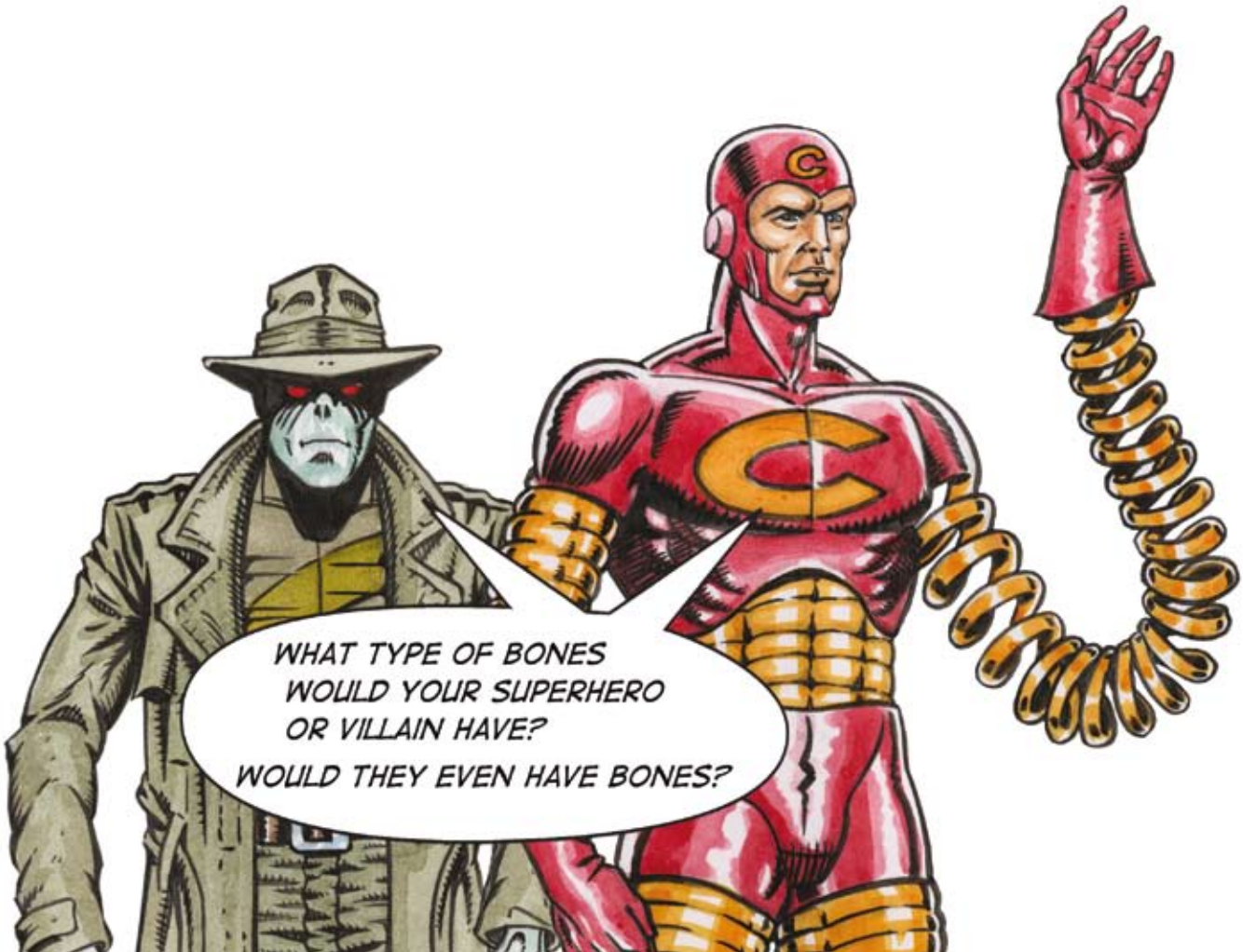
Which bone was stronger?

Why do you think it was stronger?

What is going on?

A hollow tube is weaker than a solid bar exactly the same size made from the same material. However, the hollow tube is lighter than the solid bar . If the solid bar was the same weight and length as the hollow tube it would be much thinner and weaker. Bones form our skeleton and help move, support and protect the body. They have a complicated structure that makes them very strong but also light-weight. The outside of the bone is made up of solid bone tissue and the middle is filled with spongy bone tissue.

Engineered bone can be used to speed up the healing of bones. A scaffold acts as a support structure for bone-producing cells (called osteoblasts). When the missing bone has been replaced the scaffold dissolves leaving the new bone behind. Why not do an internet search to find out what other body parts have been tissue engineered?



PLASTIC MAN, MR FANTASTIC, ELONGATED MAN AND ELASTIGIRL- THEY CAN STRETCH THEIR BODY PARTS TO SUPERHUMAN SHAPES, LENGTHS AND SIZES. BUT HOW DO THESE SUPERHEROES CHANGE SHAPE?

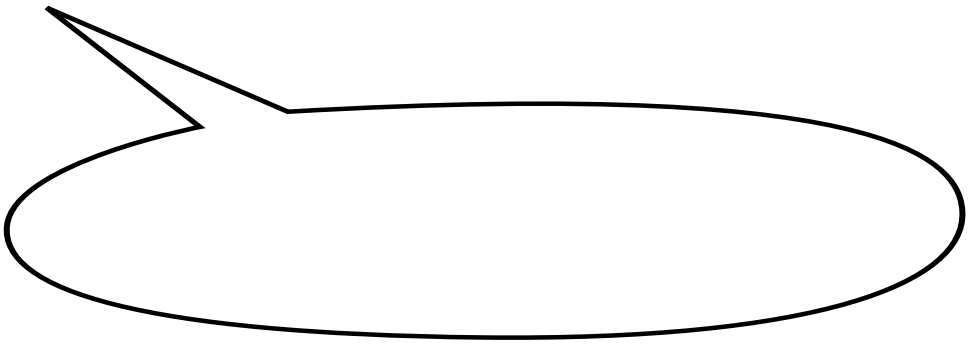
Tissue Engineering-polymorph plastic

Resource list for polymorph plastic

- **polymorph plastic (can be obtained from www.mutr.co.uk)**
- **heatproof watertight container**
- **washing up gloves**
- **hot water at 65ºC to melt the polymorph plastic pellets**

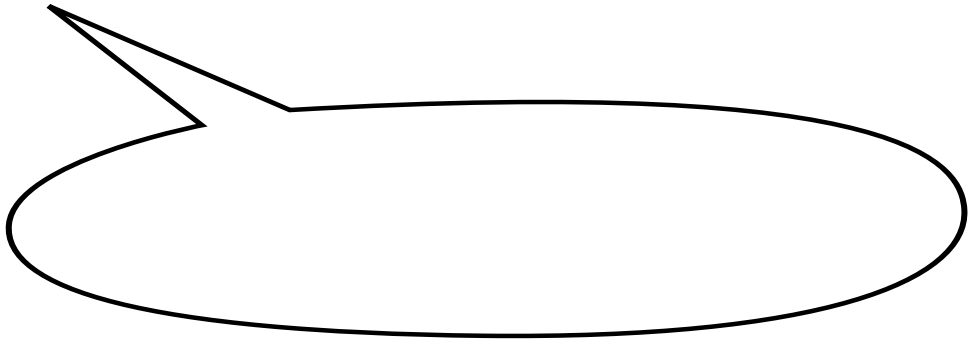
SAFETY TIPS: BE VERY CAREFUL WITH HOT WATER. TO PREVENT SPILLS ONLY PLACE A SMALL AMOUNT OF HOT WATER IN THE CONTAINER (JUST ENOUGH TO COVER THE POLYMORPH). DO NOT HEAT THE POLYMORPH ABOVE 60-65ºC. ABOVE 65ºC THE POLYMORPH CAN BECOME STICKY AND ADHERENT PRESENTING THE SAME HAZARD AS HOT-MELT GLUE. USE WASHING UP GLOVES TO LIFT THE POLYMORPH OUT OF THE HOT WATER AND SQUEEZE TO REMOVE ANY TRAPPED WATER. CHECK THE POLYMORPH PLASTIC IS COOL ENOUGH TO HANDLE BY GENTLY TOUCHING IT WITH YOUR BARE FINGER.

1. Write down the properties of the polymorph plastic pellets-are they liquid, soft, warm, magnetic, etc?

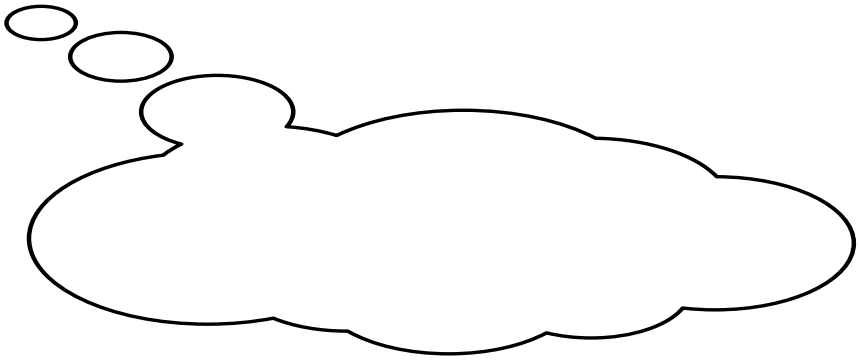


2. Now place the polymorph plastic (approx. half a teaspoonful of polymorph plastic per person) in hot water at 65ºC for approx. 5 minutes. Remove the polymorph plastic wearing washing-up gloves and squeeze out any trapped water. If you are testing the properties of the polymorph plastic with your bare hands make sure it is cool enough to touch.

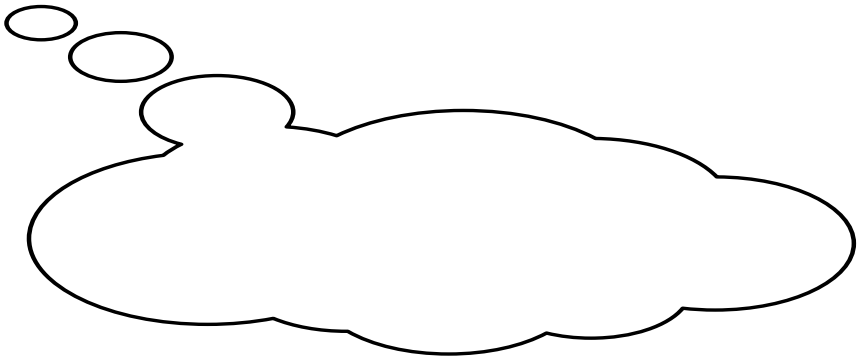
3. Write down the properties of the polymorph plastic immediately after it has been heated and while it cools down -is it liquid, soft, warm, magnetic, etc?



Look at the polymorph plastic properties you discovered when it was hot and cold. What parts of the body do you think could be replaced with polymorph plastic to create super powers?



When heated the polymorph plastic can be reshaped over and over again. Can you think of any benefits this might have for a superhero or villain?



What is going on?

The cold plastic is a hard opaque solid. When its heated above its melting point the plastic properties change and it becomes a clear, warm, mouldable solid. It can be stretched, pulled apart and the pieces moulded back together again, bent and even bounces! As it cools down past the melting point the properties change and it once again becomes hard and inflexible.

If Plastic Man was made completely from polymorph plastic, when heated he would be stretchable, flexible, capable of being reassembled and could form almost any shape but he wouldn't be human. Have a look at the properties of the polymorph plastic. Can you think of any weaknesses his enemies might be able to use to their advantage?

THE JOKER- HE IS A MASTER CRIMINAL WITH A CLOWN-LIKE APPEARANCE WHO OFTEN APPEARS TO 'DIE' BUT ALWAYS MANAGES TO RETURN UNHARMED AND FULLY ALIVE. DOES HE HAVE A SECRET LAB WITH A TEAM OF TISSUE ENGINEERS GROWING NEW BODY PARTS AND GRINS?

Tissue Engineering-tissue engineer a finger

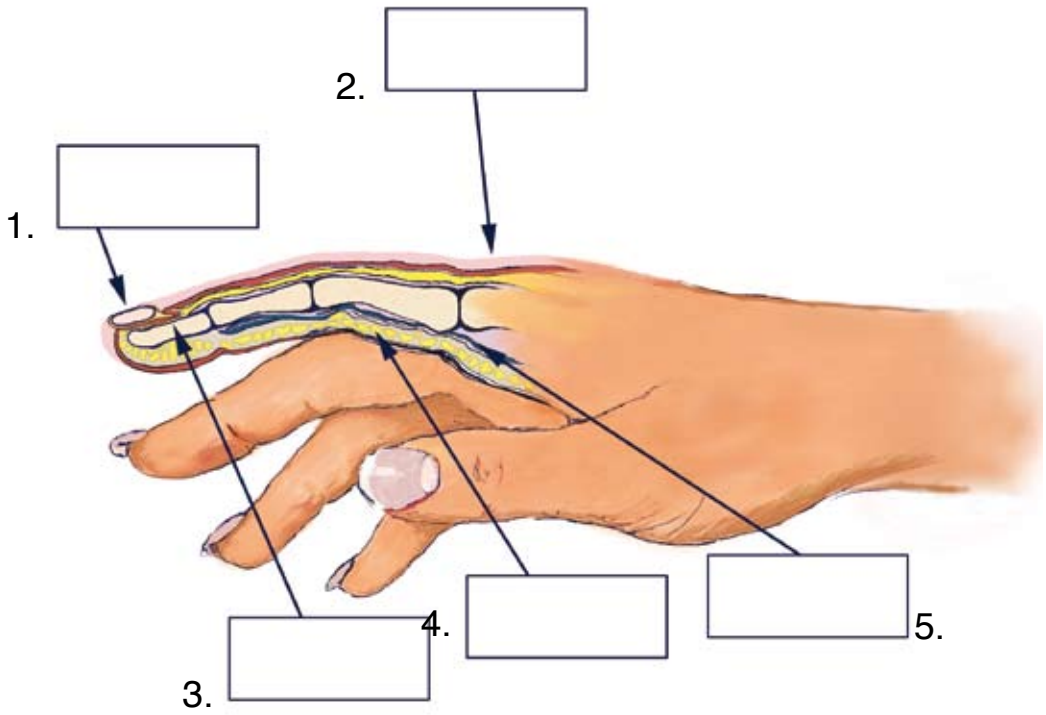
Resource list for tissue engineer a finger

- **polymorph plastic (can be obtained from www.mutr.co.uk)**
- **hot water at 65ºC to melt the polymorph**
- **deep heatproof watertight container**
- **washing up gloves**
- **cotton wool**
- **flesh coloured tissue paper**
- **blue and red thread**
- **glue**
- **scissors**
- **plain paper**

Your finger is made up of bone, tissue, blood vessels, skin and nail.

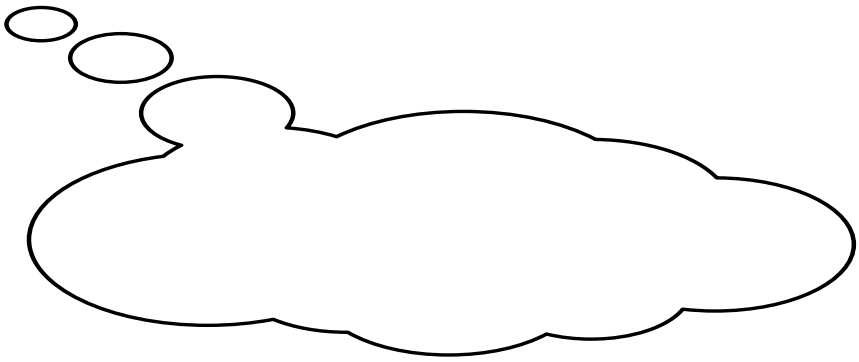
1. Match the parts of the finger (bone,tissue,blood vessels, skin and nail) to the picture and write the correct part in the box.

   To find out the answer see the Useful Website Section



2. Now using the materials listed above create a model of a finger. Your model finger should have a bone, arteries, veins, tissue, skin and a nail.

What do you think provides tissue, skin and bones with the nutrients they need to stay alive?



What is going on?

To create a finger we need to start by making a bone (polymorph) which acts as a frame for the tissue. Next attach the tissue (cotton wool) to the bone making sure there are blood vessels (blue and red thread) throughout the tissue supplying it with nutrients. Now you need some skin (tissue paper) to cover the tissue. Finally attach your fingernail (plain paper) to the end of your finger.

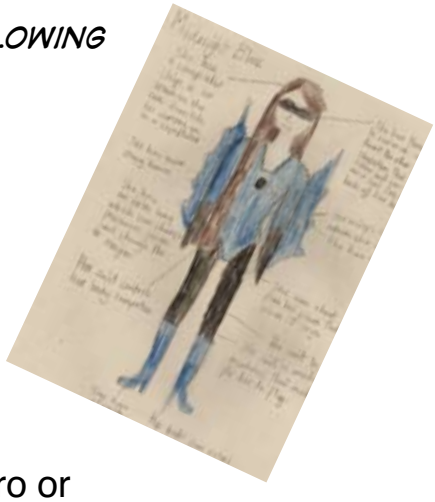
Some body tissues can repair themselves but it often takes a long time. Even small cuts and grazes take a while to heal. Tissue engineers use cells, materials, chemicals and their engineering, biology, chemistry and physics knowledge to improve or replace biological functions and tissues (e.g. bone, blood vessels, liver, etc). To grow an organ cells are placed on specially constructed scaffolds. These biological scaffolds are used to form a structure which the cells can grow on. If the environment (i.e. temperature, scaffold surface, food) is right the cells attach and start to grow. To stay healthy and continue growing the cells need a supply of food and to be able to get rid of their waste products.

PART 3: INVENTING YOUR OWN SUPERHERO OR VILLAIN

"IMAGINATION IS MORE IMPORTANT THAN KNOWLEDGE. FOR WHILE KNOWLEDGE DEFINES ALL WE CURRENTLY KNOW AND UNDERSTAND, IMAGINATION POINTS TO ALL WE MIGHT YET DISCOVER AND CREATE"- ***ALBERT EINSTEIN***

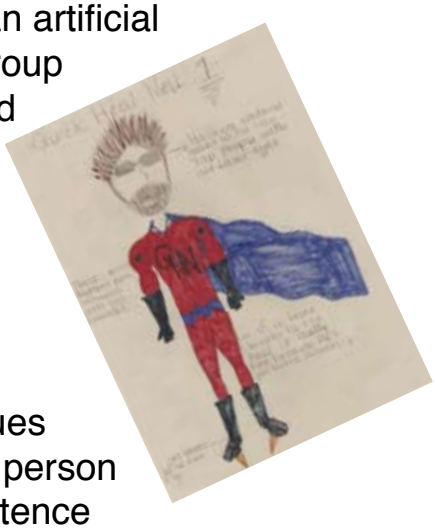
CREATIVE THINKING TECHNIQUES

STUCK FOR SUPERHERO AND VILLAIN IDEAS? TRY SOME OF THE FOLLOWING CREATIVE THINKING TECHNIQUES:



1. Get everyone to sit in a circle. Go round the circle with everyone introducing the person on their left (or right) as a well known superhero or villain, e.g. this is Spider-Man who got his powers when he was bitten by a radioactive spider and he can climb walls, shoot webs, etc.

   Then go round the circle with everyone introducing the person on their left (or right) as their own made up superhero or villain, e.g. this is Captain T who got his powers when the army rebuilt him after he was caught in an explosion during the war and he has an exoskeleton made from titanium, a bionic eye, etc.



2. Print out pictures of bioengineering technologies, e.g. an artificial lung, artificial artery, etc. Pass the pictures round the group with everyone telling a story about what the object could be. Then go round again but this time with everyone guessing what the object is. For example, an artificial lung could be a pencil sharpener with numerous holes for different sized pencils.

3. Start a story about a superhero ending the introduction with a cliff hanger. The next person in the group continues the story starting their sentence with, "fortunately". The person next to them continues the story but they start their sentence with the word "unfortunately". Go round the group continuing the story with each alternating sentence starting with fortunately and unfortunately.

'IT WAS SUNNY DAY WHEN THE JONES FAMILY DECIDED TO TAKE A TRIP TO THE SEASIDE. THEY PACKED THE CAR AND DROVE OFF. SUDDENLY HEADING DOWN CRAGGY BENDS THE BRAKES FAILED. FORTUNATELY THE SUPER HEROINE MIDNIGHT BLUE WAS GLIDING PAST. UNFORTUNATELY THE CAR HAD VEERED OFF THE ROAD AND WAS HANGING OVER THE CLIFF EDGE. FORTUNATELY MIDNIGHT BLUE.....'

THEN INTRODUCE SUPERHEROES AND VILLAINS.

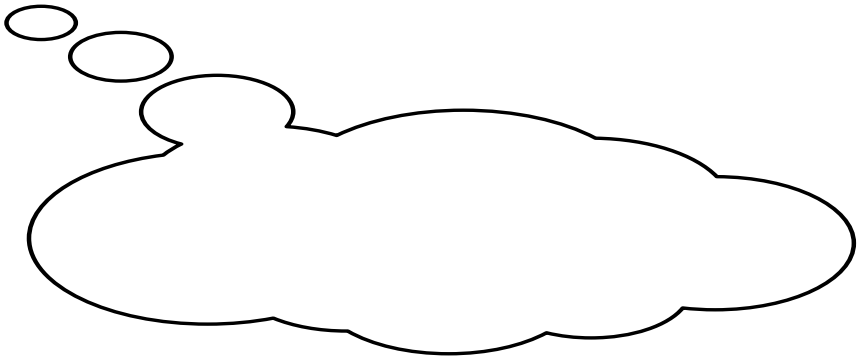
'ONE DAY THE WORLD WENT DARK AND EVERYONE HEARD A BOOMING VOICE. THE VOICE FILLED STREETS, OFFICES AND HOMES ALL OVER THE WORLD. THE VOICE TOLD EVERYONE THAT THE WORLD AS THEY KNEW IT HAD ENDED. NO MORE GREEN GRASS OR BLUE SKY, NO MORE I-PODS OR COMPUTER GAMES. EVERYONE IS NOW THE SLAVE OF THE NEW RULER AND NO ONE CAN STOP THEM..... FORTUNATELY LAB LEAH, A SUPERHERO WITH SIXTH SENSE, WAS ABLE TO LOCATE WHERE THE VOICE WAS COMING FROM. UNFORTUNATELY THE VILLAINESS SIREN SONG WAS NOW USING HER ARTIFICIAL VOICE BOX TO MAKE EVERYONE FEEL ILL AND LAB LEAH WAS POWERLESS. FORTUNATELY THE SUPER HEROINE NEMO WAS UNAFFECTED AND ABLE TO USE HER THERMOCHROMIC SUPER SUIT TO DISGUISE HERSELF AND.....'

DEVELOPING YOUR SUPERHERO OR VILLAIN

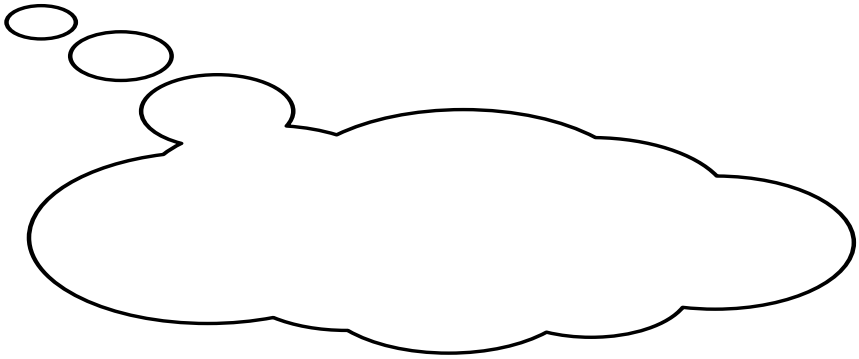
CHOOSING YOUR SUPER POWERS

Answering these questions will help you create your super powers.

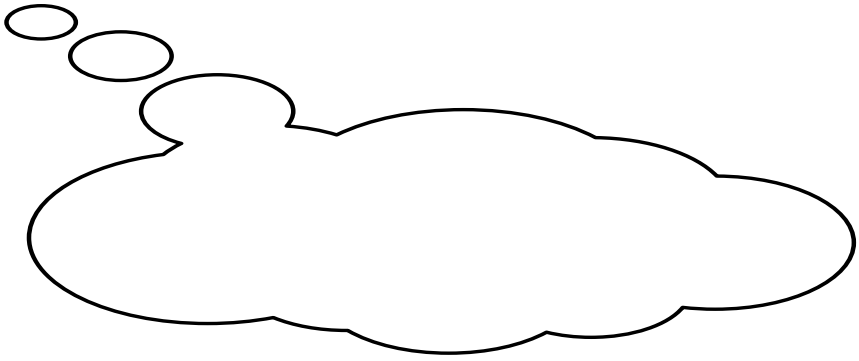
1. *What bioengineering technologies will you use for your character's powers e.g. a cochlear implant to improve hearing?*



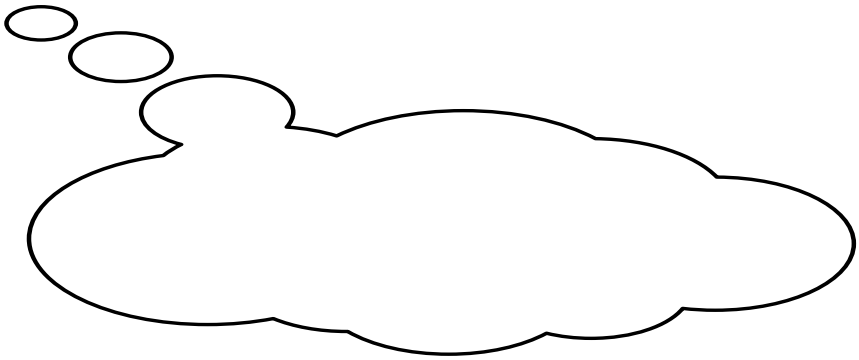
2. *Are there any technologies that you can add to improve your super power e.g. linking the cochlear implant with satellite communication technologies?*



3. *How does the power work? Could it be scientifically possible in the future? For example, if your character has polymorph plastic parts how do they heat the polymorph plastic up? How do they get back to their normal shape? And don't forget they will only be able to stretch so far before the polymorph is stretched to the limit and breaks!*

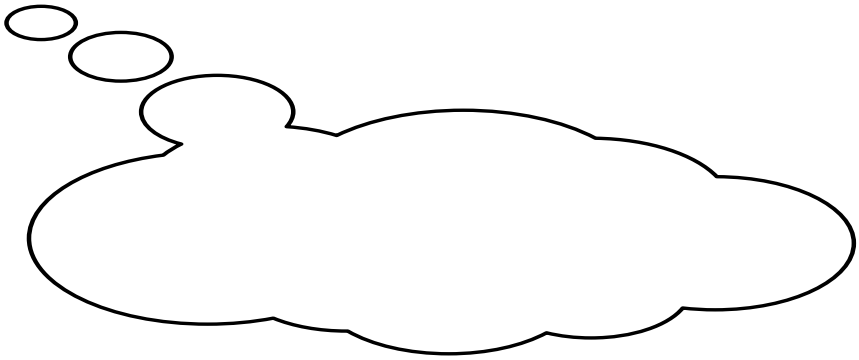


4. *What are their weaknesses and strengths e.g. how will you stop people listening in to your satellite communications or using devices to heat and cool your polymorph parts ?*

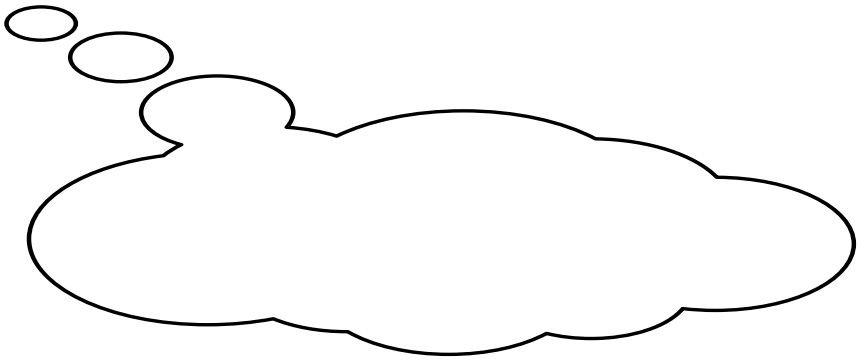


BRINGING YOUR CHARACTER TO LIFE

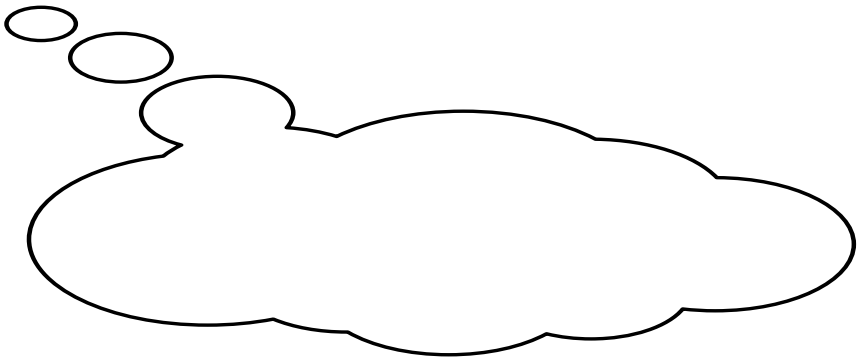
1. *How did your character obtain their powers? For example, they might have lost their hearing in an explosion and when the surgeon operated he put in the wrong implant - well they do very occasionally cut off the wrong leg!*



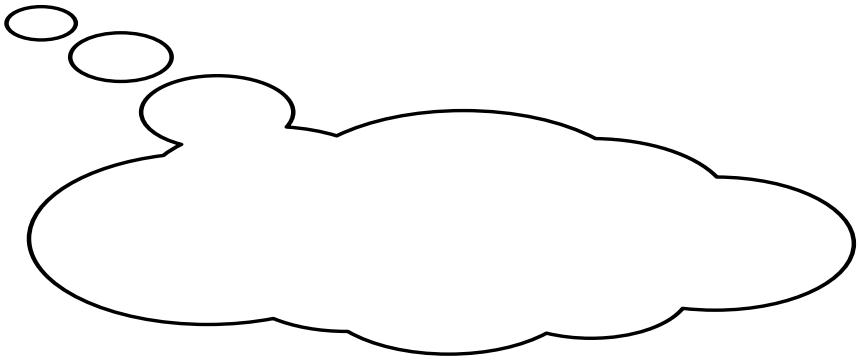
2. *Will their bioengineering super power be used for good or evil? If you are developing a villain why are they bad? Are they trying to get power, money or both? Perhaps they had a bad reaction to the technology?*



3. *Are they male or female?*



4. *What does their super-suit look like e.g.underpants on the inside or out and are capes really out of fashion*



NOW YOU ARE READY TO DRAW A PICTURE OF YOUR CHARACTER THAT SHOWS THEIR SUPER POWERS.

CREATING COMIC STRIPS

Work out how you are going to tell the story of your character and how they got their superpowers in comic strip format. Before you start your comic strip why not have a look at other comic strips to get ideas?

A comic strip has pictures in rectangular and square panels with balloon captions and a few short descriptions.

The story should flow from left to right.

Use smaller rectangles to show actions close up or pictures that have fewer details in them. Larger rectangular panels are used when you want to show more information or events that take place in the distance. To get ideas think about the way things are framed in films and on TV.

See useful websites for further information on comic strips and graphic novels.

USEFUL WEBSITES

Please note that we cannot be held responsible for the content or accuracy of any website mentioned in this resource pack. At the time of printing (October 2007) the website links were accurate, but may have subsequently changed.

First stop visit the engineering super powers website
www.engineeringsuperpowers.org

BBC website 'The Science of Superheroes'
www.bbc.co.uk/science/hottopics/superheroes/index.shtml

Extension Activity - Test your memory
http://www.bbc.co.uk/science/humanbody/sleep/tmt/

Extension Activity – Make your own edible lipstick
http://www.planet-science.com/parents/index.html?page=/parents/home.html

Motion Capture Part 2 – Generating Gollum
http://express.howstuffworks.com/gollum.htm

LTScotland - Reading and Making Comics
http://www.ltscotland.org.uk/literacy/findresources/graphicnovels/section/readingcomics.asp

WikiHow – Make a comic
http://www.wikihow.com/Make-a-Comic

ANSWERS

SUPERHERO AND VILLAIN QUIZ ANSWERS

SUPERMAN

Super Power Possible?

incapable of being injured or damaged **no**

vision powers

(telescopic, infra-red and microscopic vision) maybe possible in future with a bionic eye

accurately remembers images sounds and objects **yes**

super hearing maybe possible in future with a hearing aid

ELASTIGIRL

Super Powers Possible?

very flexible and able to stretch could be possible but not in the near future

super strength **yes**

BATMAN

Super Powers Possible?

superior human ability in martial arts, acrobatics and escape artistry

yes

large selection of specialized gadgets e.g. the Batmobile yes

a belt that contains explosives, infra-red flash light, smoke capsule, fingerprint equipment, miniature camera, pass keys, tiny oxyacetylene torch, gas capsule

yes

POISON IVY

Super Powers Possible?

skin poisons that kill **yes**

toxic lipstick **yes**

killer plants **yes**

DR OCTOPUS

Super Powers Possible?

A harness with arms that are controlled by the brain **yes**

can lift up to nine tons or two African elephants each **yes** (but he might fall over)

allow him to move rapidly (50 miles per hour) over any ground may be possible in future

SPIDER-MAN

Super Powers Possible?

able to cling to walls / stick to most surfaces may be possible in future with a gecko suit

fast and nimble with perfect balance and stability **yes**

night vision may be possible in future with a bionic eye

ability to shoot / spin webs yes but only using a gadget

BIOENGINEERING QUIZ ANSWERS

Technology It is.....

bionic eye still being developed

artificial heart still being developed

[artificial hearts that work inside the body are still being developed and not routinely used but there are heart pumps that work outside the body]

artificial arteries in use

artificial lung in use

[artificial lungs that work outside the body are routinely used but artificial lungs that work inside the body are still being developed]

hip joint prosthesis in use

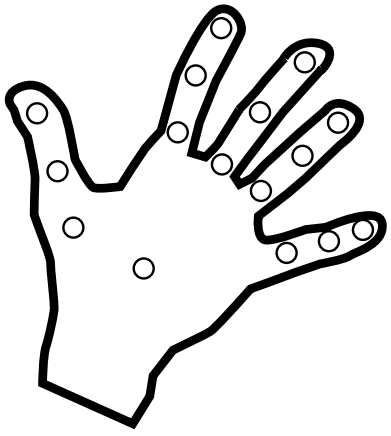
artificial leg in use

MOTION CAPTURE ANSWERS

A–4, B-5, C-1, D-3, E-2

TISSUE ENGINEERING AND FINGER ANSWERS

1. NAIL
2. SKIN
3. BONE
4. TISSUE
5. BLOOD VESSEL



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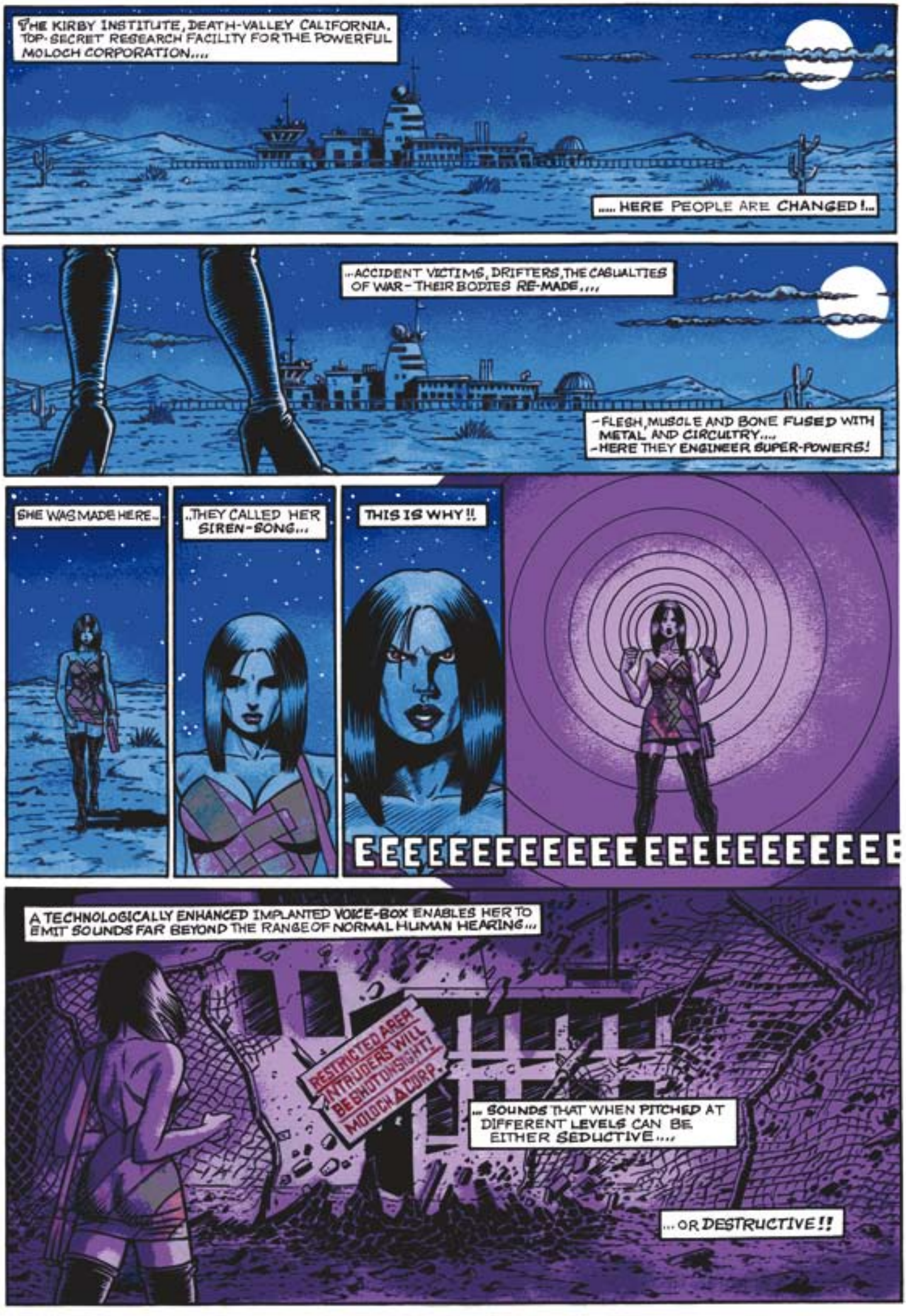
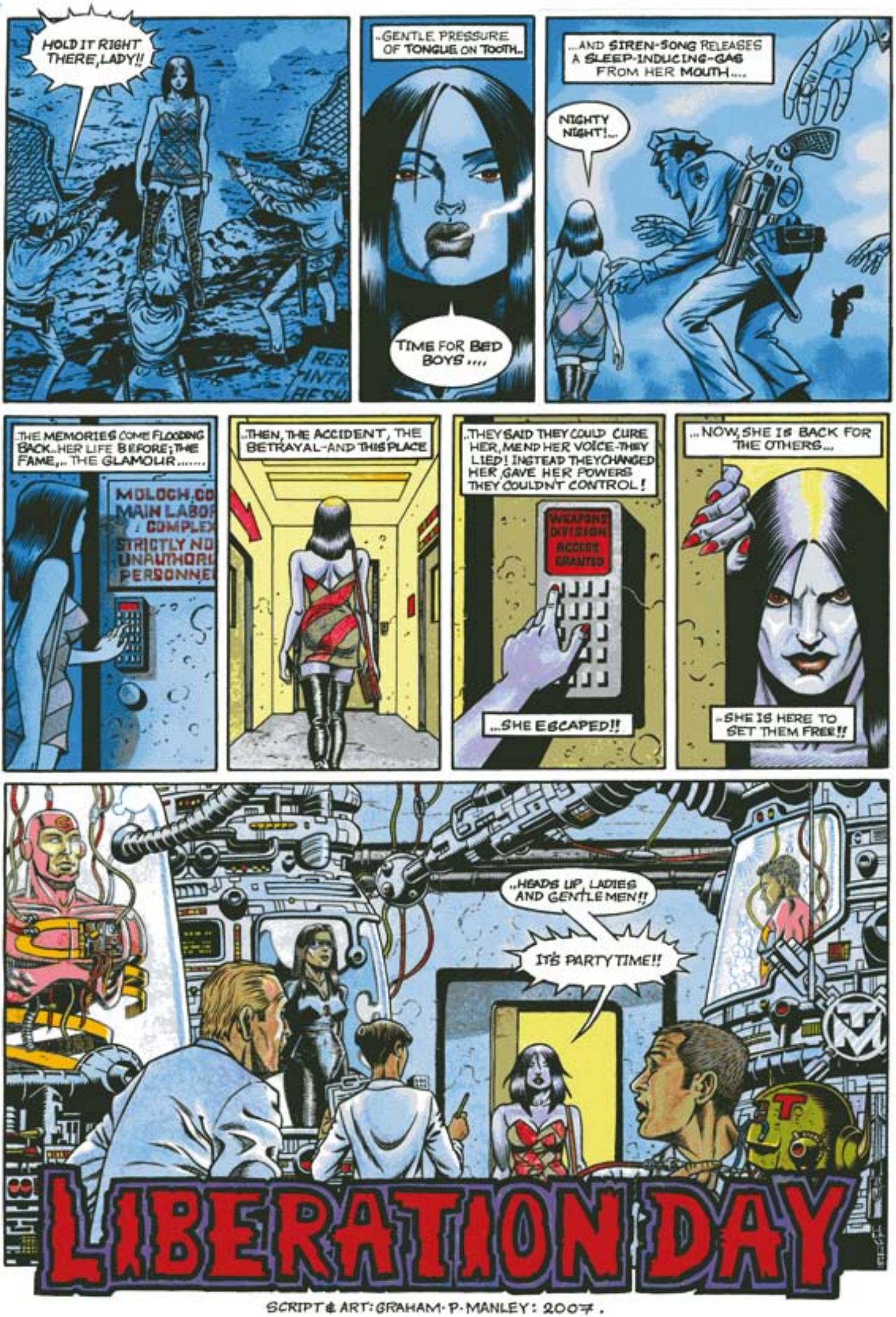

THE KIRBY INSTITUTE, DEATH-VALLEY CALIFORNIA. TOP-SECRET RESEARCH FACILITY FOR THE POWERFUL MOLOCH CORPORATION....
.... HERE PEOPLE ARE CHANGED!...
...ACCIDENT VICTIMS, DRIFTERS, THE CASUALTIES OF WAR - THEIR BODIES RE-MADE....
- FLESH, MUSCLE AND BONE FUSED WITH METAL AND CIRCUITRY....
- HERE THEY ENGINEER SUPER-POWERS!
SHE WAS MADE HERE...
..THEY CALLED HER SIREN-SONG...
THIS IS WHY!!
EEEEEEEEEEEEEEEEEEEEEEEEE
A TECHNOLOGICALLY ENHANCED IMPLANTED VOICE-BOX ENABLES HER TO EMIT SOUNDS FAR BEYOND THE RANGE OF NORMAL HUMAN HEARING...
RESTRICTED AREA INTRUDERS WILL BE SHOT ON SIGHT! MOLOCH CORP.
... SOUNDS THAT WHEN PITCHED AT DIFFERENT LEVELS CAN BE EITHER SEDUCTIVE....
... OR DESTRUCTIVE!!



SCRIPT & ART: GRAHAM·P·MANLEY: 2007.


MERIDIAN CITY: ONE YEAR LATER....
'...SIR?...'
'...I'M PICKING SOMETHING UP, SIR.....'
'...SOMESORT OF, UH, SUPER-BEING....'
COMMUNICATIONS & SURVEILLANCE CENTRE: MOLOCH CORPORATION H.Q....
...SHALL I CONTINUE TRACKING, SIR?...
...IT'S PROBABLY KILLCAT! SHE'S OF NO INTEREST TO US....SHE'S A FREAK, A VIGILANTE! - SHE'S NOT ONE OF THE PROGRAM...
...BUT...ON THE OTHER HAND.... SHE MAY LEAD US TO ONE OF THE OTHERS..
KEEP WATCHING HER!!....
'.. THESE TYPES MIGHT HAVE A TENDENCY TO SEEK EACH OTHER OUT..'
KILLCAT!!.. WE NEED TO TALK..
WHA-?!!
WHO?-WHAT THE HELL ARE YOU?!!
.. I AM CALLED COILER... ...THIS IS MIDNIGHT BLUE... — KILLCAT, WE NEED YOUR HELP!...THERE IS A GREAT DANGER COMING TO ALL OF US THAT ARE.... "DIFFERENT!!"...
"...DIFFERENT?!!?" -LOOK, I DON'T KNOW YOU AND I DON'T CARE ABOUT YOUR 'DANGER' - I WORK ALONE AND I LIKE IT THAT WAY....


...WAIT !!— YOU DON'T UNDERSTAND...
—I CAN TAKE CARE OF MYSELF!!...
-KILLCAT— PLEASE... COME WITH US— WE HAVE SOMETHING TO SHOW YOU !!
..DO I HAVE TO SPELL IT OUT...
.....I'M NOT INTERESTED!!!
NOW, WHAT HAVE WE GOT HERE ?!? IT SEEMS YOU CAN'T TURN AROUND IN THIS TOWN WITHOUT BUMPING INTO A BUNCH OF WEIRDOS' !!??!!
..WELL, WELL, .. IF IT ISN'T TINKERBELL AND THE HUMAN--SPRING!!—AND I SEE YOU'VE PICKED UP A LITTLE FRIEND!!
.. ANYWAY, I'M HERE TO OFFER YOU A CHOICE - IT'S QUITE SIMPLE REALLY.. EITHER JOIN MY LITTLE GROUP— OR DIE!!
...AND AS FOR YOU, KITTY--KAT... YOU'D BETTER DECIDE WHOSE SIDE YOU'RE ON 'COS THINGS ROUND HERE ARE ABOUT TO GET MESSY!!!
TO BE CONTINUED!!