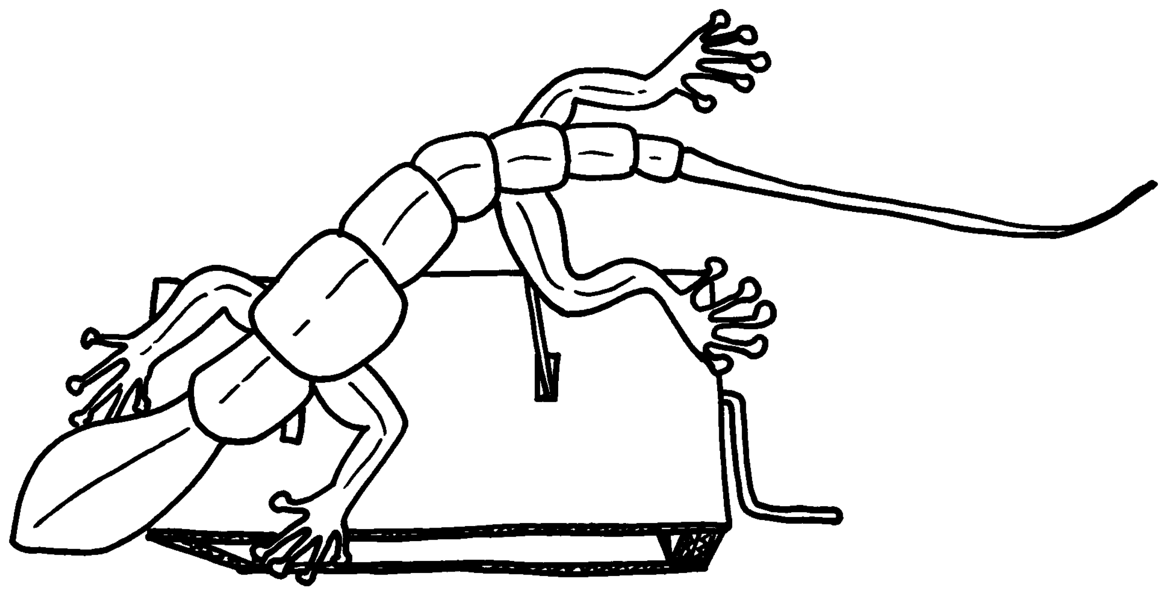
HOW TO DESIGN AND MAKE SIMPLE Automata

ROBERT ADDAMS



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The web site is an educational tool available to everyone worldwide.
As well as providing general information it also supplements parts of the book.

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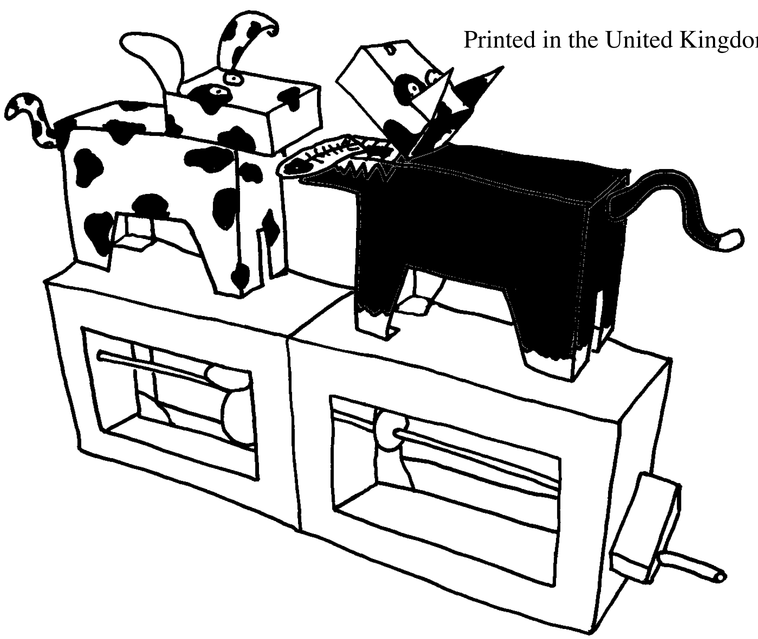
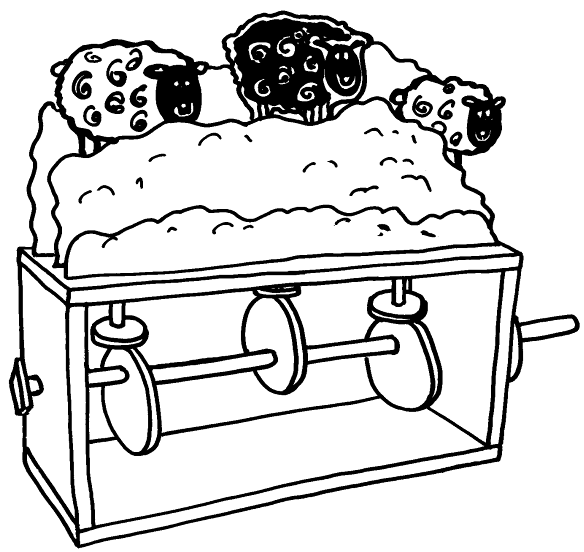
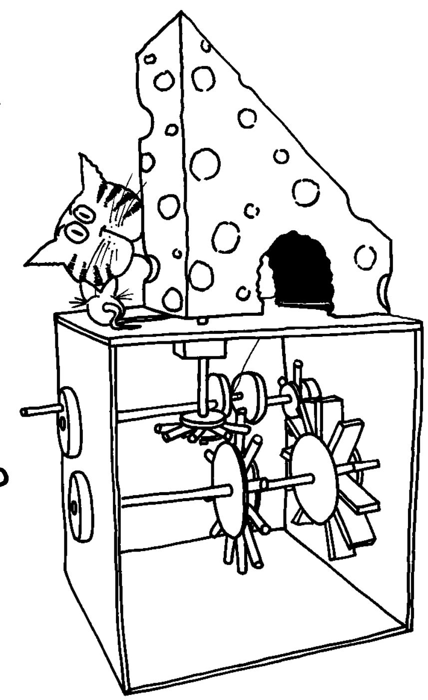






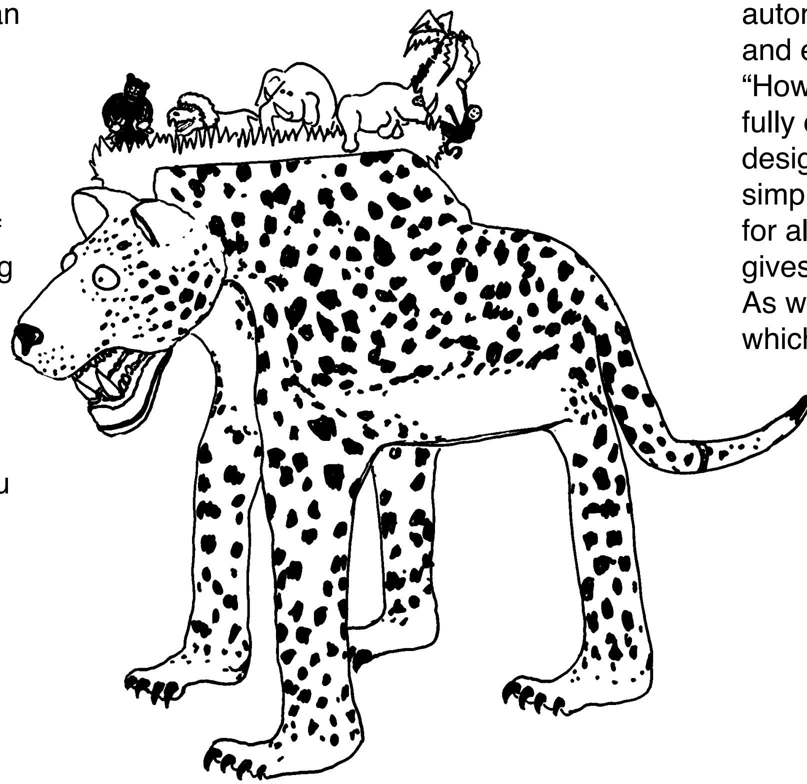
This book is dedicated with grateful thanks to my long suffering wife, Beverley, to whom I owe so much and to my 3 sons Toby, Oliver and Dominic who helped to test the automata featured in this book to destruction, also to my Mum, for the hours spent proof reading.

CONTENTS

INTRODUCTION

This book is intended as an overview to the mechanical principles behind automata, as well as guiding the reader through the design process to make successful, exciting automata with young children aged 7-11.
The book also looks at construction methods, materials and useful tools.
In essence this book will provide both a stimulating project base for teachers delivering Design and Technology at Key Stage 2, and help with lesson planning for the national curriculum. Sections of the book can also be photocopied so teachers can then disseminate the information to their class in the way they feel is most effective.
It also serves as a guide to those people interested in making their own simple automata but are deterred by the thought of having to have lots of tools for wood working or a workshop. All the automata featured in this book are made from card or paper, the only wood used is for the drive shafts, this can be a barbecue stick or 5mm wooden dowel which can be easily cut. It is full of ideas, tips and information and provides you with the perfect introduction to making your own simple automata.

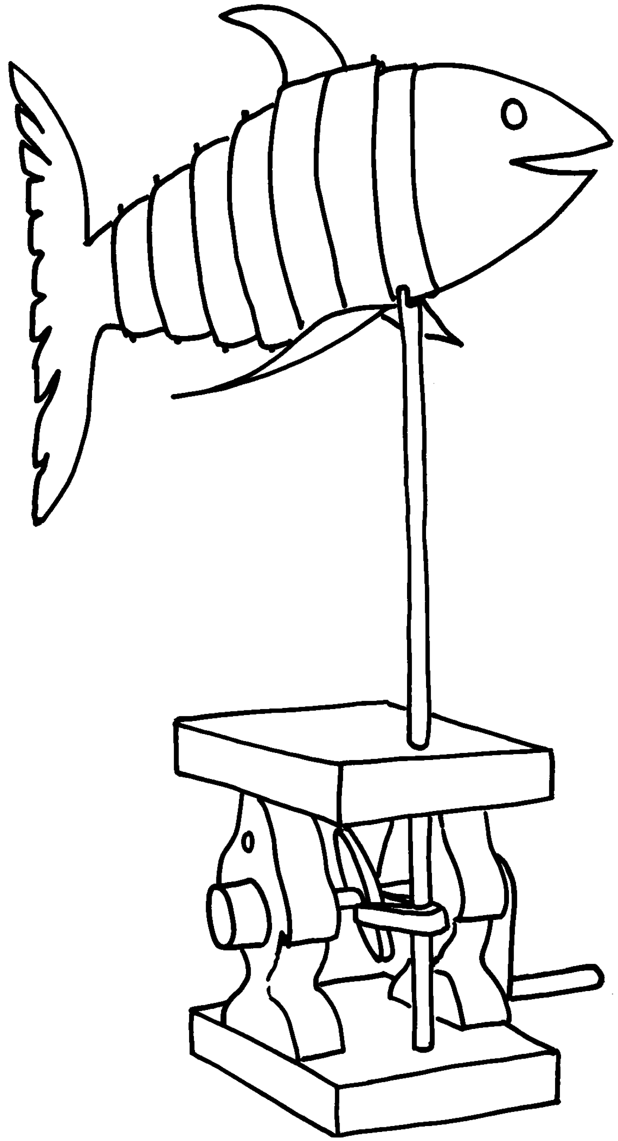
Automata are fascinating mechanical marvels that utilise a wide range of the mechanical processes found in modern machinery.
Designing and making automata covers a range of skills and processes from art, engineering and maths through to craft skills using card, wood and metal. It is a complex process that has a lot of potential for stimulating the imagination of children and providing a fun, practical learning platform.



Design and Technology in the National Curriculum provides a wide scope for the teacher to explore. The designing and making of automata lends itself extremely well to this subject, encompassing all of the major criteria that need to be covered. Importantly, it allows this to be done in a fun and stimulating way.
Many teachers already set projects based on automata and this book will be a useful guide for expanding upon this. It also provides a comprehensive look at all aspects of automata making, as well as suggesting fresh and exciting ideas for inclusion into lessons.
“How to Design and Make Simple Automata” fully covers all aspects of the mechanical, design and construction processes, from simple to more complex automata. It caters for all student abilities and skill levels and gives valuable advice on the design stage.
As well as providing a sound basis from which to evaluate project work.

THE NATIONAL CURRICULUM

Every child in the UK has to undertake some form of Design and Technology activity. The design and making of automata is a great way of meeting the curriculum requirements.
It encompasses all the elements needed for key stages 2, QCA units 3C, 5C, and 6C.
In education terms this book is designed to be a guide rather than offering prescriptive, pre-packaged course work, and to give practical advice as well as suggestions and ideas to be included in lessons. The A4 format can be easily photocopied for use as handouts or wall charts. The design process has been covered in detail in order to meet the basis of Design and Technology curriculum requirements.
The emphasis is on working with card and paper as well as household packaging material, which introduces the topic of re-cycling.
A number of patterns have been included which you may find useful as a practical introduction to unit 5C "Moving Toys".



MAKING A START

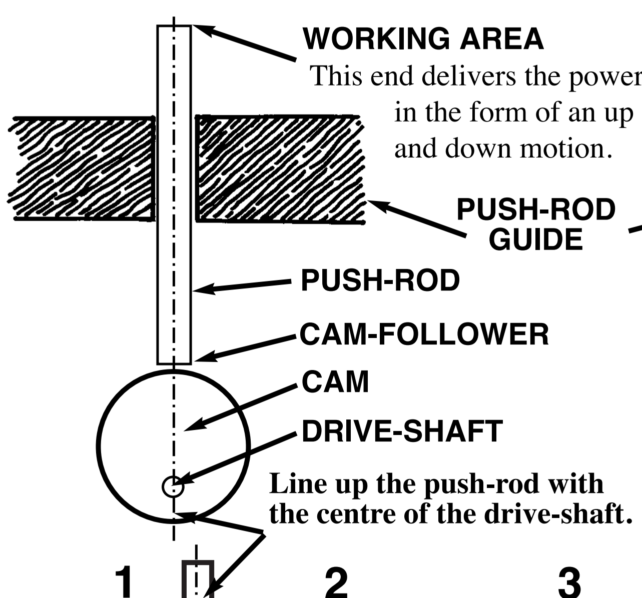
Although aimed at teachers and young children this book will be of great benefit to anybody interested in making simple automata or any other mechanical device, sculpture or toy. If you are not involved in education, parts of the design process can be tackled in a less structured way, without the need to be accountable to an assessor.
The book is broken down into logical sequences, starting with mechanisms. You will need to study this section first as it underpins all the concepts and principles needed to make any automata or mechanical device. It should also help with ideas for your own projects. Feel free to copy or adapt any of the examples featured.
All creative work involves challenges, difficulties, triumphs, tragedies and rewards. Making automata will offer these in abundance but do not lose sight of the need to keep it a fun and enjoyable process.

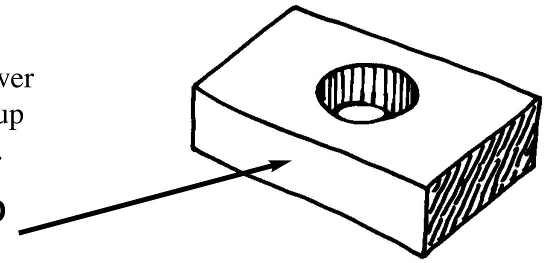
CAMS

Cams act like small computers, storing information that can be turned into movement. They can be very simple or complex, the only limitation is their size.

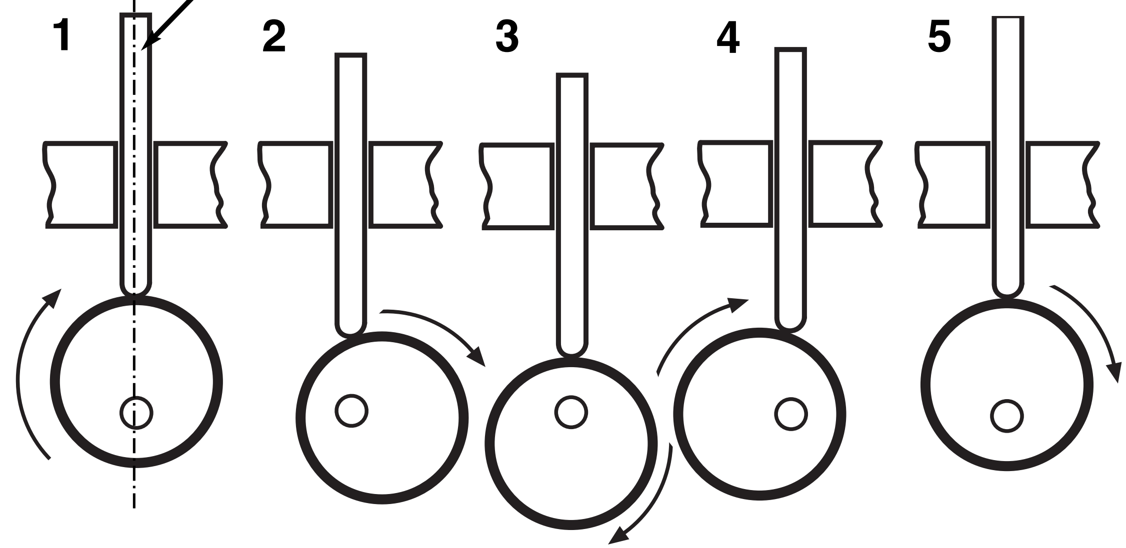
The basic principle of the cam is to turn a circular motion into a linear one. This is referred to as reciprocating movement. In it’s simplest form you turn a handle to make something move up and down.

The cam is very useful for automata and is probably the most commonly used mechanical action. As you will see, the cam is simple to make and very versatile.
Cams work in conjunction with a "Cam-Follower". As the name implies this follows the movement of the cam and transfers the movement to the working area. The cam-follower is connected to, and part off, a shaft known as the “Push-Rod”. The push-rod controls the direction of motion and transfers the cam’s movement. The cam-follower should be designed with a smooth end that can easily follow the cam’s contours and movement. This is very important as the cam and follower will jam if not properly designed. The cam-follower should line up with the centre of the cam and the “drive-shaft” it is attached to. When making simple automata, the best mechanism to start with is the cam as it is the simplest to make and operate.





This block supports and guides the push-rod preventing it wobbling from side to side. This helps the push-rod to only move up and down. In order for the follower to rise and fall without jamming. It is important to make this guide fairly thick and reasonably close to the cam. Always align the push-rod to the centre of the cam.

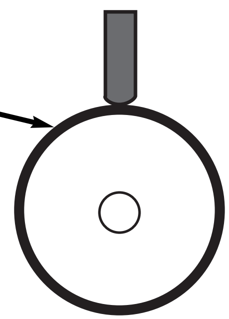


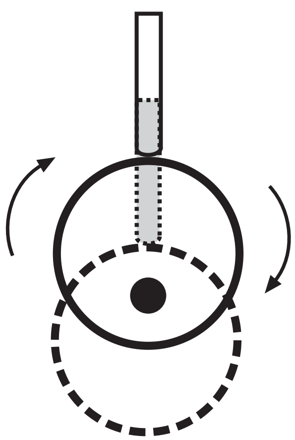
This cam is turning a circular motion into an up and down one. This is referred to as reciprocating motion. As you can see in diagrams 1-5, the cam-follower steadily drops before rising up again. The whole process repeats as long as the cam keeps rotating clockwise.

CAMS

In order to design a cam you need to know what you want it to do. It may have just one or several movements per revolution.
Cams turn on a shaft and so need to be offset to create movement. If you have a circle with the shaft running through the centre then nothing happens. However, if you offset it you can create a mechanism that can lift. With this lift you can create many marvellous automata.

A circle with a drive shaft running through the centre will simply turn and produce no lift.

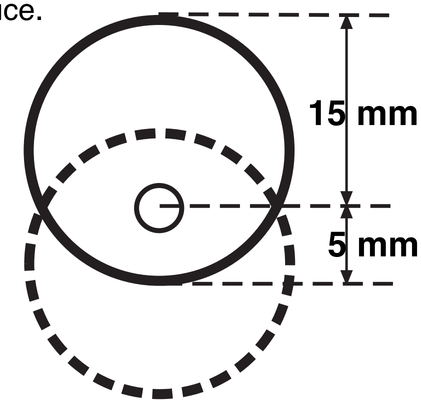




Offset the centre and you have made a concentric cam.

The cam-follower has lifted by this amount. So the more you offset the cam, the greater the amount of lift you produce.

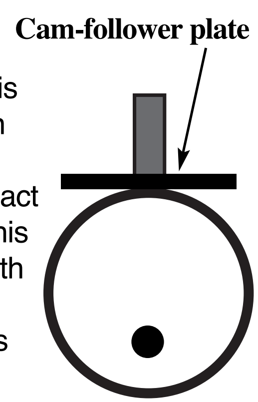
It is very easy to calculate the amount of lift by simply taking the measurement from the centre of the drive shaft to the lowest point of the cam and subtracting this from the measurement to the highest point. This calculation will give the amount of lift the cam will produce.



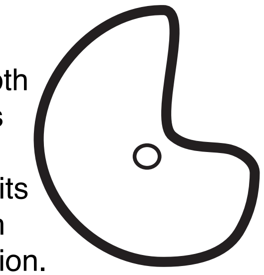
15 mm - 5 mm = 10 mm

This simple equation will enable you to work out how much lift a cam will give.

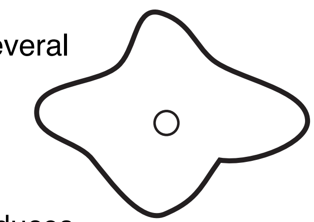
Cam-follower plate
A thin, card cam when used with a wooden dowel cam-follower may jam. To avoid this a circular cam-follower known as a “Plate” should be used. Because of it’s large, flat contact area, it is less likely to jam. This type of follower works best with concentric and some lobed cams. It will not work on cams with complicated shapes .



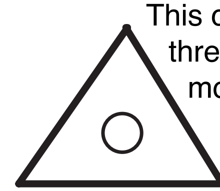
Different types of cam
This cam produces a smooth uplift which suddenly drops down. It is often referred to as a snail cam because of its shape or contour. This cam can only work in one direction. If you turn it the other way the cam-follower would jam. You need to bear this in mind when you are designing cams.



This cam produces several short up and down movements from one revolution.

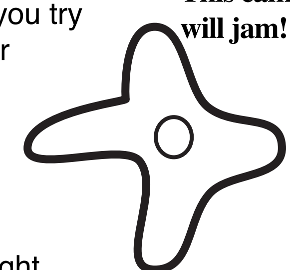


This cam produces three very distinct movements from one revolution.



You can combine as many movements as your cam will allow. Remember that the cam-follower has to work smoothly. If you try to make it do too much or make the contours too steep, such as this one on the right, it will jam. The cam-followers can only move on gentle curves, make them too tight and you will have problems!

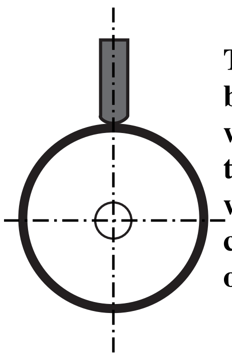
This cam will jam!



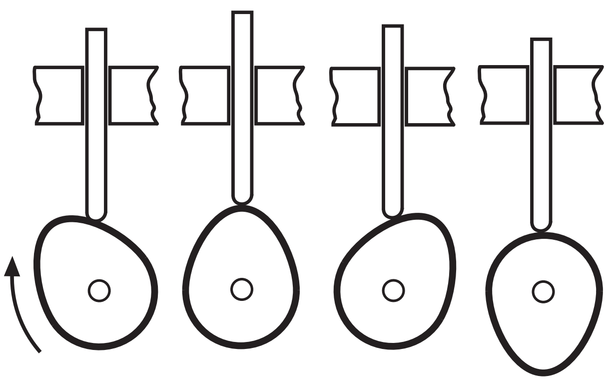
CAMS

LOBED AND DROP CAMS

From the basic round cam you can increase the diameter across one axis, to produce an egg-shaped, or “Lobed” cam. Alternatively, you can create a recessed area that drops below the circumference of the circle, producing a “Drop” cam. You can combine these two elements in a single cam, which is why they are so versatile.



The lobed and drop cams are based on a concentric circle with the drive shaft running through the centre. Obviously, without a lobe or drop, this cam will not produce any effect on the cam follower.

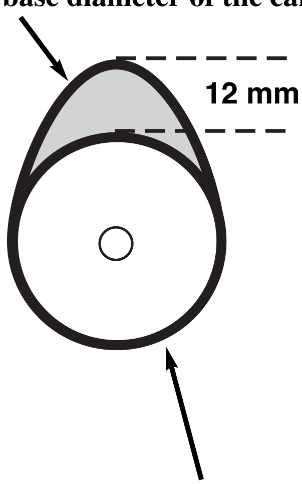


The cam - follower is rising | The cam - follower is at its highest point | The cam- follower is descending | The cam - follower is stationary as it follows the circumference or dwell angle

THE LOBED CAM

If you raise part of the circumference, you produce a lobe, hence the name lobed cam. This will lift the cam follower by the maximum height from the tip of the lobe to the circumference of the circle. When the cam-follower returns to the circle it will pause and this is referred to as the dwell angle. You can produce a pause or dwell angle on top of the lobe if you design it properly.

A lobe refers to any part of the circumference raised above the base diameter of the cam.



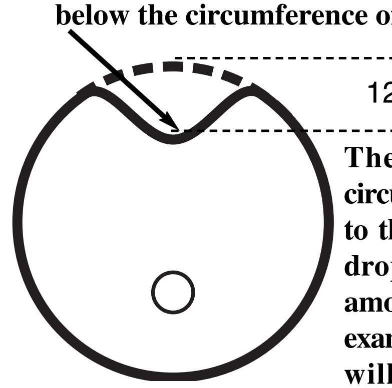
The distance from the circumference of the cam to the highest point of the lobe will determine how much lift it will produce. In this example the cam-follower will smoothly rise to 12mm before dropping.

When the cam-follower is not being lifted, that part of the cam is referred to as the dwell angle. This will produce a pause in the action.

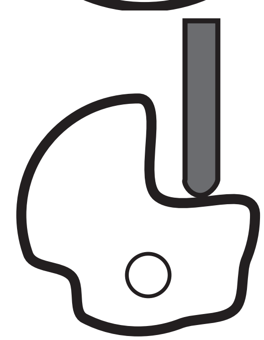
THE DROP CAM

If you dip below the circumference of the circle then the cam follower drops, hence the term drop cam.
You can calculate the drop of the cam by measuring from the lowest point of the drop to the circumference.
A very popular form of drop cam is called the snail cam. This has a sudden drop that slowly rises to the next drop point. This cam is used a lot in automata and is a blend of both drop and lobe cam.

A “Drop” refers to any surface that goes below the circumference of the cam.



The distance from the circumference of the cam to the lowest point of the drop will determine the amount of travel. In this example the cam-follower will smoothly drop to 12mm, before rising.

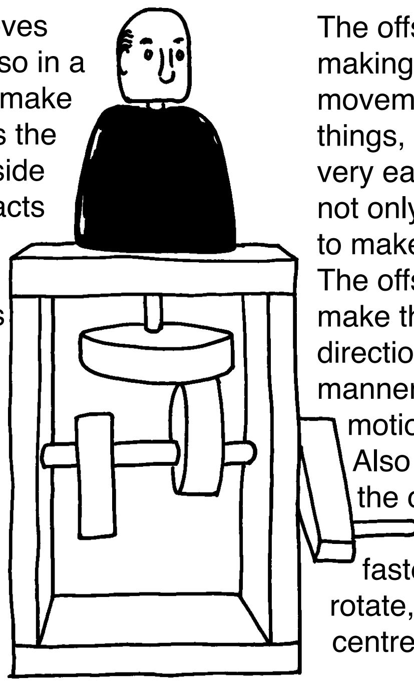


This snail cam both drops and lifts. You could even add some extra lobes and drops on the cam face.

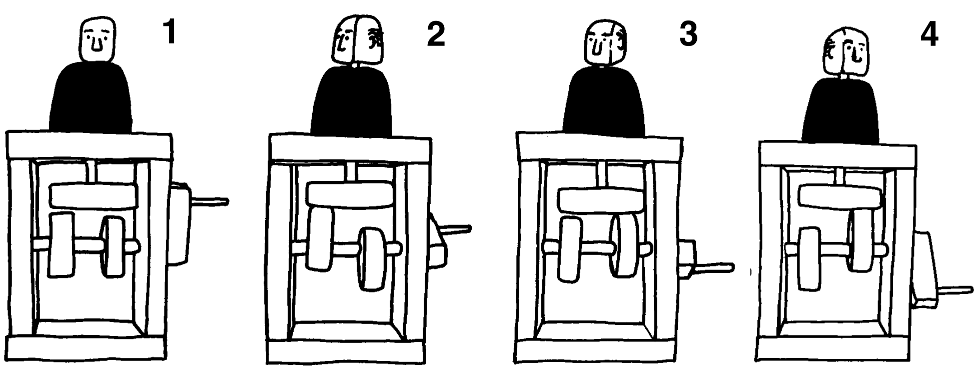
SPECIALITY CAMS FOR AUTOMATA

The cams covered so far are fairly simple. They are the sort that can be found in many everyday machines like car engines and washing machines, but there are a range of more unusual cams that can be used for added versatility or sophistication when making automata. In themselves, the cams are very simple but require a certain amount of skill to make them operate effectively.

An offset cam not only moves things up and down but also in a circular motion. You must make sure that the cam contacts the cam-follower plate either side of the cam shaft. If it contacts directly underneath then it will only lift. Offsetting two cams either side produces movement in opposite directions, giving you both up and down as well as a side to side movement.

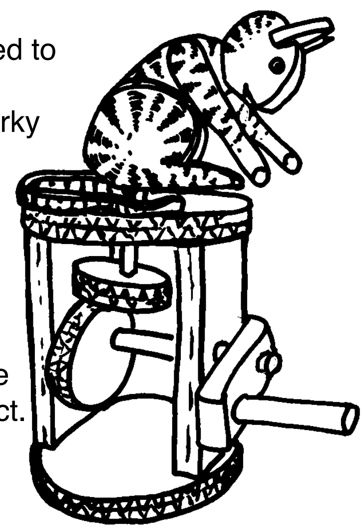


The man in this automata shakes his head from side to side. There is a small amount of lift but it is not really noticeable.



The offset cam offers a lot of scope when making simple automata. The side to side movement can be applied to many different things, animals and people in particular are very easy to adapt. The movement created is not only very interesting but is not very difficult to make.

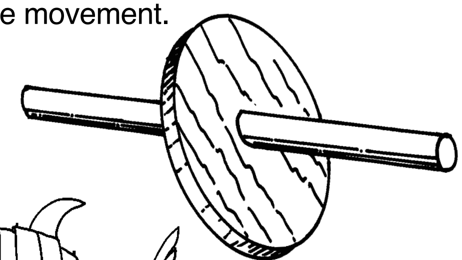
The offset cam can be adapted to make things move in one direction, albeit in a slightly jerky manner. This intermittent motion can be exploited. Also note that the closer the cam is to the centre of the “follower” the faster and further it will rotate, moving away from the centre has the opposite effect.

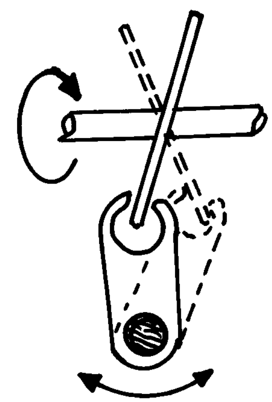


The single cam, lifts and turns the cat in a circle with an intermittent motion.

The man and the cat both use simple offset cams to produce circular motion.

The skew cam has a thin plate which is attached to the drive shaft at an angle. As it turns, it contacts a forked lever which it turns from side to side. This twists a vertical rod and so transfers the movement.

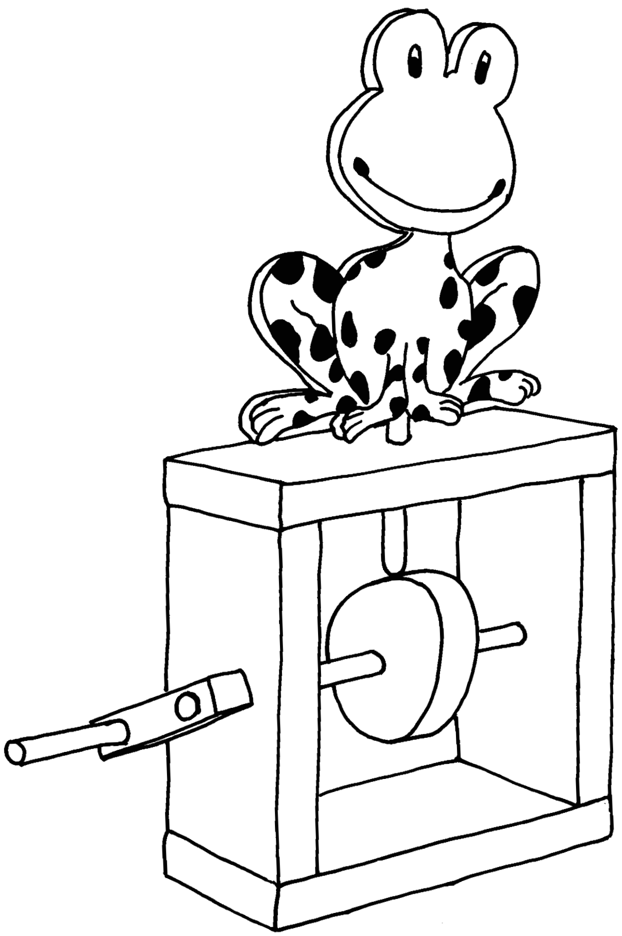




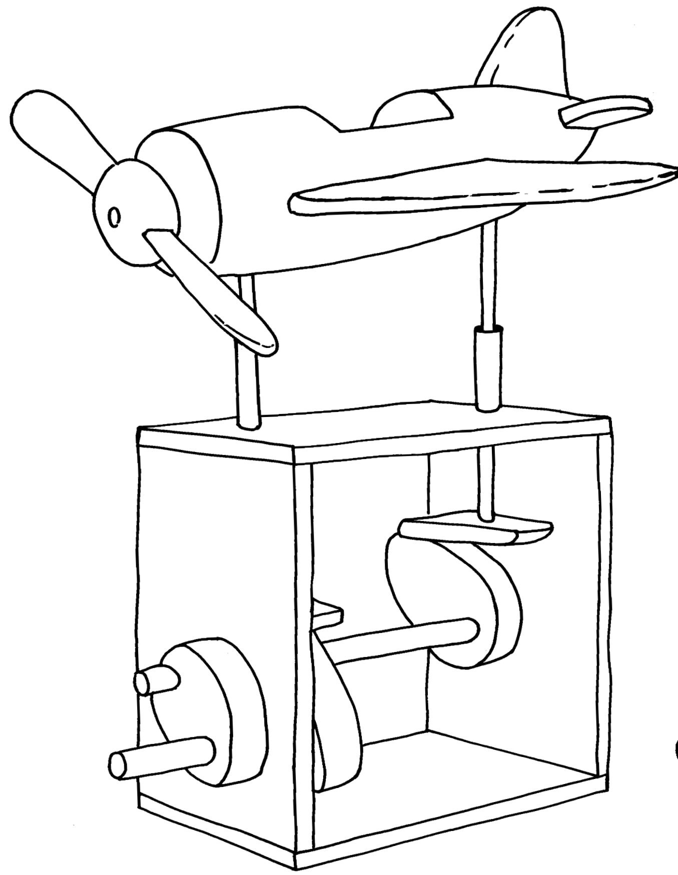
The skew cam is like a wobbly plate and turns a circular motion into a side to side one.
This can be adapted to form the axle of a pull along toy.

CAMS FOR AUTOMATA

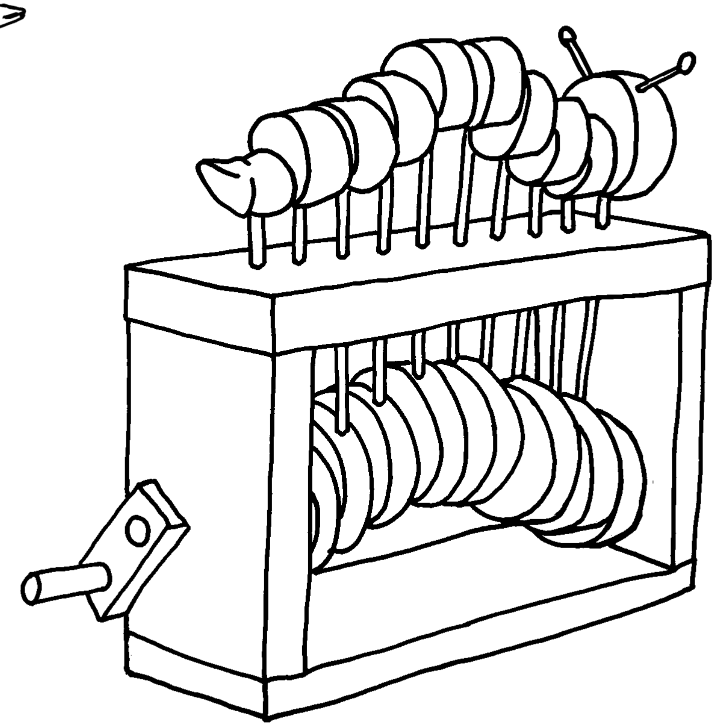
The examples below show how you can use cams when making automata. The key point to make in mechanical terms is that cams produce a linear movement from a rotating input. With this motion you can create an enormous variety of automata. The illustrations below show a range of uses for simple, single lobe cams.



FROG - USING A SINGLE LOBE CAM.
This will produce a single, smooth up and down movement.



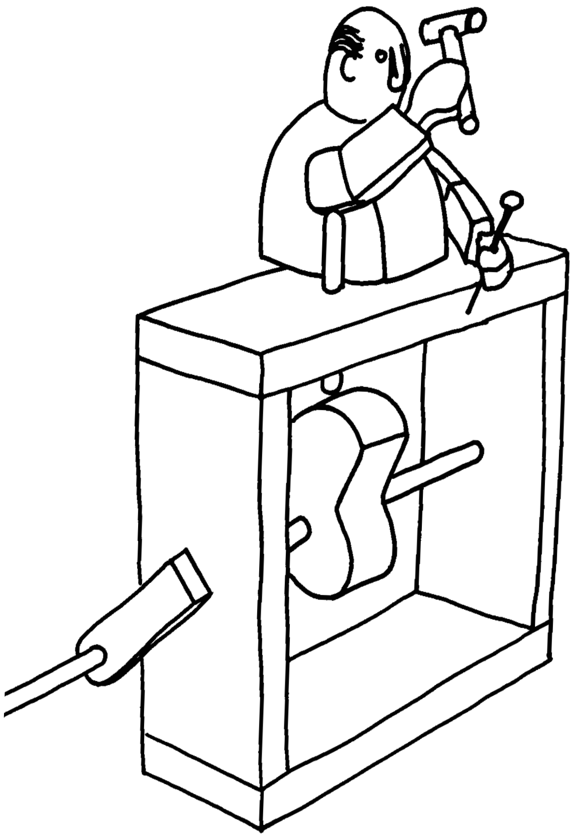
AEROPLANE - USING TWO SINGLE LOBE CAMS.
The two cams are at opposite ends and set at 180° to each other. This causes the plane to dip up and down from nose to tail.



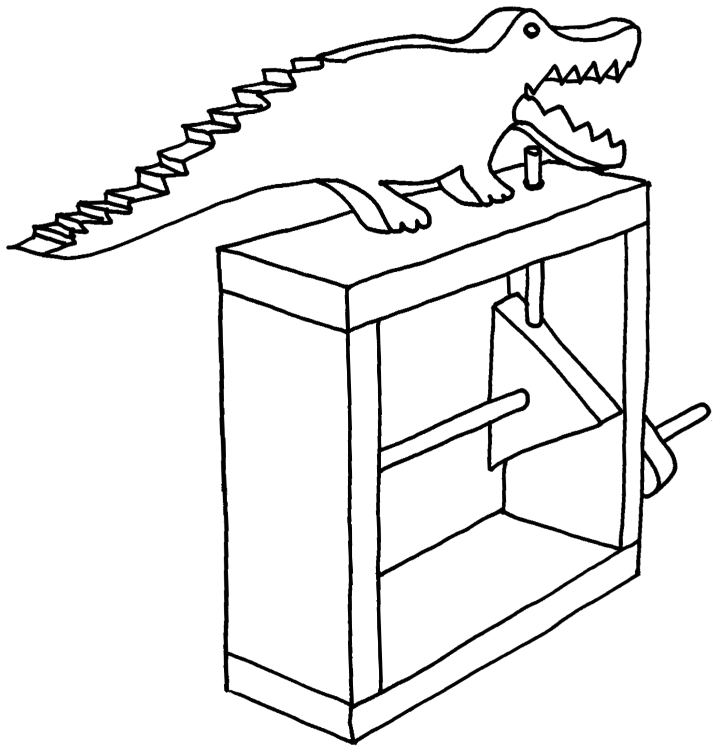
CATERPILLAR - USING MULTIPLE CONCENTRIC CAMS.
Each cam is slightly offset from the preceding one. This gives a smooth, wriggling motion.

CAMS FOR AUTOMATA

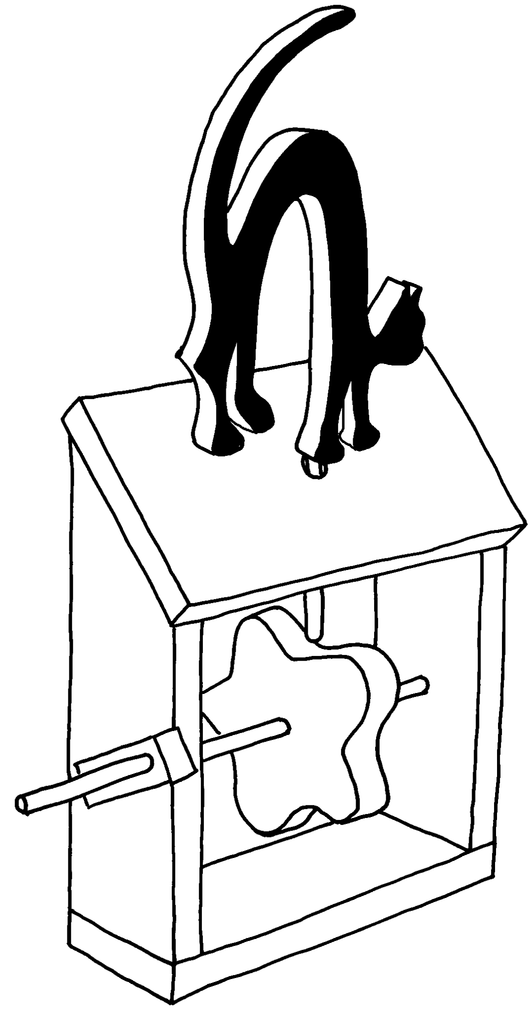
Cams can often have more than one lobe. Multiple lobe cams produce even more diverse and exciting movements.



This drop or snail cam allows the hammer to rise smoothly and then suddenly drop.



This pointed triangle will produce three equal, sharp movements in one revolution, snapping the jaws open and shut.



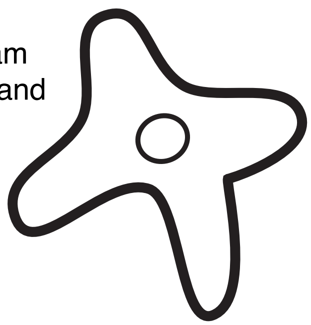
This cam has five lobes, one of which is higher than the rest. The cat will make four small jumps and then one big one.

CAMS

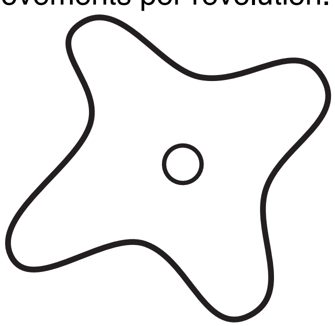
DESIGN TIPS

When designing a cam, think about it creating a performance or event in one revolution. This can be simple or complex. Remember to use gentle curves to allow the cam follower to operate smoothly. If you design a cam that produces several events you may need to make it bigger.

The designer of this cam wanted to create 4 up and down movements per revolution.
This design would probably jam and not function properly.

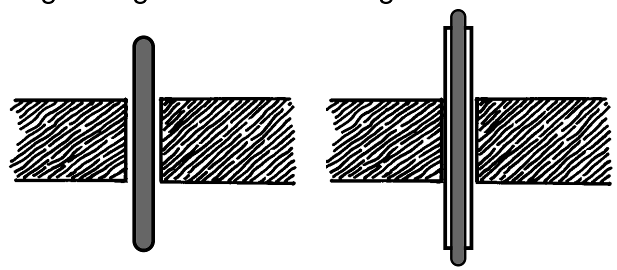


This bigger cam will do the same job but now the cam follower is able to follow the contours as they are more gradual. It will still produce 4 varying up and down movements per revolution.

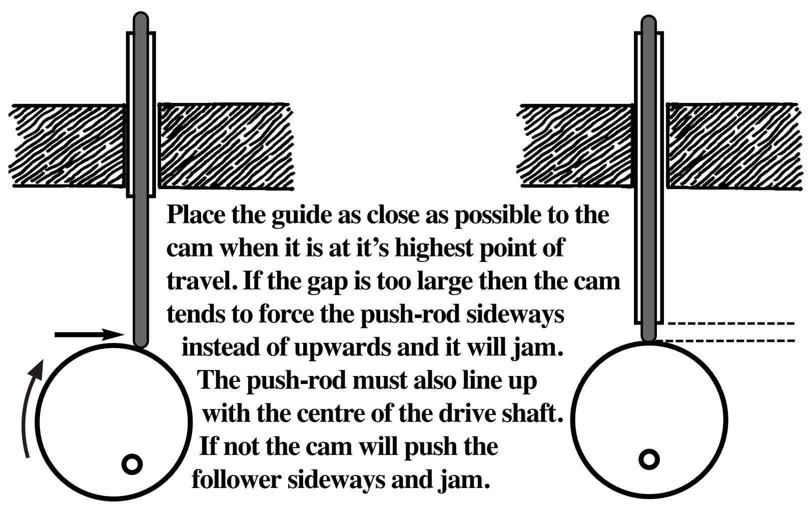


CAM SHAFTS

The biggest single problem you are likely to encounter with cams is that the follower jams and does not lift up. The main causes are that the push-rod guide supporting the push-rod is too short or that the guide is too far away from the cam. When designing automata with cams make sure that you make the push-rod guide long enough and close enough to the cam.

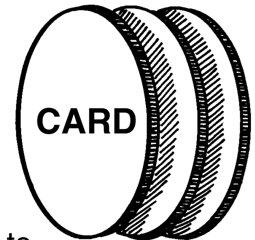


In most cases the push-rod will benefit from extra support. In the above example a straw is used for the guide. This gives much better support.

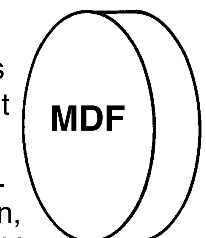


Place the guide as close as possible to the cam when it is at it's highest point of travel. If the gap is too large then the cam tends to force the push-rod sideways instead of upwards and it will jam. The push-rod must also line up with the centre of the drive shaft. If not the cam will push the follower sideways and jam.

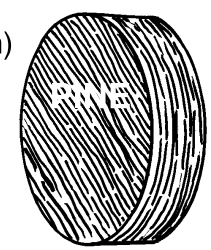
MATERIALS



When you have designed your cam, you will have to think about what to use to make it. The ideal material should be soft enough to cut easily but strong enough not to break or wear out too quickly. Cardboard, for example, can be a useful material. Several thin sheets can be cut to size and then stuck together (or "laminated") using wood glue or PVA. This produces a very strong and durable cam. Alternatively you can use thick corrugated cardboard. The cams don't have to be "industrial" strength, very often a single 2mm or 3mm thick card one will work adequately.



MDF (medium density fibre board) can be bought in various thicknesses. 4-6 mm works best and it is fairly easy to cut and can be shaped with sand paper. The dust is harmful to breathe in, always use a mask if working with MDF. We strongly advise you do not let children cut or sand it.



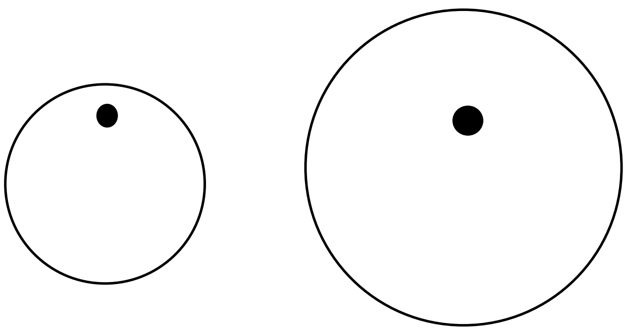
Thin pine wood (again 4-6 mm) is another effective material to work with. It takes a little more time to cut and shape but is very durable, works well and looks good.

CAMS

MAKING AND MEASURING

This final section shows you how to use a simple mathematical formula to work out the lift for concentric cams.

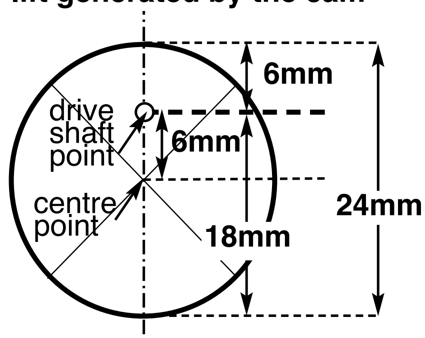
The concentric cam, is a circle with an offset centre. By offsetting the centre we are able to produce the lift. The further you move away from the centre point the greater the amount of lift you will produce. Do not overdo things, it is better to make a larger cam that rises gently than a small one that rises rapidly. They will both do the same job but the smaller cam is more likely to jam.



Both cams lift by the same amount but the larger circumference of the bigger cam will produce a much smoother lift. As a rough guide, try to make the biggest cam that will comfortably fit into your automaton.

When making automata, you need to work things out fairly accurately. This applies to cams if you need to produce lift to a specific height. The following formula is very simple and shows you quickly and accurately how to work out the fixing point for the drive shaft.

"Every millimetre that you move away from the cam's centre point, you must double, in order to calculate the amount of lift generated by the cam"



In this example you can see that the centre point has been moved up by 6 mm. Doubling this figure shows the cam will lift 12mm.

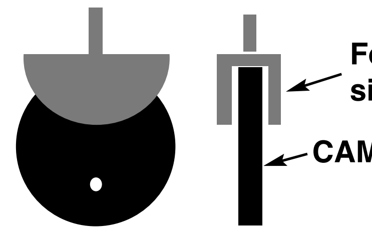
You can confirm this by using the formula we looked at earlier. By subtracting the two distances from the new centre point

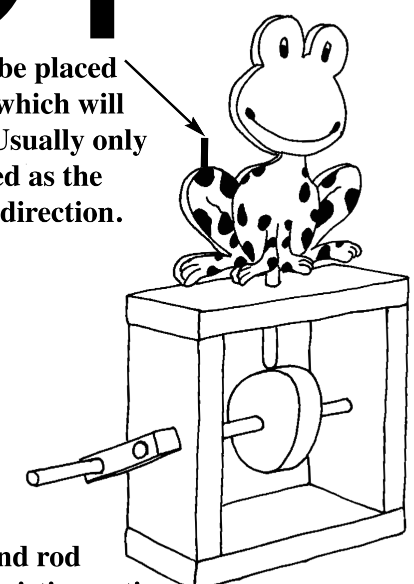
$$18\text{mm} - 6\text{mm} = 12\text{mm}$$

It's as simple as that. Remember you only have to accurately locate the centre point of the drive shaft. The actual diameter of the drive shaft is not important.

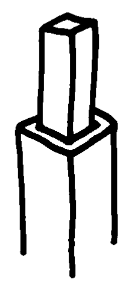
TWIST AND TURNING

A rather annoying characteristic of the cam is that it produces a turning motion on the push-rod. This may only be very slight but can cause problems. The leaping frog for instance slowly turns round as it moves up and down, which in some instances could be a problem. To eliminate the turning affect you can either build stops to prevent turning, (this can affect the overall look of your automata) or put guides either side of the cam.





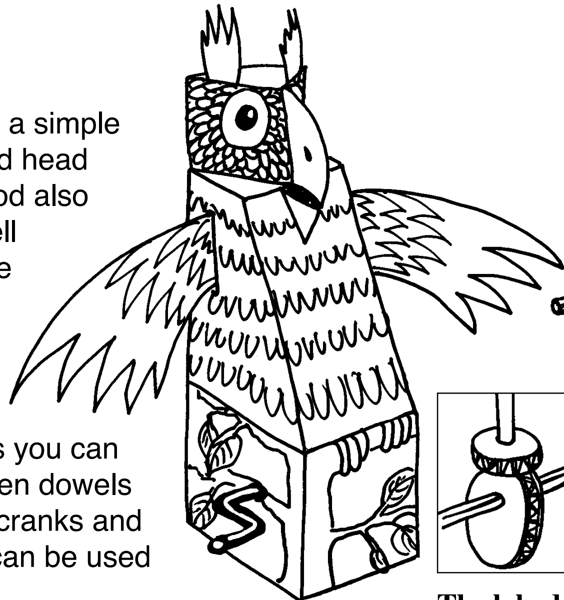
A small pin can be placed behind the frog which will stop it turning. Usually only one stop is needed as the motion is in one direction.

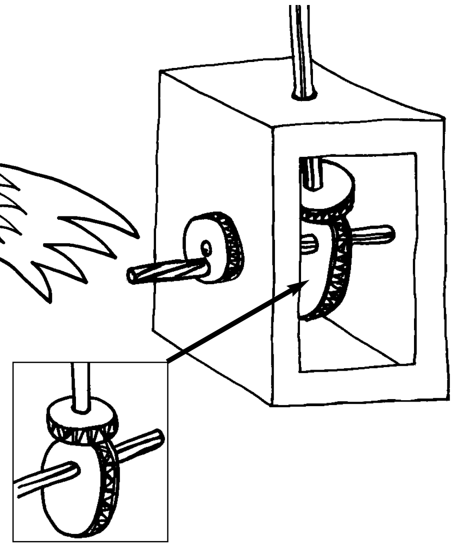


A square tube and rod eliminates any twisting action.

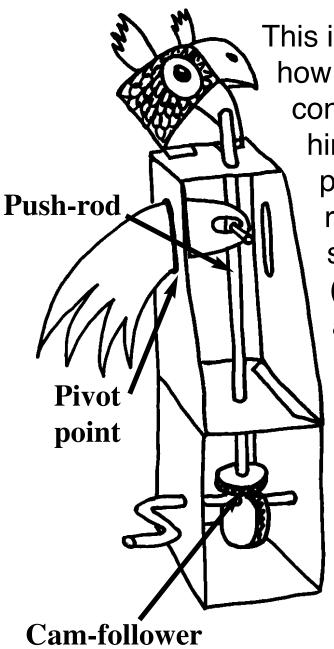
CAMS

The automata on the right uses a simple cam to make the owl's beak and head snap up and down. The push-rod also links the wings, which act as bell cranks and give the appearance of flapping. This entire automaton is made from paper and card. The lobed cam is constructed from thick corrugated card. As with cranks you can use pencils, art straws or wooden dowels to make the supporting shafts, cranks and push-rods. Wood glue or PVA can be used to stick all the parts together.



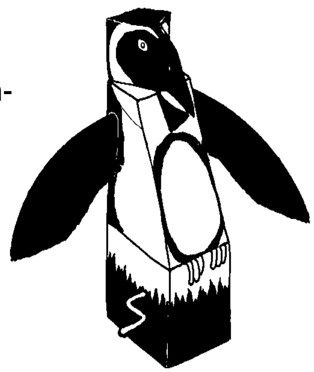


The lobed cam above is made from corrugated cardboard. The base is made from a cereal box.



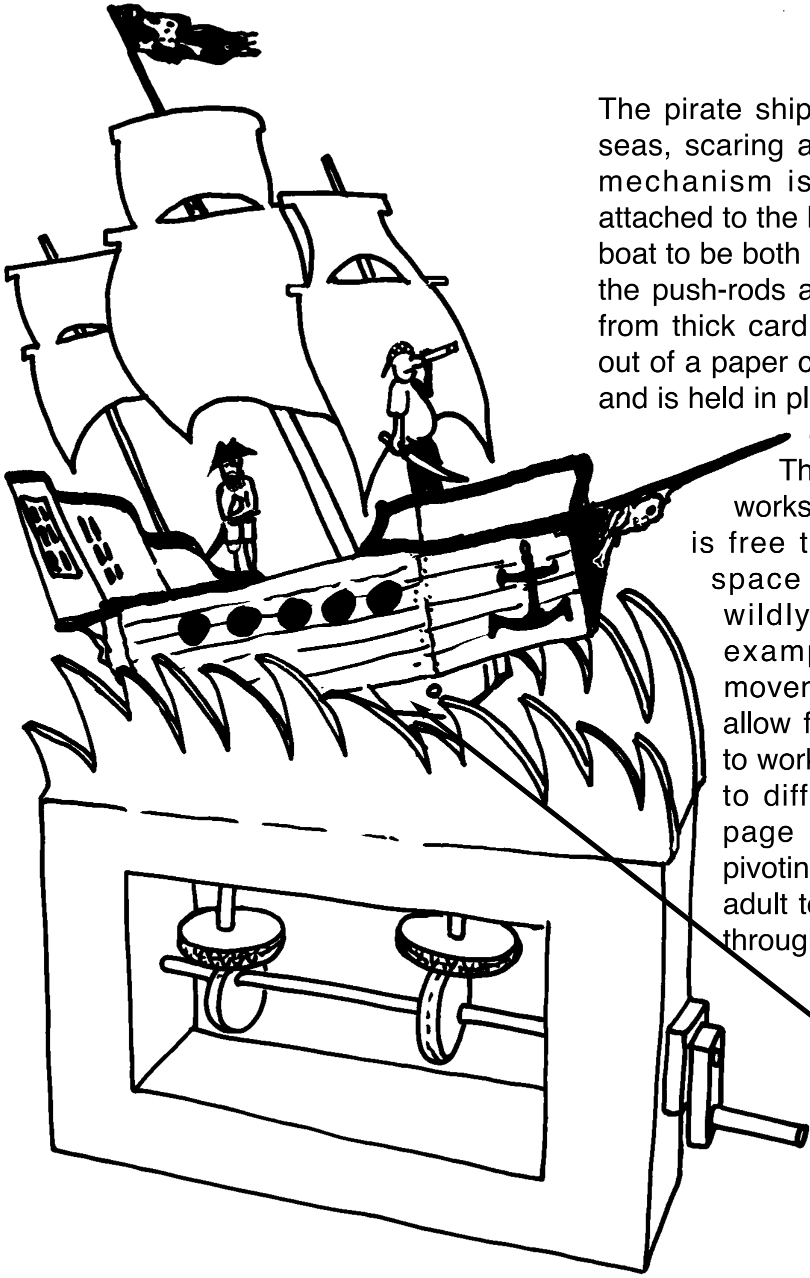
This illustration shows you how the mechanisms are constructed. The head is hinged at the back and is pushed up by the push-rod. The wings are slotted through the body (which acts as a pivot) and are attached to a rod that is in turn connected to the push-rod. This provides the lift for the wings. Both the head, wings and cam follower are assisted by gravity which provides the downward force.

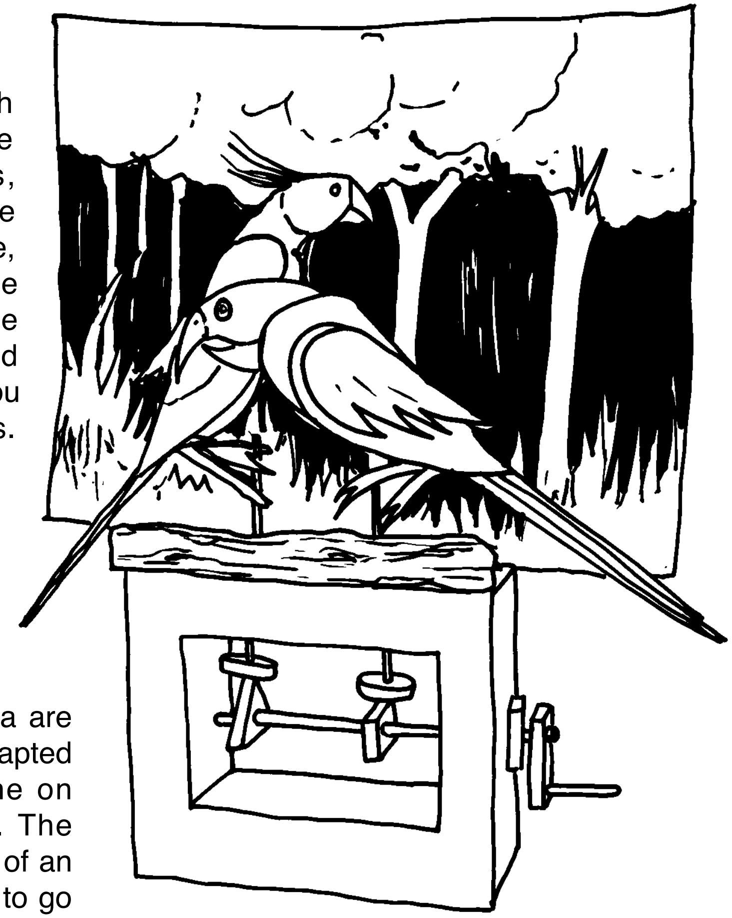
This automaton can be adapted very easily to make other birds such as penguins, parrots, or even animals and people.

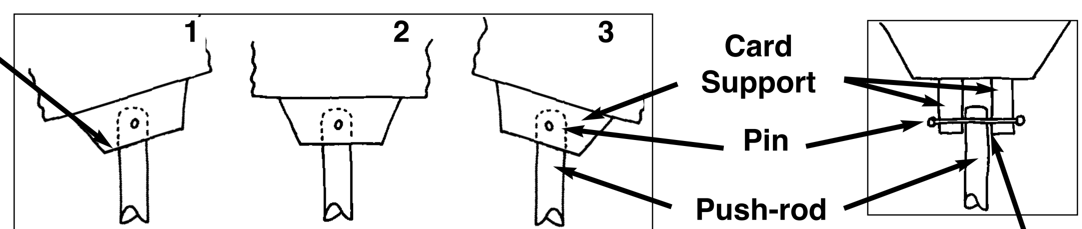


The owl, pirate boat and parrots are all made from card and paper, employing only a simple cam mechanism. The parrots use a triangular and square cam which give jerky movements. They look very exciting because of the surface and background decoration. The beauty of making these types of automata is the scope they offer in allowing a creative and artistic outlet. This could be adapted to a scene from history, a local event, or even a personal experience.
The pirate boat is made from a simple card net, comprising of a pointed rectangle. The bow and stern are then wrapped around this shape to give them their form. The sails and characters are all flat. To simplify this automaton even further you could make the whole thing two dimensional and it would still work extremely well. This simplification means young children should be able to enjoy designing, making and painting their own automata.
The parrots are made from thin coloured card which is folded to give them a little more form and shape. Origami can also be used to create many simple animal shapes.
The pirate ship and parrots use a base made from a cereal box. This is covered in more depth in the chapter "Construction". This works well if you need space around the model and is a great way of recycling.

The pirate ship bobs up and down on the high seas, scaring all those that cross it's path. The mechanism is made from two offset cams, attached to the bottom of the boat. In order for the boat to be both held in place and be free to move, the push-rods are pivoted on two supports made from thick card. There is a small wire pin made out of a paper clip that goes through the push-rod and is held in place by bending over the ends, you could also use paper fasteners. The diagram below shows how this works. It is important that everything is free to move. However, too much space and the boat would wobble wildly from side to side. In this example a little side to side movement looks good. You have to allow for this movement if the automata are to work properly. This device can be adapted to different automata. The aeroplane on page 10 used a similar mechanism. The pivoting device requires the assistance of an adult to help make the hole for the pin to go through but the rest is fairly easy to make.







The diagram above shows how the boat is free to pivot as it tips up and down. The push-rod remains vertical.

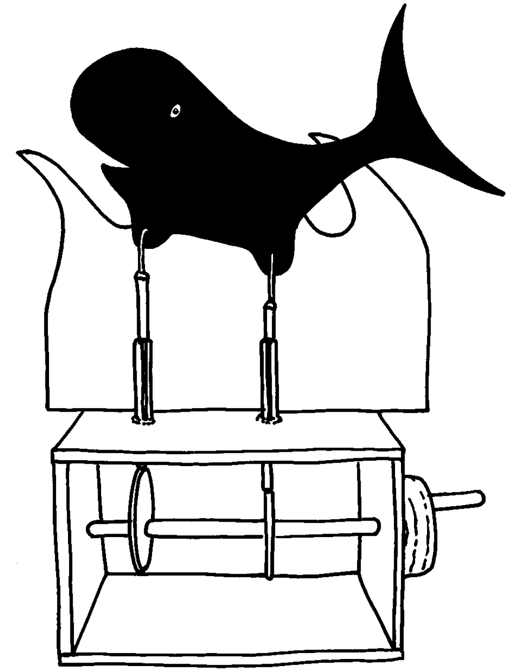
You need a small gap between the push-rod and card supports.

CAMS

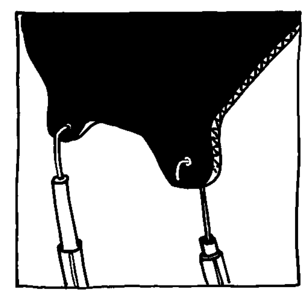
2D IMAGERY

The following automata are all based on flat, two dimensional imagery and use either single, double or multi cams. These automata are still very effective and open up a lot of possibilities to young makers, who usually enjoy the colouring-in part the most.
The advantage of this way of working is that children can still turn a fanciful, creative idea into a reality. If they can draw it and cut it out, it can be made to move!
The boxes are made from corrugated card. You can use a two layer, ply construction for larger work, (see the chapter on construction for more details) or a simple 160 gsm card box (plans on page 19). The push-rods can either be barbecue sticks, pencils or wooden dowels. Everything is kept as simple as possible and although these automata follow a very nautical theme you can adapt them.
Finally, they all incorporate a circular offset cam, which produces a very smooth lifting action and is easy to make, but you could always explore using other shaped cams.
The examples shown here only work because of the precise alignment of the follower to the cam. You may choose to incorporate a circular cam-follower which allows the follower to be less accurately aligned.

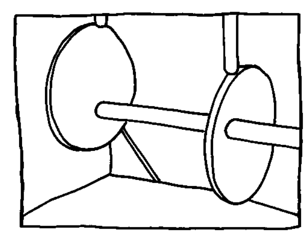
The whale, like the pirate ship, uses two cams to produce a rocking motion. The whale is made out of a single piece of thick cardboard, so are the waves, these are fixed and only decorative. This is a very simple yet effective automaton.



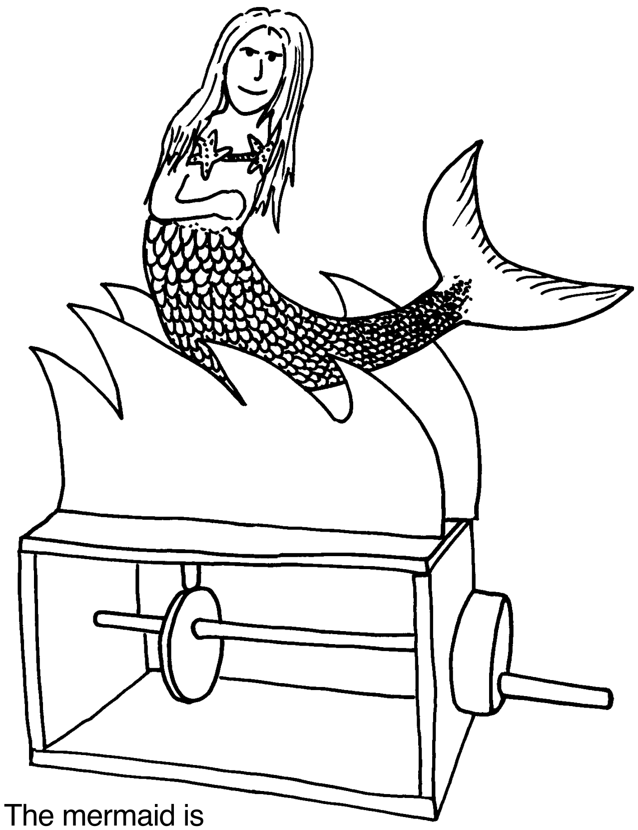
With the front wave removed you can see the whale is supported on two push-rods made from wooden dowel running in drinking straws.



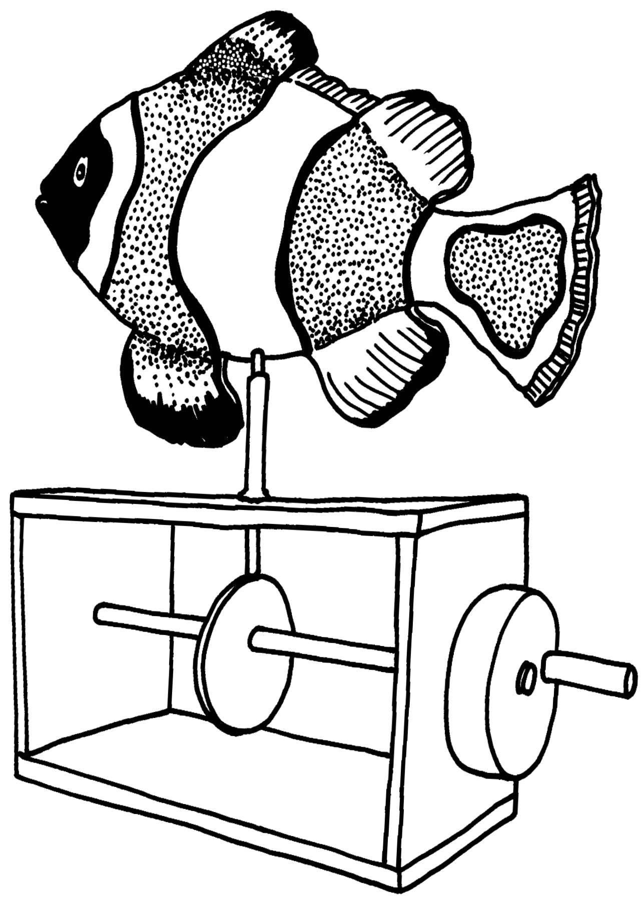
Two pieces of florist wire allow the whale's body to rock as it travels up and down. The automaton would jam if there was no allowance for this movement.

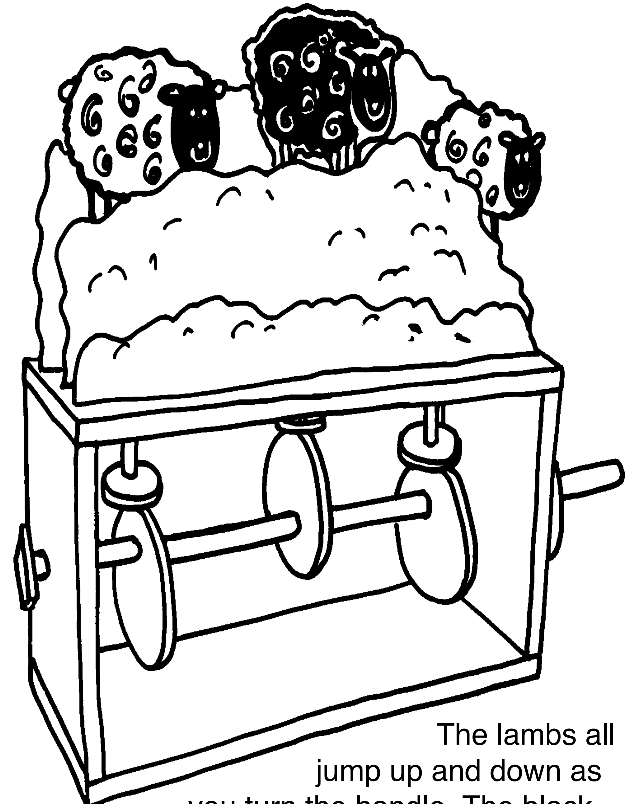


The cams are made out of thick card, and the wooden dowels line up with them.



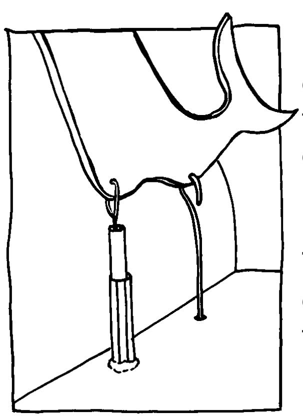
Like the other automata, the fish is made from thick corrugated card and is painted. You could use pictures cut from magazines. Most children find it more rewarding to make and decorate their own designs. The fish is stuck to the push-rod with strong glue (UHU). The wooden dowel is first pushed into the corrugated card for strength. The push-rod guide is a made from a drinking straw and glued into the base.

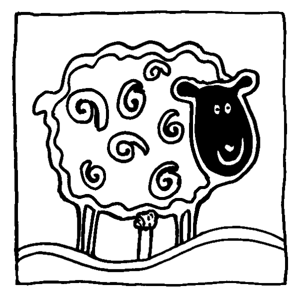




The lambs all jump up and down as you turn the handle. The black one is always out of step with the other two. This automaton uses three circular, offset cams, but you could experiment with different shapes. Note the circular cam-followers.

The mermaid is similar to the whale in the way that it works, except it only has one cam. The other cam is substituted with a fixed wire mount. This creates a less pronounced bobbing motion.
The chapter on construction goes into the wire supports in more detail.





The lambs, like the fish, are made from corrugated card, the wooden dowel, gluing and fixing process are the same too.

CAMS

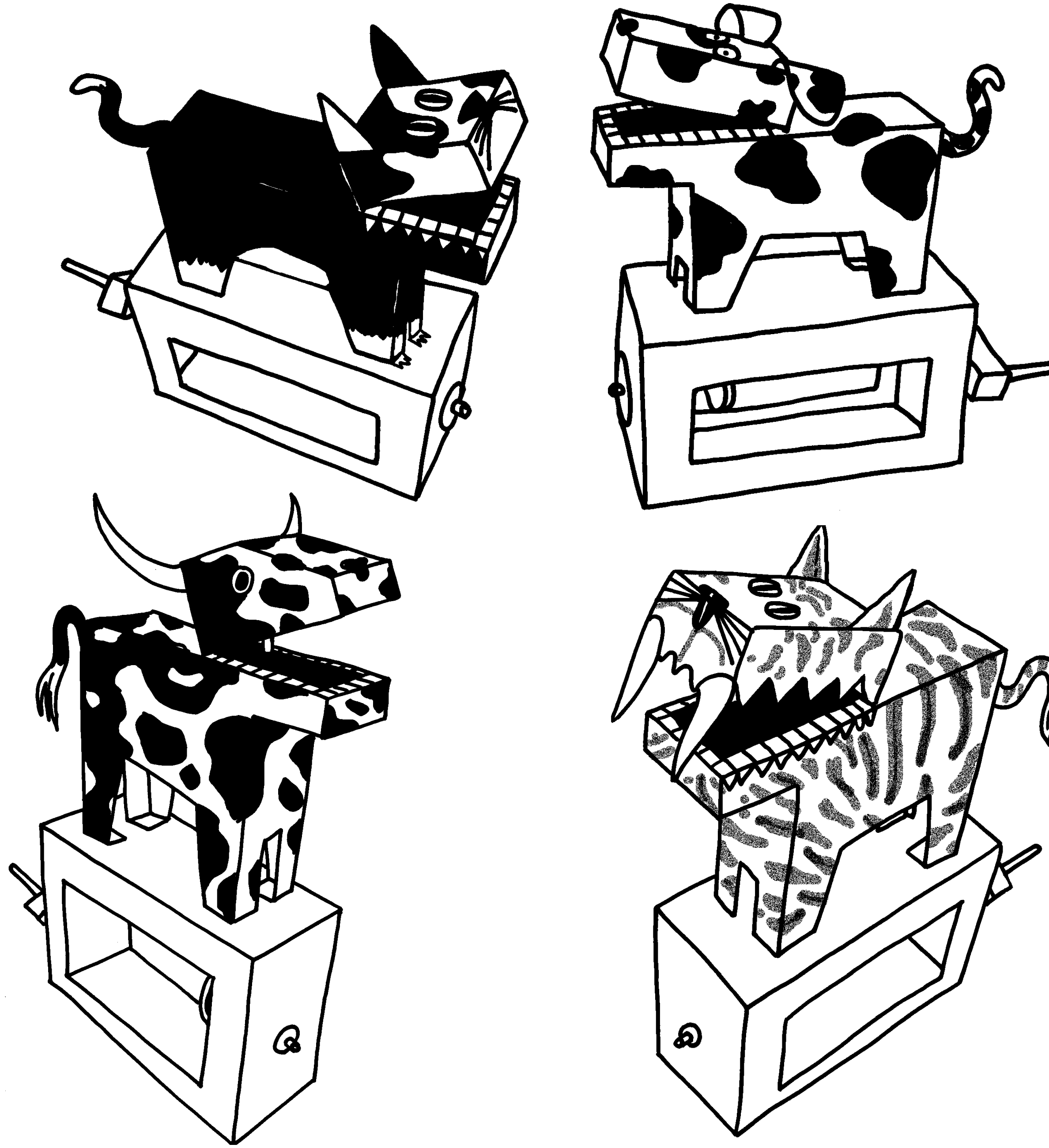
SIMPLIFYING CAMS

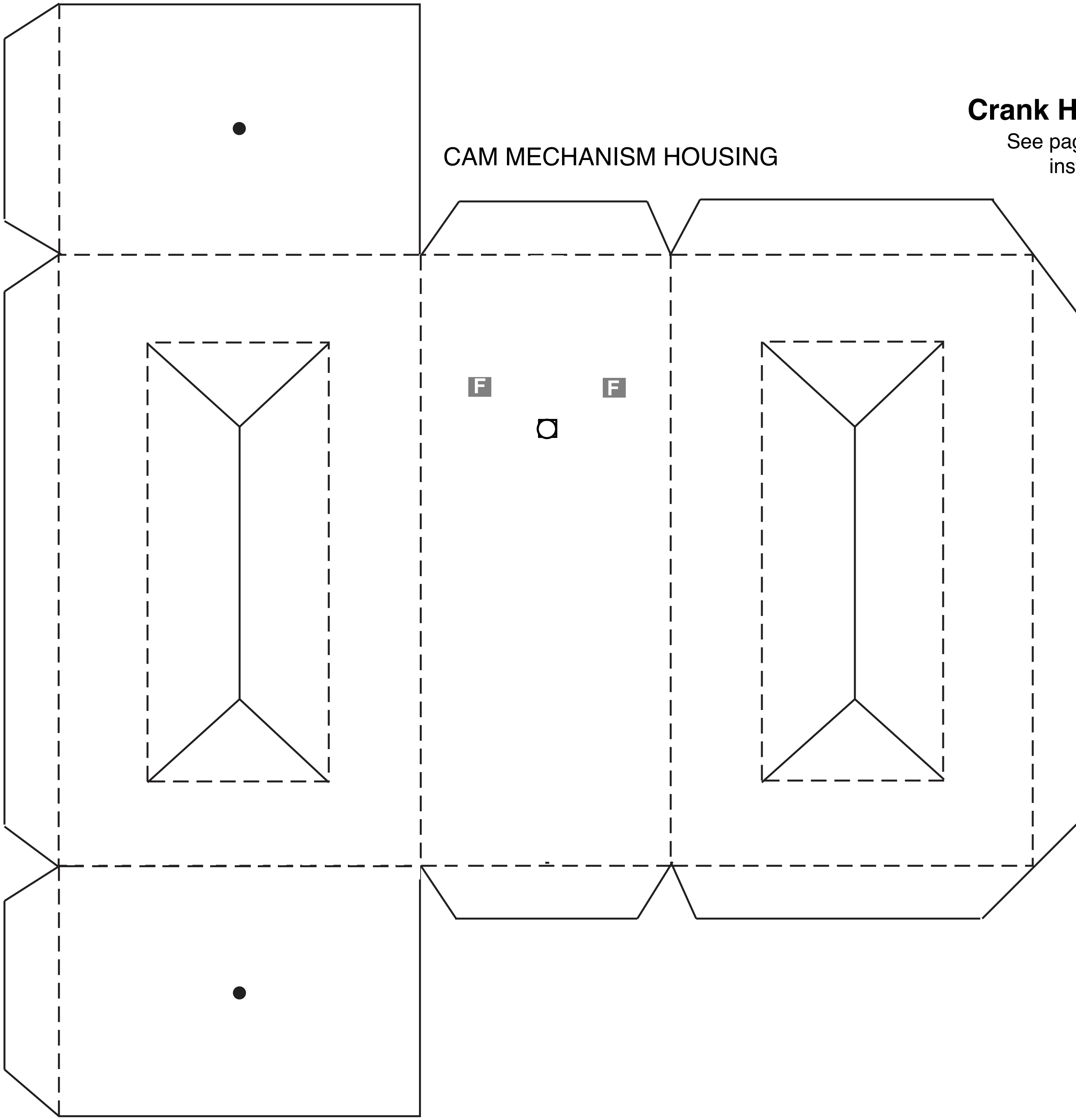
The theory and examples of cams we have looked at so far should have given you a pretty good idea of what they are capable of doing and how relatively simple, yet sophisticated a movement you can make with them. As with any practical activity it is best to keep things as simple as possible. It takes quite some time to make even small automata. If children's interest is to be maintained it is important that things are kept achievable within as short a time span as possible.

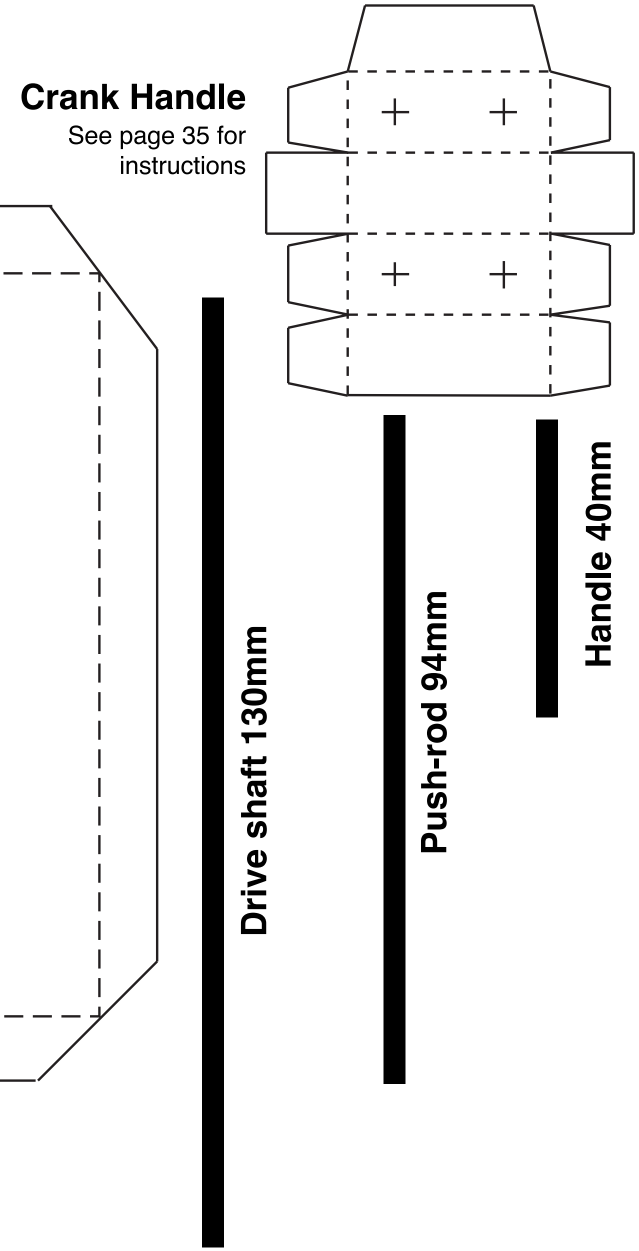
The following automata are designed to be simple, and fairly quick to make. They can be adapted to different situations and age groups, providing a stimulating and exciting point from which to start.

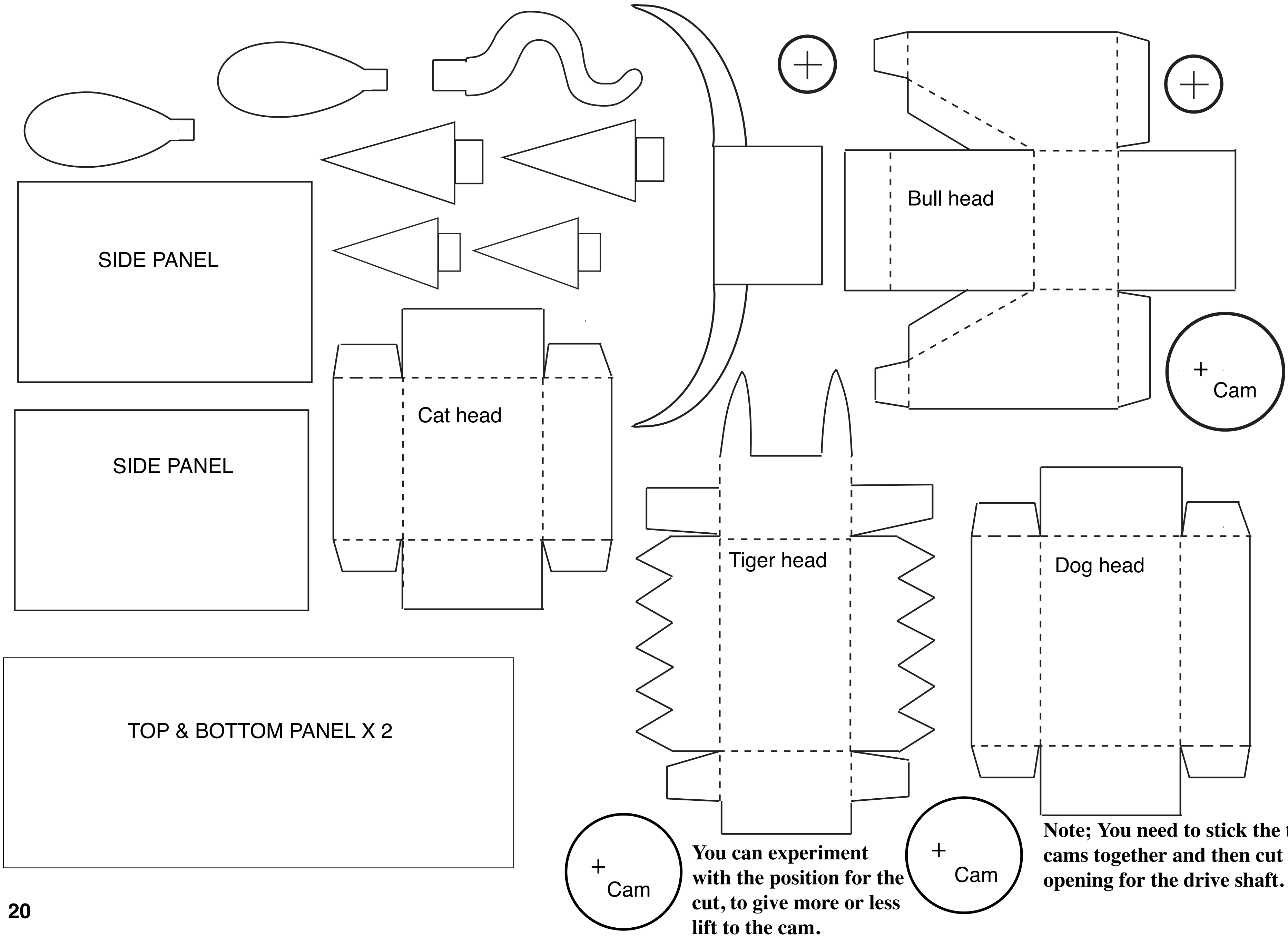
All of the following automata are constructed from 160gsm photocopying card. This is not too thick yet strong and easy to work with. You can make A4 photocopies of the nets and instructions.

The nets were reduced to 95% in order to fit them on the page. You can enlarge them slightly or even take them up to A3.



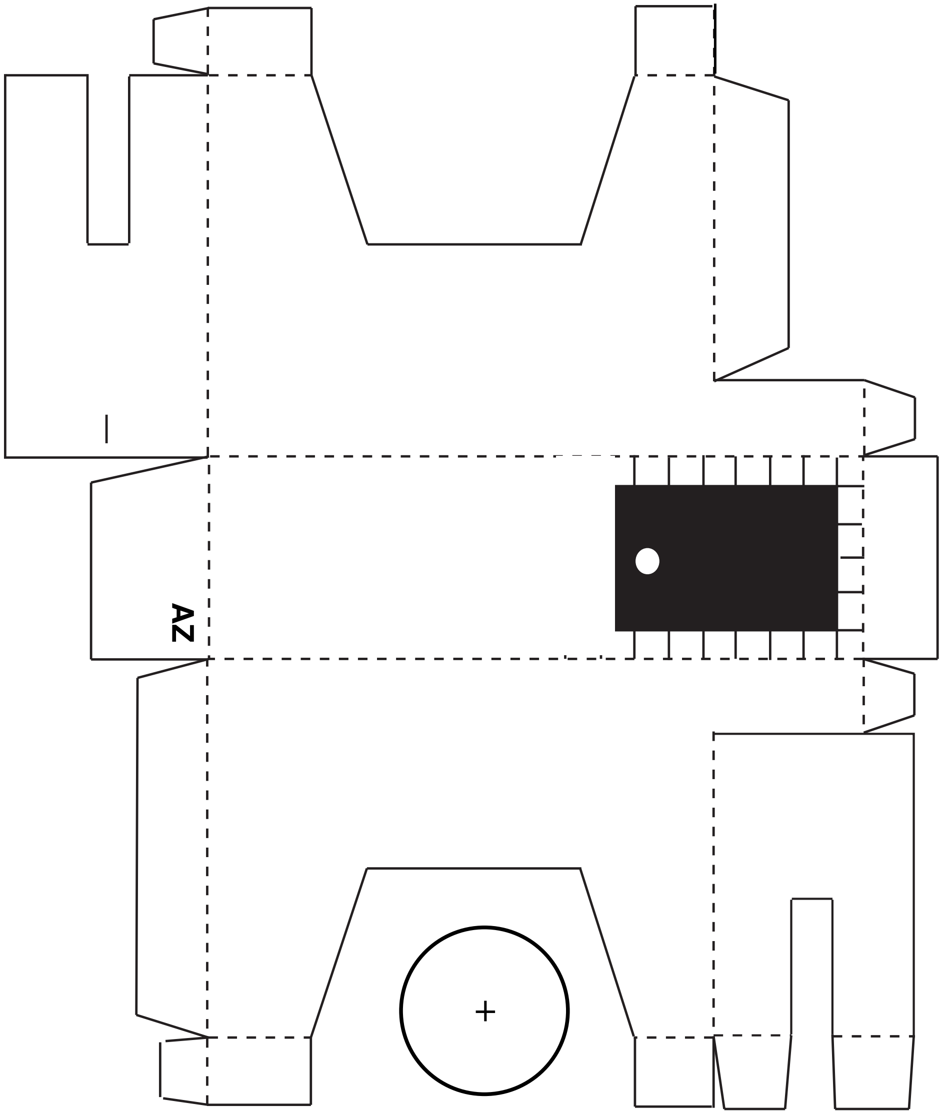

CAM MECHANISM HOUSING
F
F

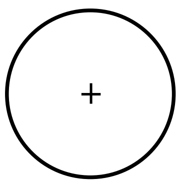

Crank Handle
See page 35 for instructions
Drive shaft 130mm
Push-rod 94mm
Handle 40mm



You can experiment with the position for the cut, to give more or less lift to the cam.

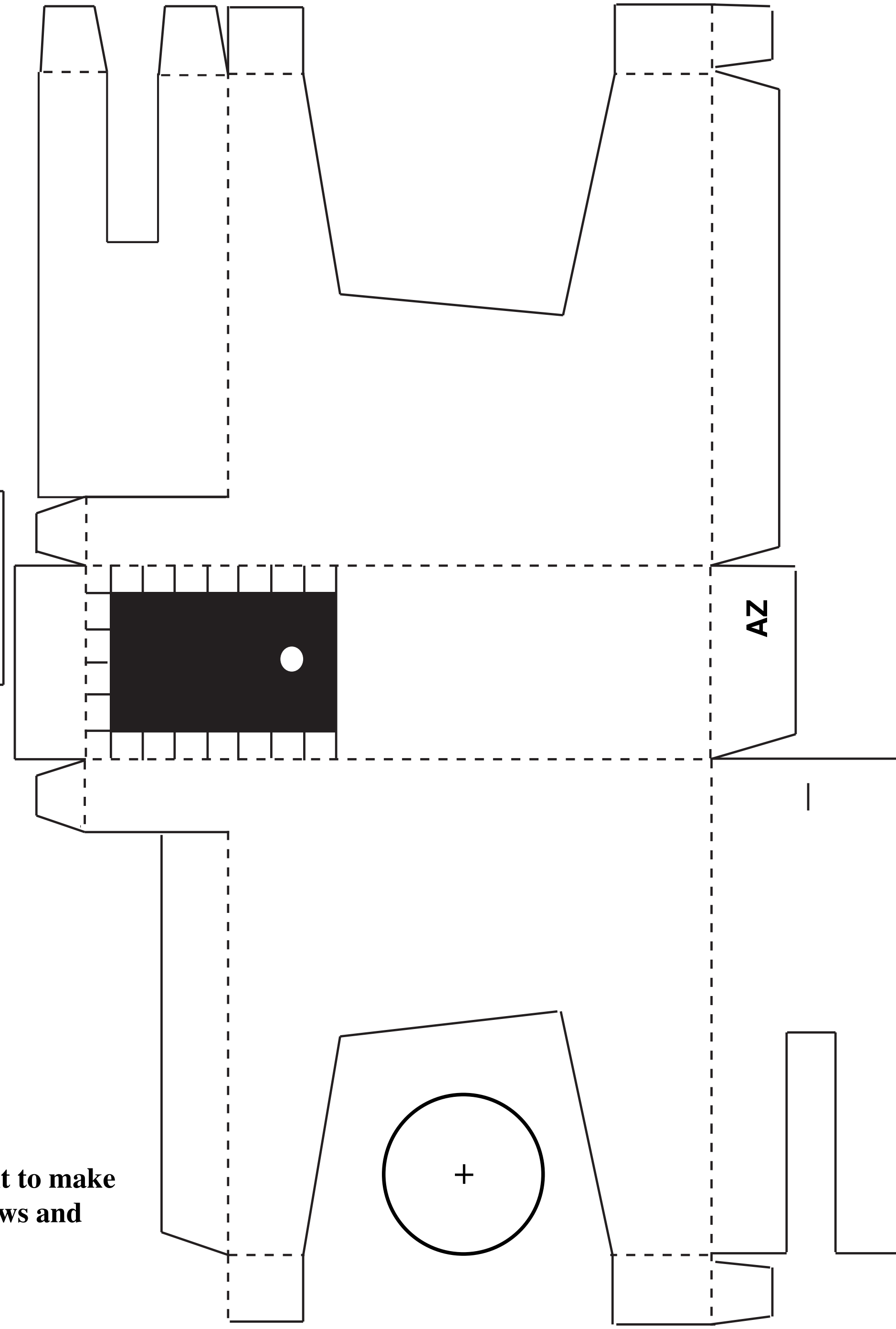
Note; You need to stick the three cams together and then cut the opening for the drive shaft.



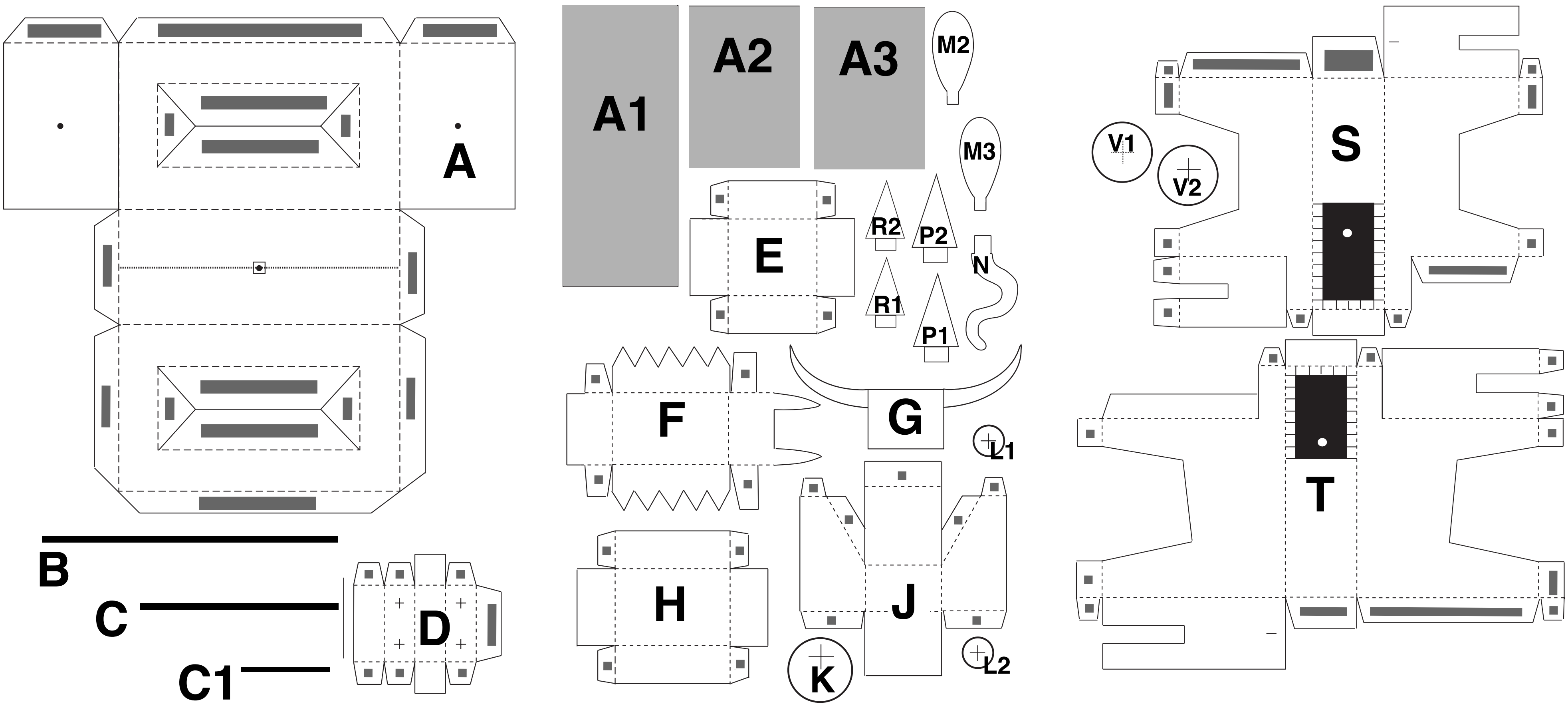


Cam-followers

Use the net on the right to make tall animals such as cows and horses.



CAMS Instructions for making the nets



Instructions

- - - - - - - - Fold along the dotted line.

——— Cut along the solid line.

GLUE Glue the tabs marked in grey.

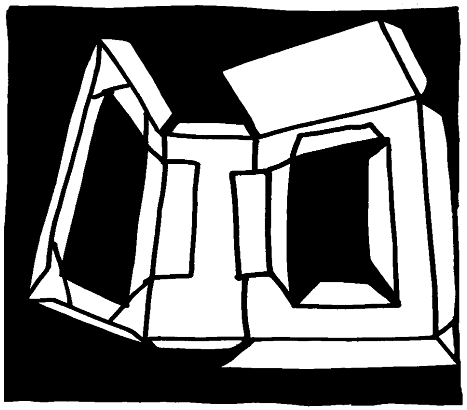
A The letter in bold is the part being referred to.

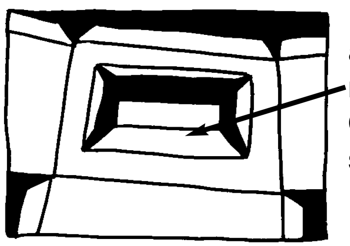
The folds are made by bending the card backwards, along the dotted lines and creating a “valley” fold.

You need to work with a good glue. PVA will do the job but takes a little while to dry. You can use a wood glue which is safe for children (details on the website www,automata.co.uk). UHU make an excellent solvent-free adhesive which is washable and non-toxic.

CAMS

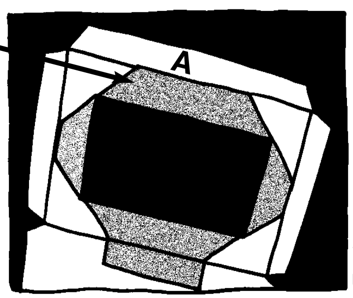
INSTRUCTIONS:
Start with the box and cut out the main shape using scissors or a craft knife, then fold back all the tabs.

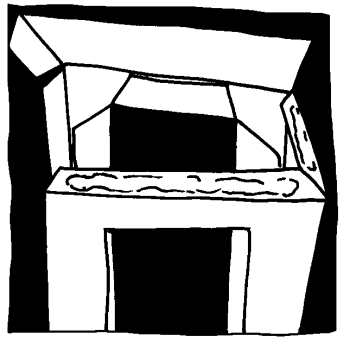


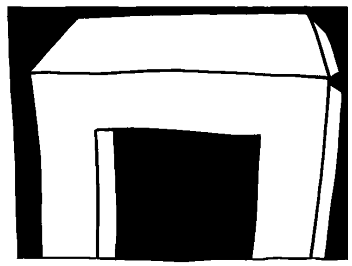


Pay special attention to the middle cut outs. Only cut along the solid black lines.

Note the inner tabs, shown here in grey. They have been folded and glued to the side of the box. The longest tab (A) attaches to what becomes the bottom of the box. This is glued down later.

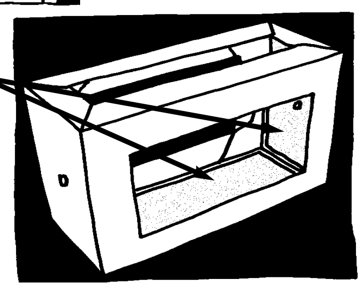


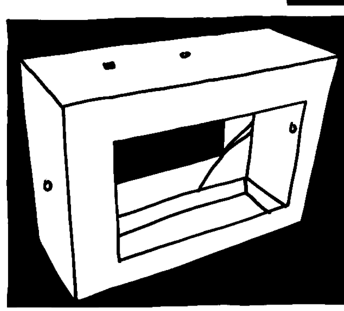




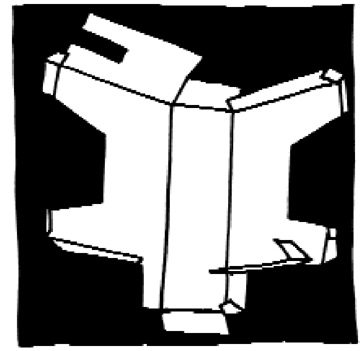
When all the inner tabs are glued down you then need to attach the side panels. They are glued to the two tabs on the side and top of the box. Note the lower tabs are not used at this time. This keeps the bottom of the box open which makes fitting the cams much easier. A final panel is glued on at the end.

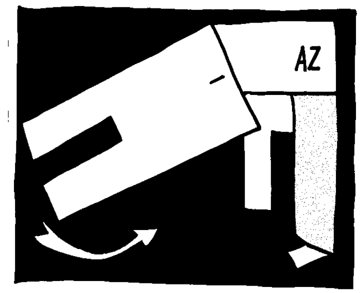
You then need to glue parts **A1**, **A2** and **A3** (marked in grey) to the inside of the box. This will give it extra strength.





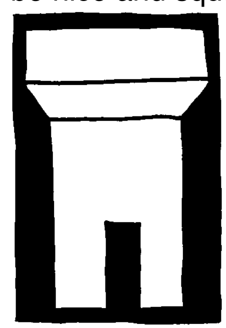
The final box should look like this. Note you may have to cut out the holes for the cams using a craft knife.

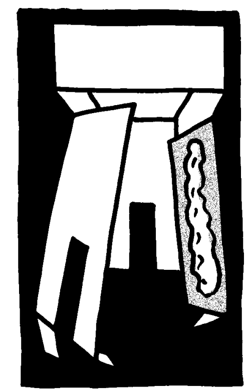




As with the box you need to cut out the animals body and bend back all the tabs ready for gluing. The rear of the animal should have tab AZ attached first. Note this has a 90º straight edge. Glue this carefully to ensure that the body is square. Finally, glue the hind legs.

Now do the same for the front of the animals body. Take care when attaching the feet. They should also be nice and square.

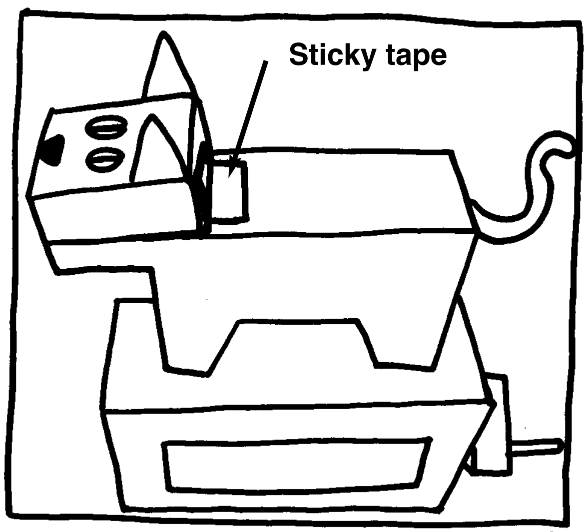


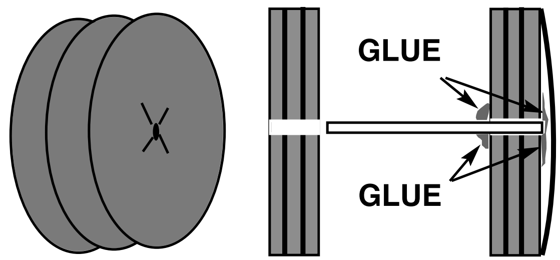


The front legs should line up with the body. This will give the animal's body a straight and strong structure.

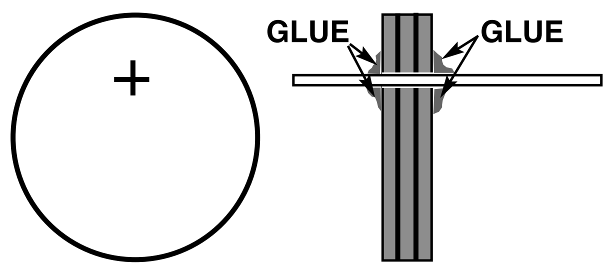
CAMS

Finally make up the animal's head, (cat, dog cow etc) and place it on top of the animal's body using a strip of sticky tape. Then glue the animal on top of the box, lining up the feet with the position markers. The two holes should also line up, this is where the push-rod (stick) is going to go. It needs to be free enough to move up and down and not catch. The holes should not be too big as this may cause the mechanism to jam. The guide marks are clearly shown on the template so only cut to these lines. You may have to enlarge them if the holes don't line up initially.



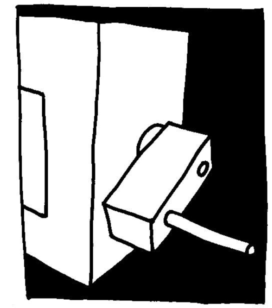


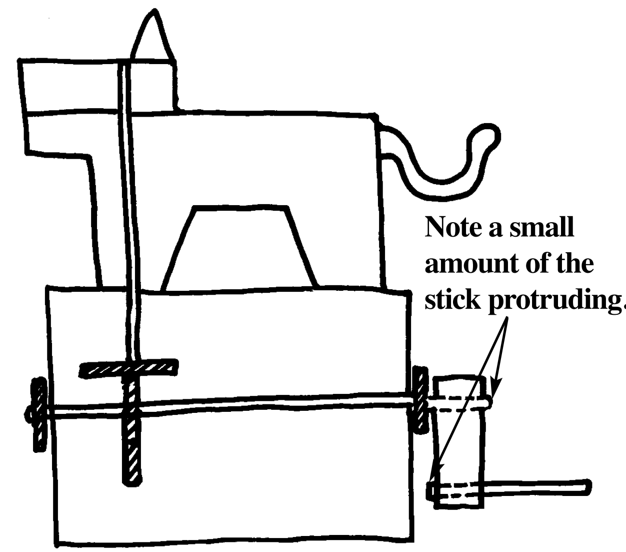
You will need to stick the cam followers together. You can use 2 or 3 layers of card. When dry, cut a small cross in the centre and push the 94mm stick through. A small amount should protrude from the end, cover this with glue to make it stronger. A final disk covering the glue and protruding stick, makes a nice smooth cam-follower.



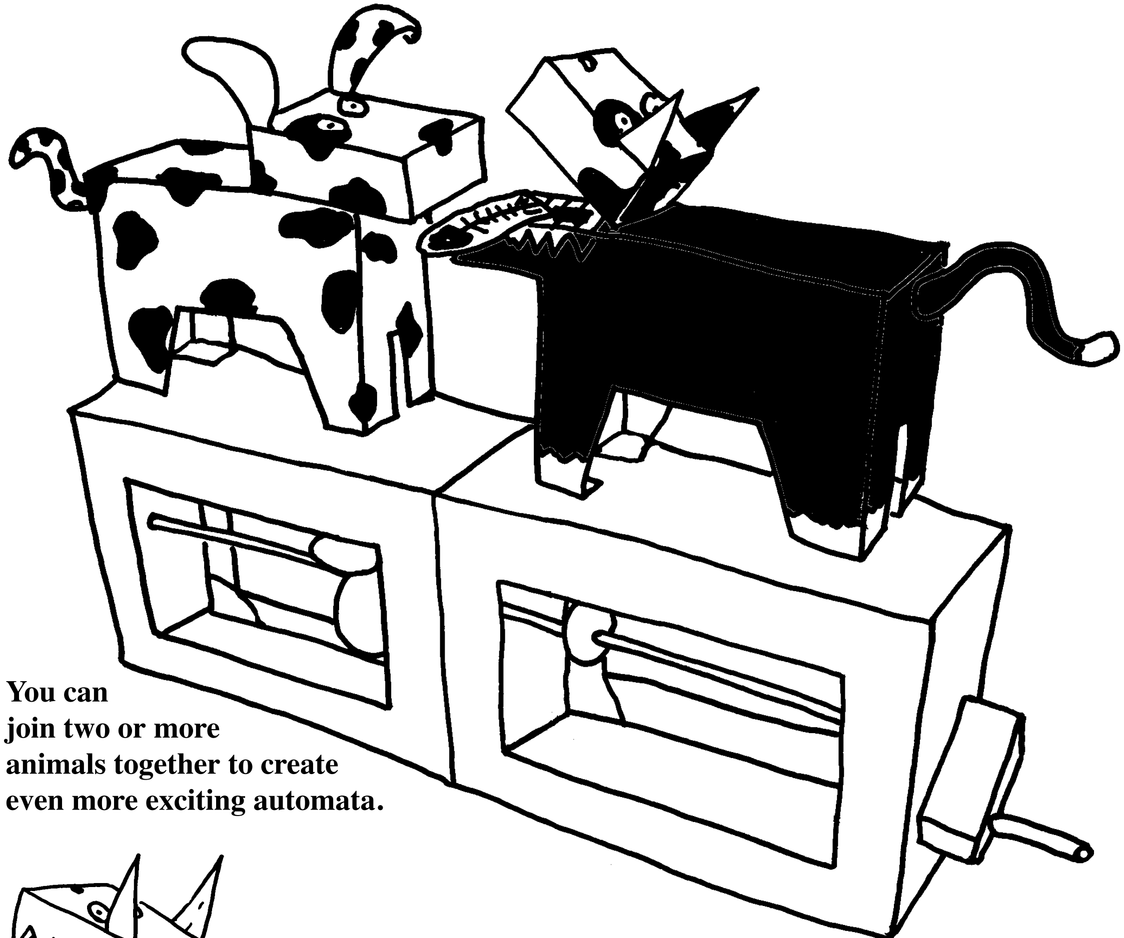
The cam is made in a similar way to the follower except it is offset and is glued on the 130 mm stick and should sit underneath and in the middle of the cam-follower. Once in position you can glue the end stop and spacer parts number. **V1** & **V2.**

The crank handle is simple to make and folds together like the big box. You will need to make sure that the sticks used for both the handle and drive shaft go through both ends. Allow about 2mm to protrude and put a blob of glue on to hold them firmly in place.



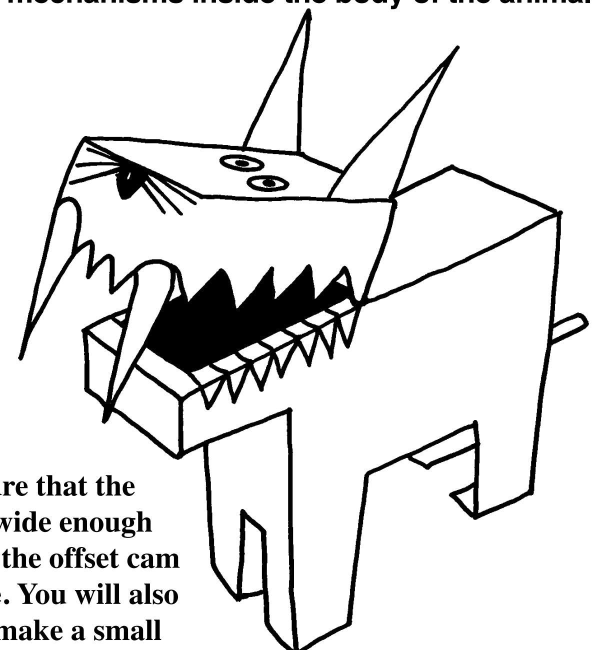


The illustration above shows the cams in place and the push-rod running up through to the top of the head. Turning the crank handle will make the mouth open and close. Unlike real life the top of the head moves and not the lower jaw.

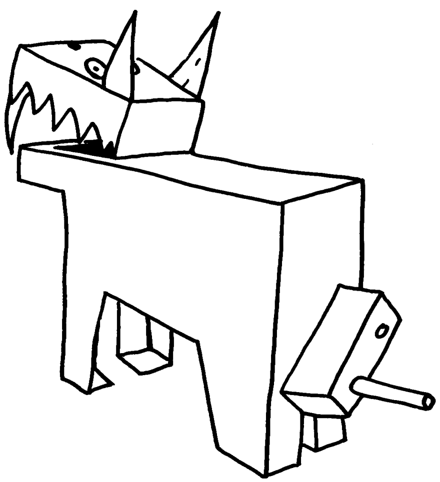


You can
join two or more
animals together to create
even more exciting automata.

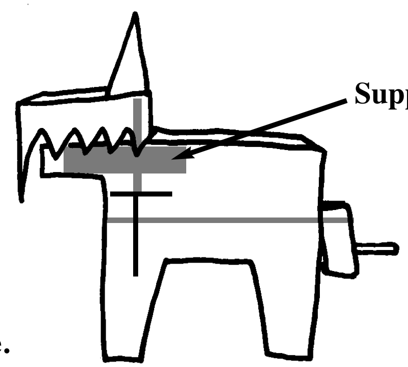
You can dispense with the box and house the mechanisms inside the body of the animal.



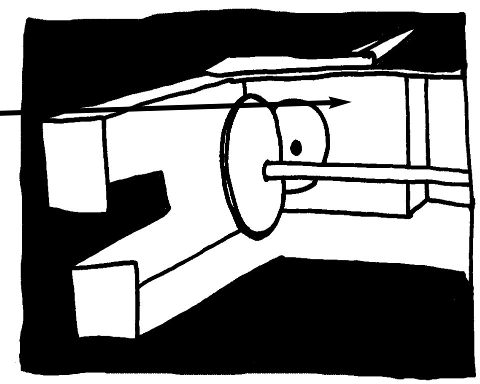
Make sure that the body is wide enough to allow the offset cam to rotate. You will also need to make a small support box. This stops the cam from jamming. The head net on page 20 was used for this model.



Putting the mechanism in the body simplifies the automaton, but is a little more fiddly to make.



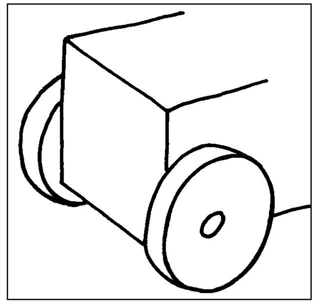
Support box



CAMS

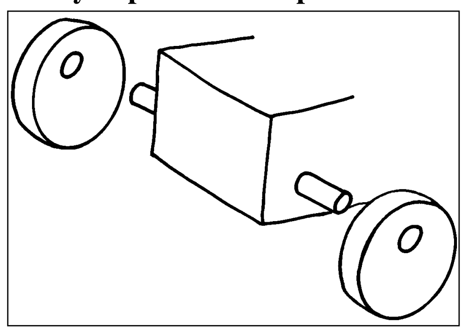
PULL ALONGS

The pull along toy uses it's wheels instead of a crank as the drive force, when pulled along their movement is transmitted along the axle. In simple terms, pull the toy along and something happens. The most common mechanisms used are offset wheels which produce the same sort of motion as offset cams. You can create some very interesting and amusing motions using this simple device. A children's favourite is the caterpillar that wobbles along. You can attach legs to the wheels which then give the appearance of it's legs moving up and down as it is pulled along. This same technique could be applied to a frog or rabbit etc. These sorts of toys are relatively simple to make and help to learn about basic mechanisms. In fact they are very simple automata which instead of turning a handle you turn the wheels to make them move. The beauty of pull alongs is the scope they offer, especially to young children. 7-9 year olds could start with these and progress onto traditional automata. They also offer the opportunity to expand on the simple offset cam. You can use the axle as the starting point for any of the automata we have looked at. The following illustrations should help you to devise your own pull alongs as well demonstrating their versatility.

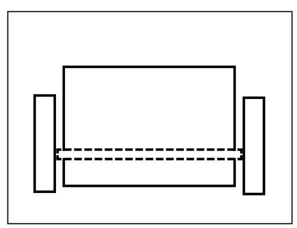


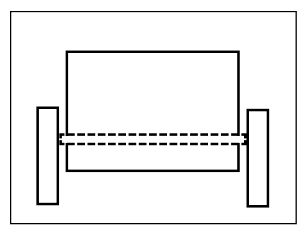
If the wheels are set level and centred on the axle you should have a smooth rolling action. This is the simplest mechanism.

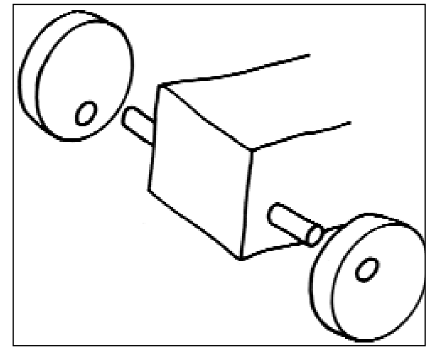
By offsetting the wheels from the middle of the axle you produce an up and down motion as the toy moves backwards or forwards.



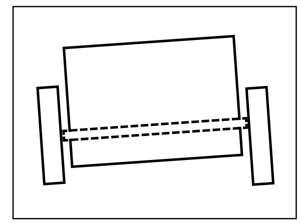
The wheels below are offset by the same amount, this gives a very definite but smooth movement. The more you offset the wheels on the axle the greater the up and down movement you will produce.

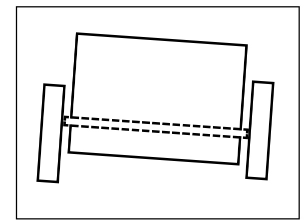






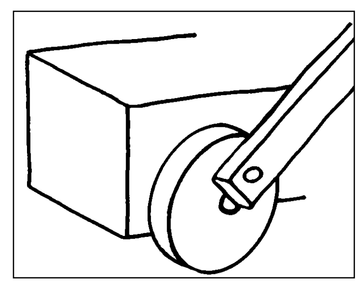
If you offset the centre of the wheels on the axle and synchronise the high and low points to be opposed you will produce and up and down as well as a pronounced side to side wobble.



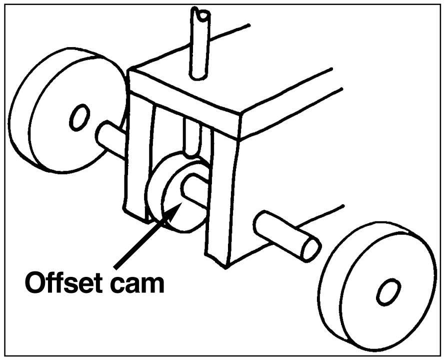


The more you offset the wheels on the axle the greater the wobble you will produce. This simple mechanism produces a very exciting movement when pulled along, yet is very easy to make.

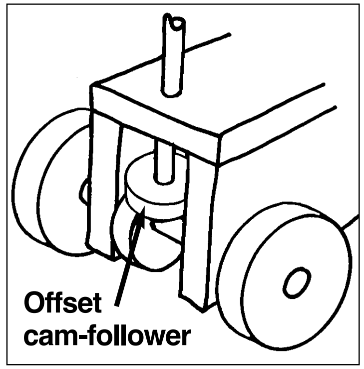
The wheel is centred on the axle and a con-rod is attached to an offset peg. This produces a back and forth, or up and down motion. You can use this to mimic legs.



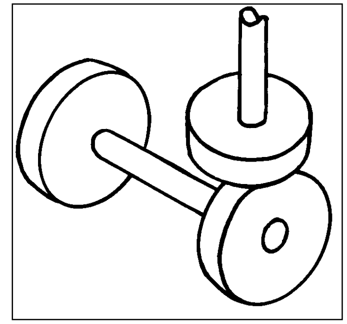
CAMS



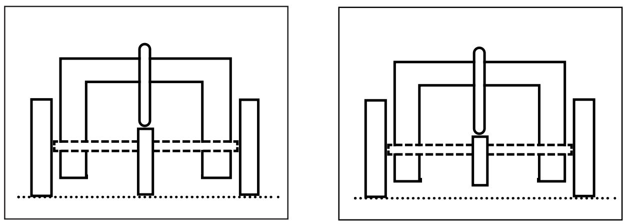
You can have an offset cam on the axle which produces an up and down movement.



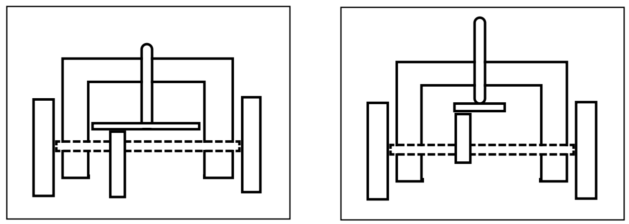
This example employs an offset cam. The cam follower is also offset. This produces both rotary and up and down movement.



You can use friction too, so that an offset cam rotates as the toy is pulled along.

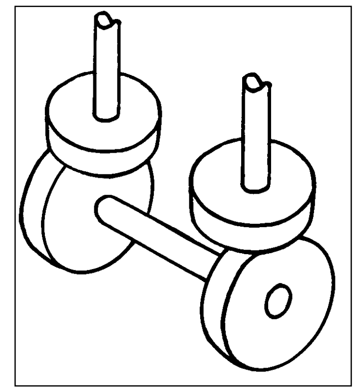


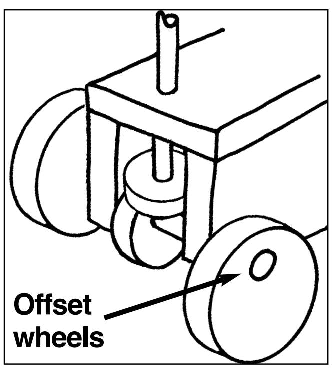
The offset cam should not make contact with the ground, allow room for it not to “stick” if used on a thick carpet. Bear in mind that the larger you make the cam the better and more smoothly it will work.



The offset cam must clear the ground and the cam follower plate must not touch the sides.

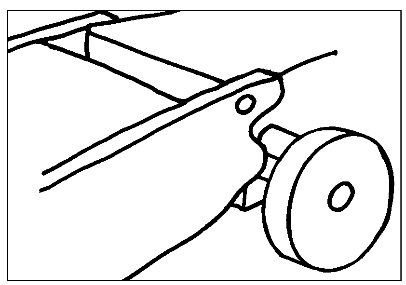
You can add an extra cam. These two will now rotate in opposite directions, adding even further interest.

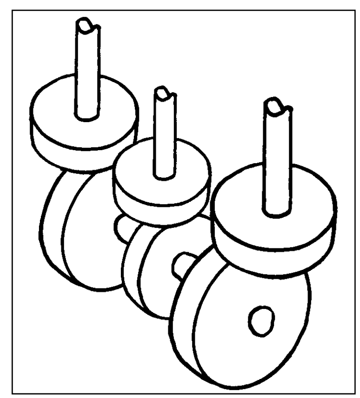




You can build up on the mechanisms for the axle. The example on the left not only has an offset cam-follower but the wheels are also offset and will create a wobble.

The example below uses a peg attached to the inside of the wheel. As the peg is rotated it contacts a pivoted part and lifts it up. When cleared, the part drops down. The art is to make sure that you don’t lift too high and that the part being is lifted is made out of light material such as balsa wood.

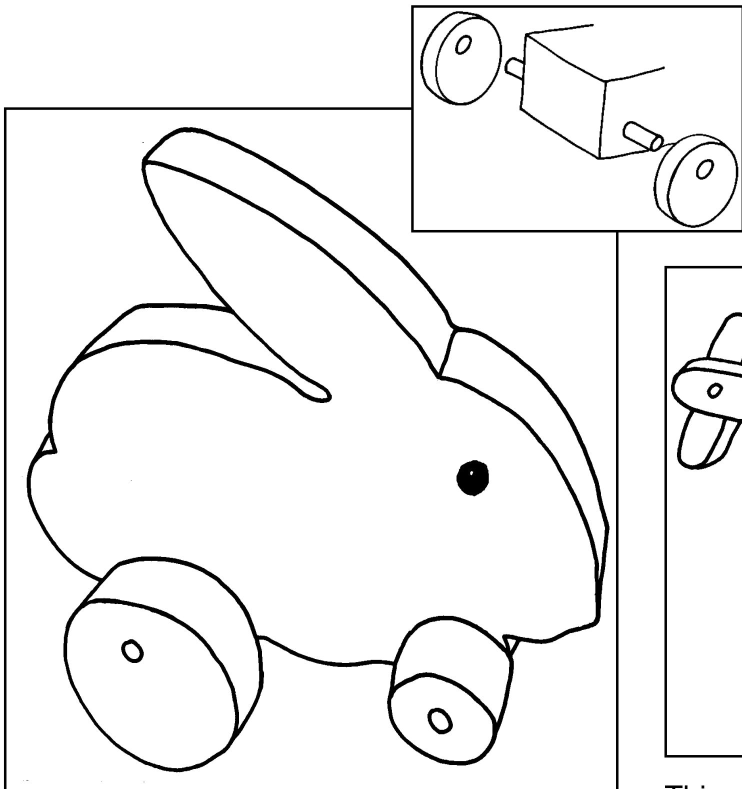




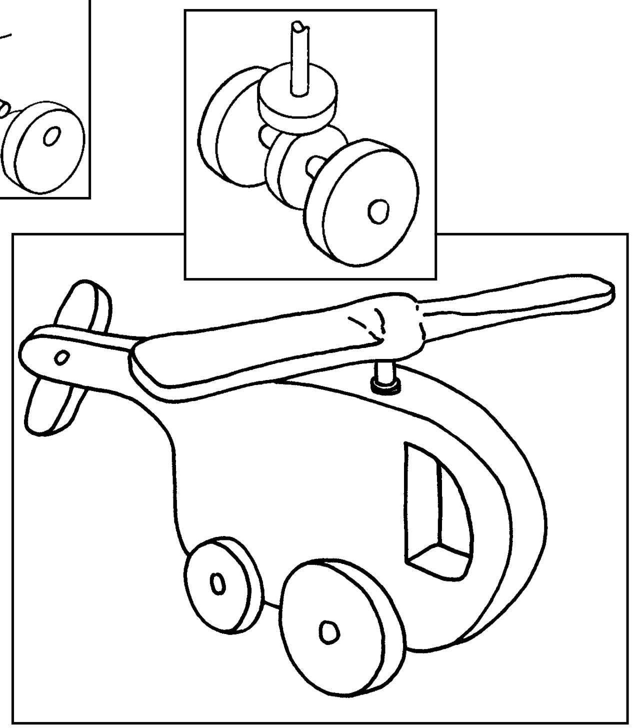
You can use the axle as well as the wheels to create movement.

CAMS

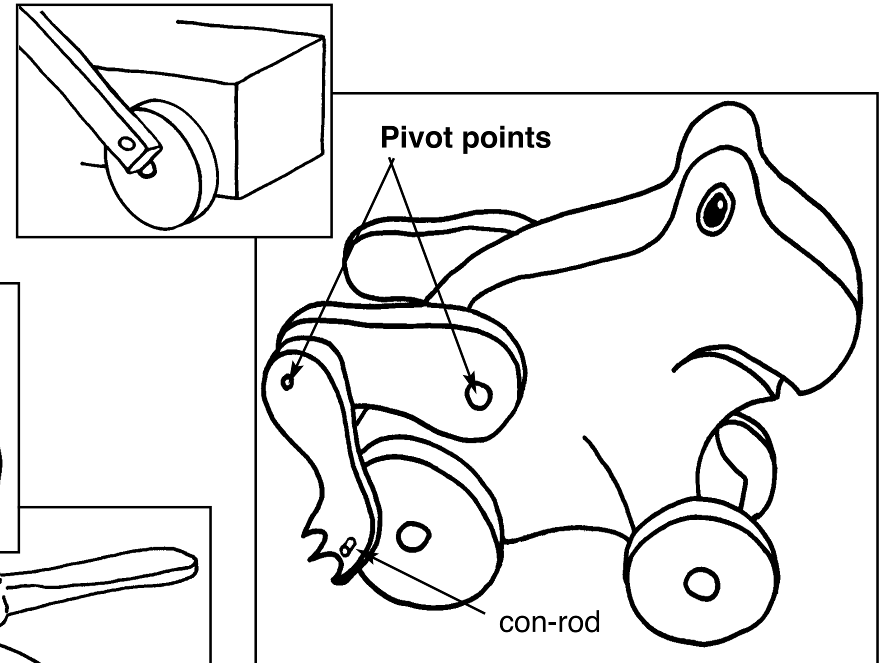
The simple pull-along automata on these pages could be used as the starting point for your own projects. Most of them are based on animals but other subjects can be explored, for example modes of transport.



The rabbit has four wheels. The back two are offset and larger than the front ones. When pulled along it bobs smoothly up and down. This is a very simple and effective mechanism which can be easily adapted to other models.

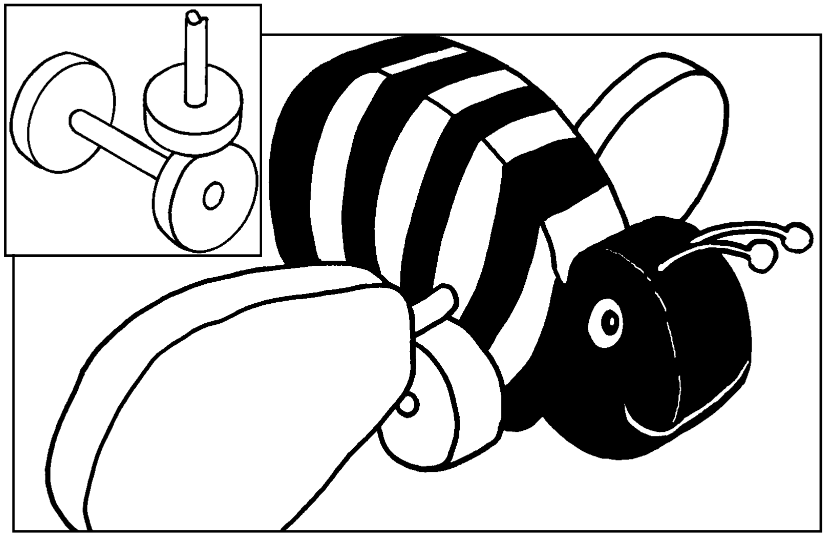


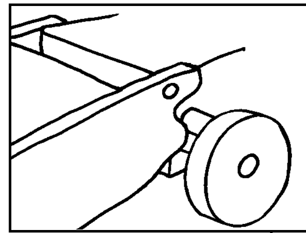
This corrugated cardboard helicopter uses an offset cam to provide movement to the rotor blades. The shaft runs up through the body. A straw is inserted through the cardboard and a wooden dowel is used as the push-rod. The straw helps to reduce friction.

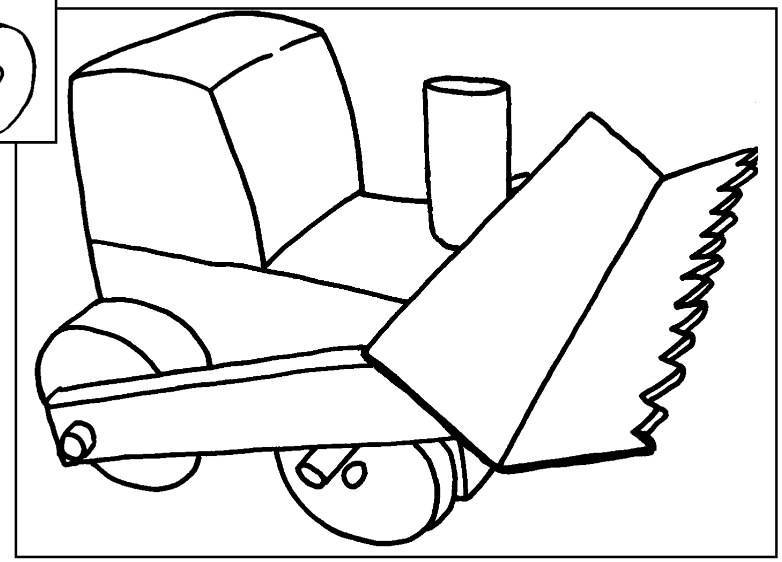


The frog is a little more complicated to construct. It makes use of a con-rod attached to an offset peg on the frog's foot. As he is pulled along his legs, which are all pivoted, move up and down in a jumping motion. It is very important that everything is able to move freely or the mechanism will jam. Again, this can be adapted in many different ways.

CAMS

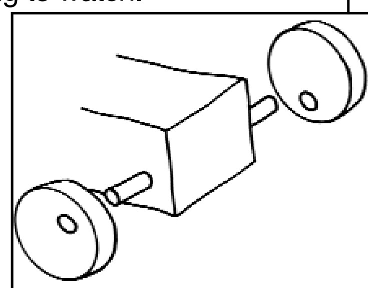


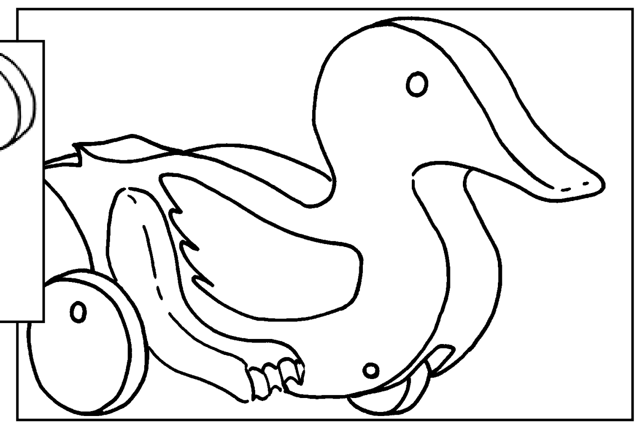




The bulldozer uses an offset peg to lift the digger arm up. The other end is attached to the wheel axle and is free to pivot. This example uses the peg on the outside of the wheel, in the above diagram you can see the peg is used on the inside. This mechanism has a lovely smooth action and is fascinating to watch.

This pull-along bee uses friction to turn the wings around and is an adaptation of the offset cam.There are many possibilities for this mechanism.
You should try to make the shaft that contacts the wheel as large as is practical. This will help to achieve a better friction drive. The bee's wings are very light (polystyrene) which allows them to turn easily. The shaft hole running through the body extends a little way above and below the line of the wheel. This small amount of free movement helps ease the rotation and is very important.



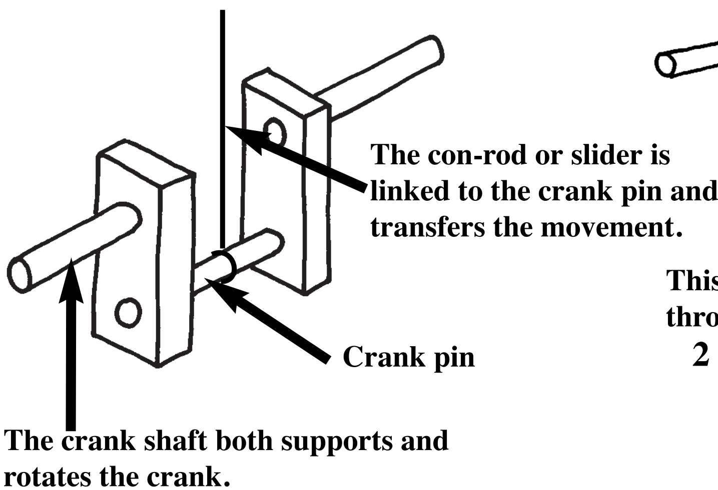


Ideally pull-alongs should be made out of wood. This gives them weight and durability. This may not be practical with young children in a classroom, so you could use cardboard instead. Most of the examples on these two pages are made from two thick sheets of corrugated card stuck together. This works fairly well. The main problem is getting enough weight for friction to work when turning wheels and cams etc. This can be overcome by sculpting modelling clay over the card, to give both shape and weight to the model. You can also mix some PVA glue either with paint or a little water and apply the mix onto the modelling clay. It will seal it and also give a certain strength.

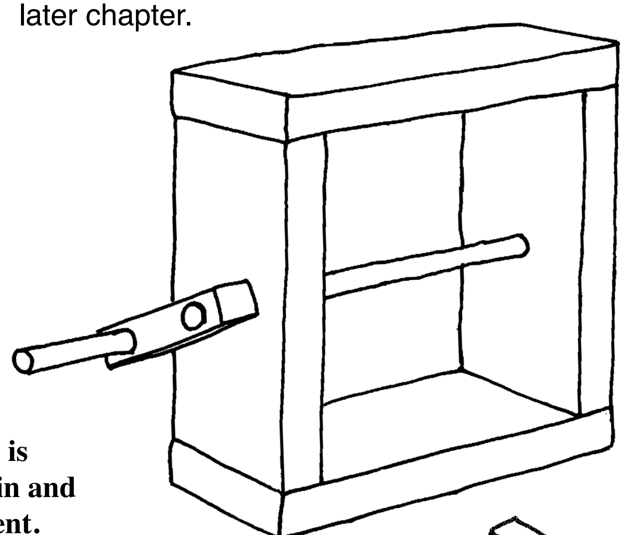
This duck has two offset, parallel wheels at the back and a single wheel at the front. This makes him bob and wobble at the same time. He is also coated in modelling clay to add extra weight to the cardboard base.

CRANKS

Cranks are similar to offset cams. They convert circular movement into a reciprocal one (up and down motion) or vice versa. However, there are a couple of fundamental differences. Firstly, cranks only ever work in a circular motion and secondly they only have one drive action per revolution. That said, when it comes to automata you can use the crank to make some amazing machines. A crank needs thought and care when making but it is an adaptable mechanism. Even young children should be able to make simple cranks with a bit of help and incorporate them in their designs.

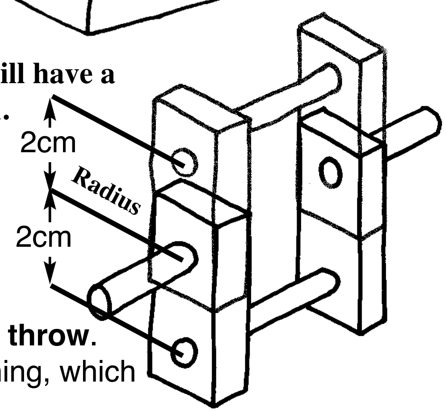


The crank has many uses. It is often the driving mechanism for hand-operated automata. It is important to support the crank with some type of bearing. For most automata the sides of the box provide the support. Bearings and shafts are covered in a later chapter.



This crank will have a throw of 4cm.

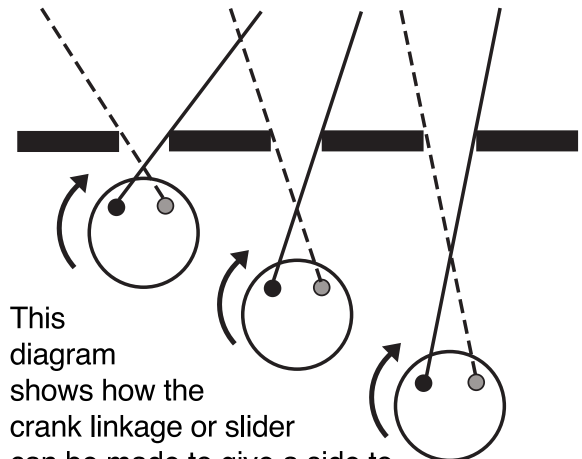
2 + 2 = 4



The amount of up and down movement of a crank is called the **throw**. It is measured by the diameter of the circle it scribes when turning, which will be twice the radius.

Although the crank only works in a circular motion, it's drive can be made to go from side to side as well as up and down (which can't easily be achieved with a cam) and when applied to automata you can create some very special effects.

Another big advantage with the crank is having power on both the upward and return strokes. This means you don't have to rely on gravity, which can be a problem with cams.

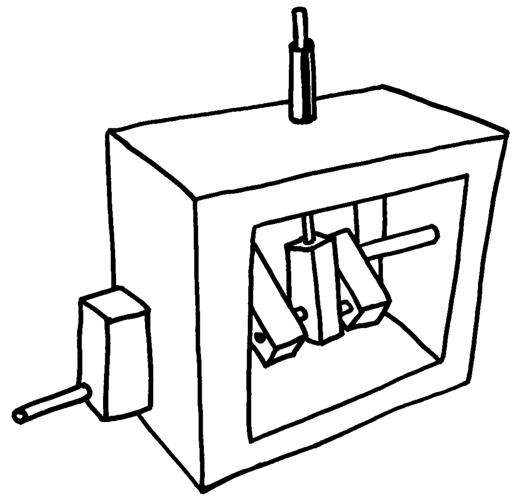


This diagram shows how the crank linkage or slider can be made to give a side to side movement. By adjusting the height from the opening you can increase or decrease the amount of sideways movement. Adjusting the size or aperture of the opening will also have an effect on the amount of lateral movement. As with many aspects of automata you will find that trial and error play a big part in making things work.

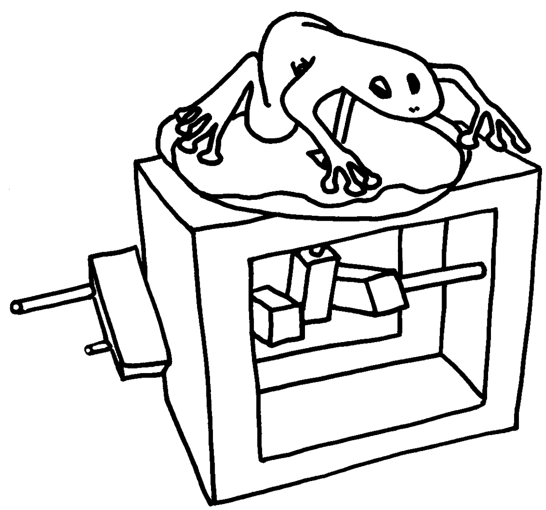
CRANKS

SIMPLIFYING CRANKS

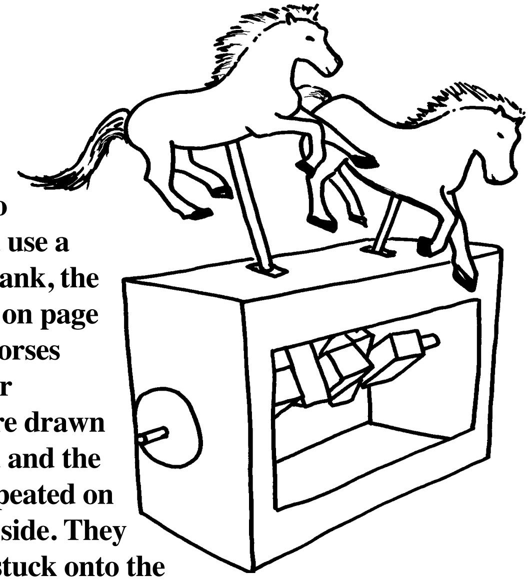
Cranks can be successfully made from card. The following examples and "Nets" will help you to get started. The construction has been kept as simple as possible and most work can be undertaken with scissors. However, you will need a sharp craft knife for some parts and so would advise adult supervision for those tasks or pre-cutting them for young children. The following automata have been constructed out of 160 gsm card (thick paper really). The eccentric crank on page 36 uses thick card for the mechanism and corrugated card for the box housing. 3mm wooden dowel (barbecue stick) has been used for the shafts. Although the mechanisms are simple themselves they need care and thought to make. They are fairly forgiving so great accuracy is not essential. Which is why they are included in this book. A confident 10 or 11 year old should be able to tackle a project incorporating some form of crank. Young children will find it easier working with wire. (see later examples).



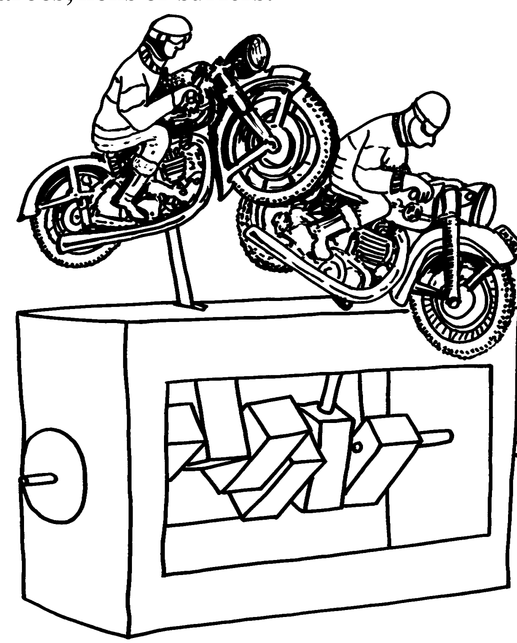
The above crank is made from card using the templates on pages 32-33. It can be used as the basis for a whole range of automata.



The tree frog uses a single crank to generate a leaping movement. The frog is made from coloured card which is cut and then bent to give a more 3D appearance.



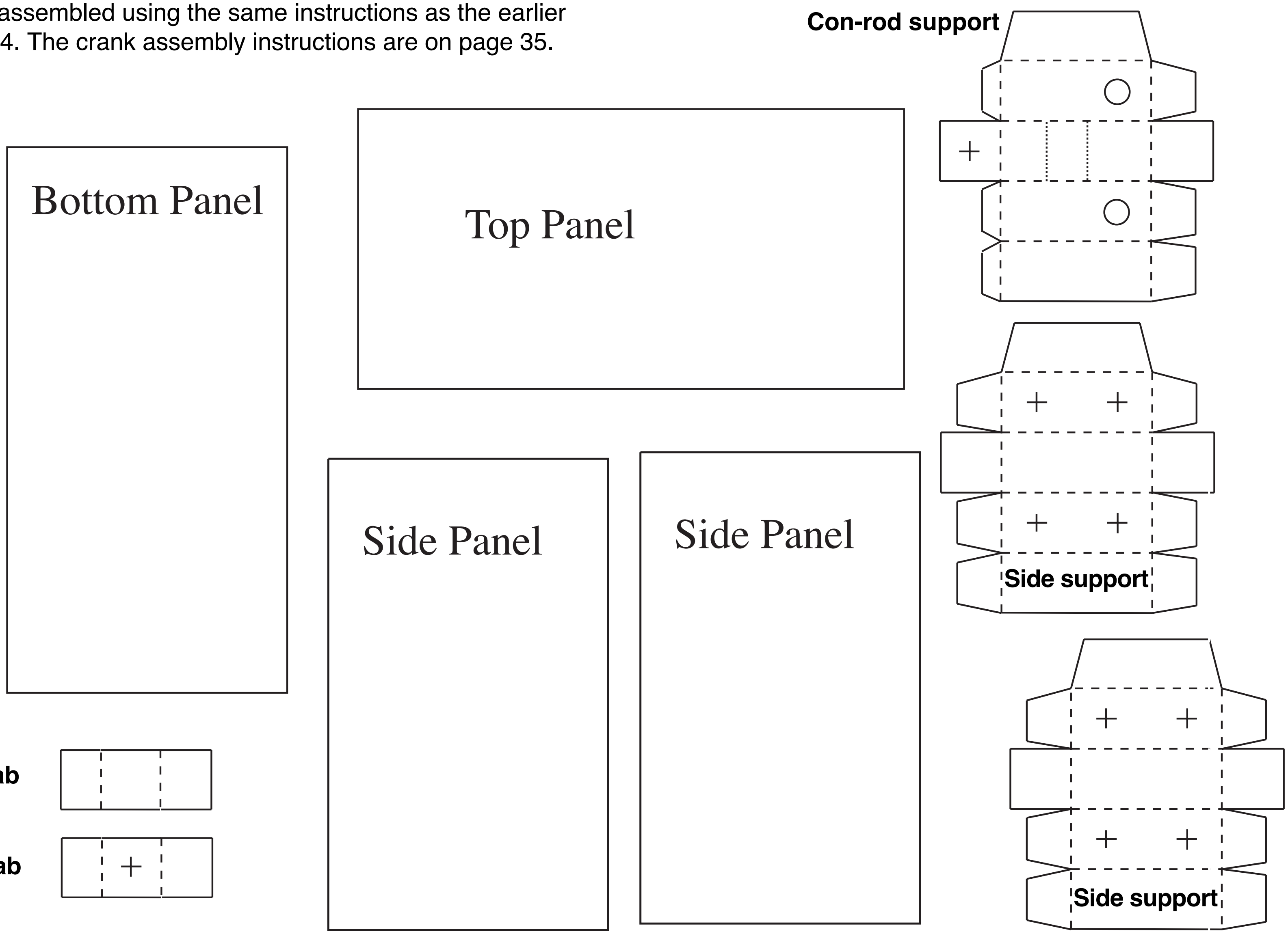
These two automata use a double crank, the plans are on page 34. The horses and motor cyclists are drawn onto card and the design repeated on the other side. They are then stuck onto the con-rod and give the appearance of jumping or leaping as the handle is turned. You can substitute the designs, for example, BMX bikes, zebras, kangaroos, lions or surfers.



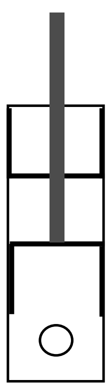
CRANKS

TEMPLATE

This net template can be assembled using the same instructions as the earlier example on pages 23 & 24. The crank assembly instructions are on page 35.



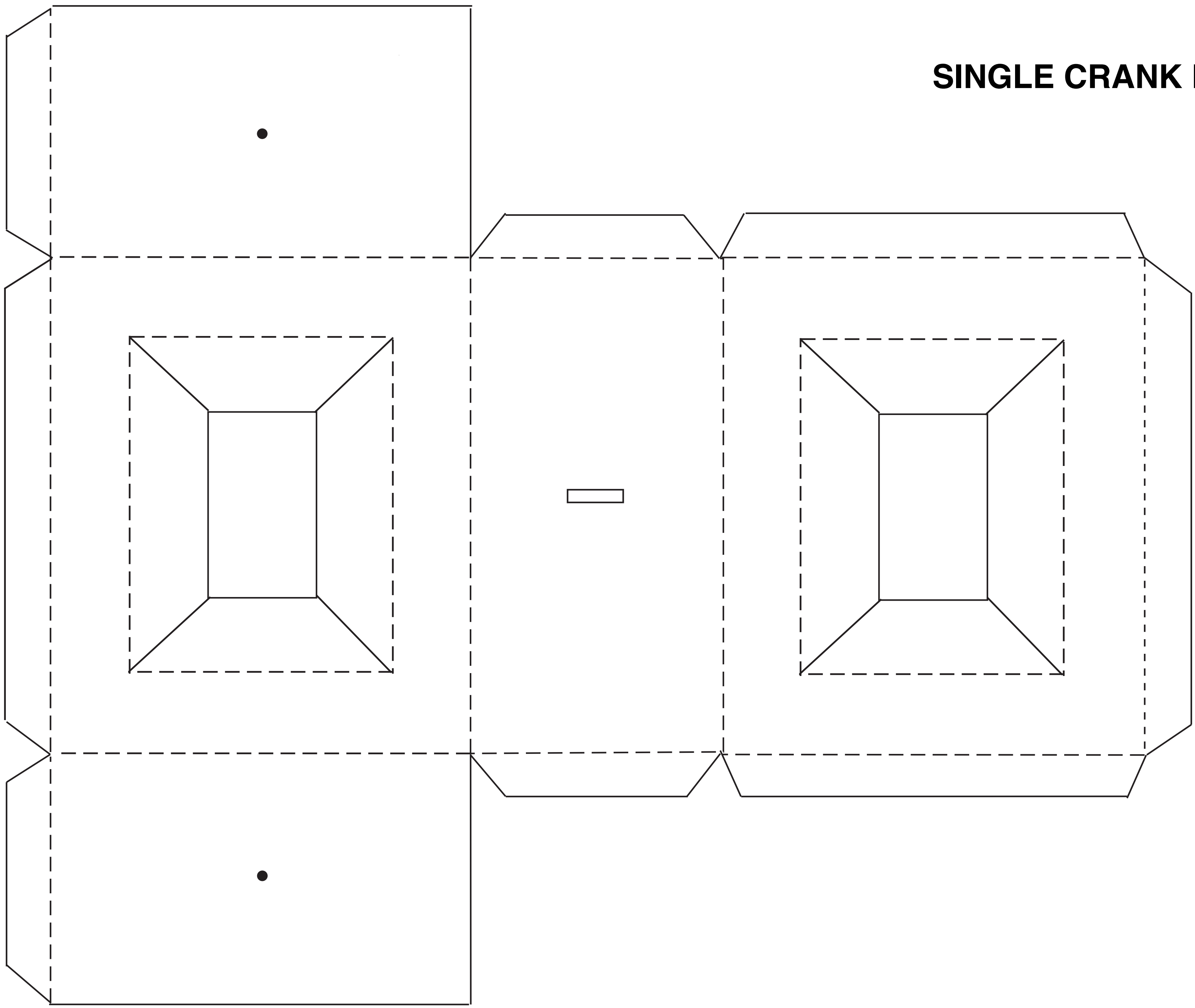
The two tabs are folded into a U shape. Note the upper tab lines up with the top of the support. The con-rod goes through it and rests on the lower tab.



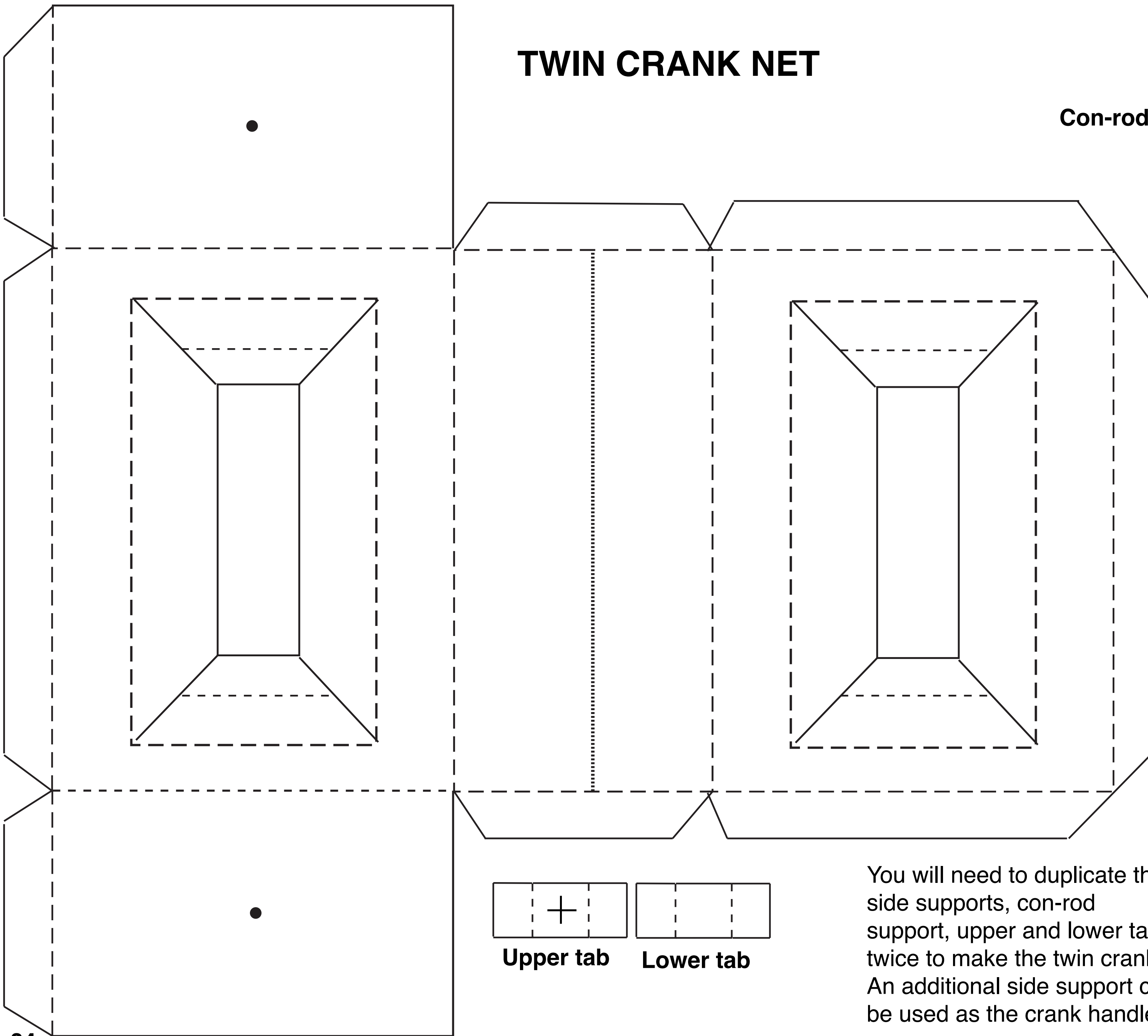
Lower tab

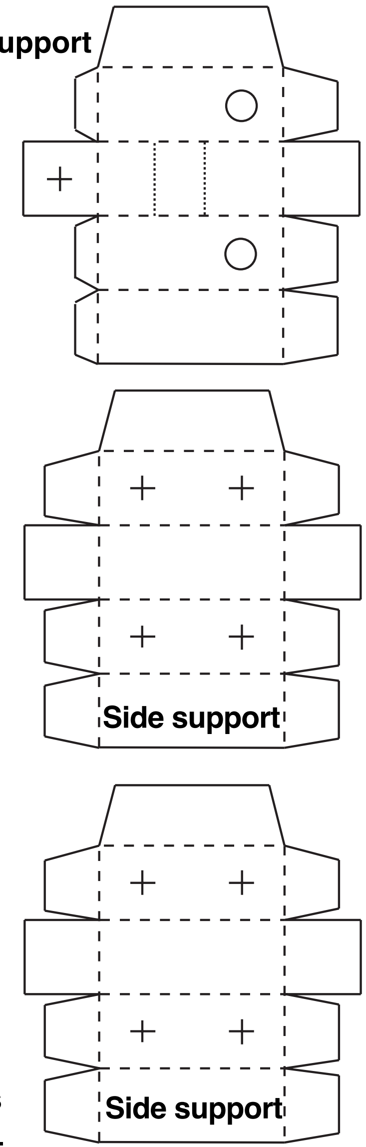
Upper tab

SINGLE CRANK NET



TWIN CRANK NET





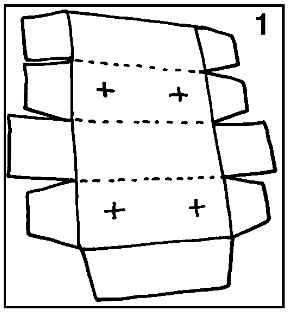
You will need to duplicate the side supports, con-rod support, upper and lower tabs twice to make the twin cranks. An additional side support can be used as the crank handle.

CRANKS

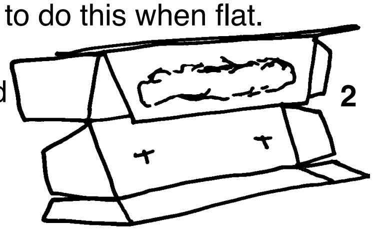
INSTRUCTIONS

This template makes up a twin cam set-up illustrated on page 31. The actual crank is fairly simple to make and all shafts are wooden barbecue sticks about 3mm thick.

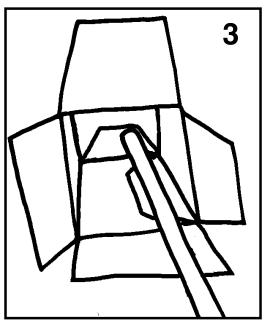
This mechanism relies on a good, strong bond, made using UHU or similar adhesive. Always allow all parts at least 12 hours to dry before putting any strain on them.



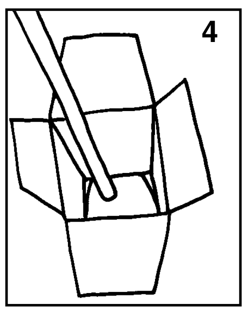
(1)Cut out the two crank supports, make sure you cut through the 4 crosses. This is where the crack shafts will be going. It is much easier to do this when flat.

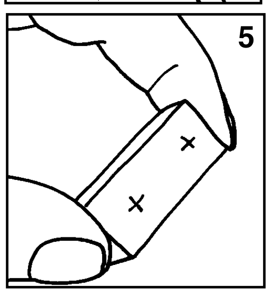


(2)Glue the end tab to make up a rectangular shape.

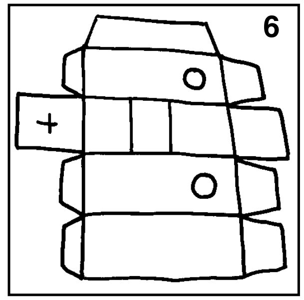


(3)-(4) Use a barbecue stick to put pressure on the tab and press it flat. This will help it to glue faster and stronger. Fold the tabs at one end, glue and use the stick to apply pressure.



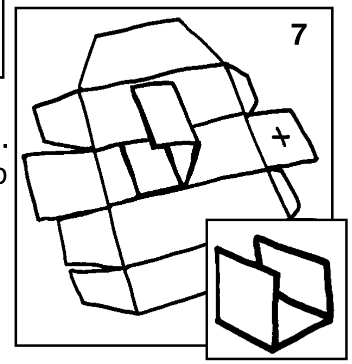


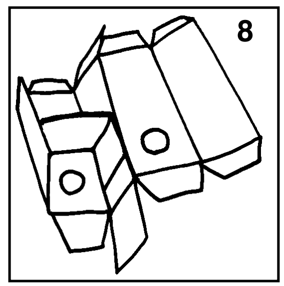
(5) You now need to glue the tabs at the other end. The trick is to fold them “outward” in the opposite direction. Then push them back and apply the glue. The tabs will now be trying to spring back and will push against your fingers as they dry. Repeat this for the other crank support.



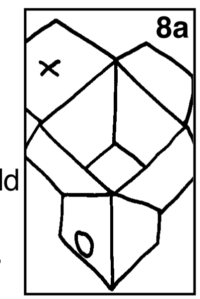
(6) Cut out the crank slider. Remember to cut the crosses and the circles.

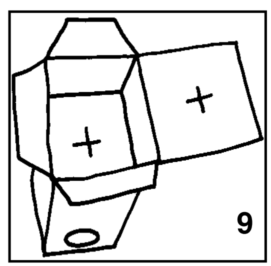
(7) There are 2 lines marked on the inside. Glue the first stop tab (this is the one without a cross) to the lower line nearest the two holes.



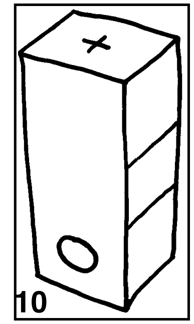


(8) Now fold over the sides and glue the other side of the tab. You will have to fold the lower end tabs as per step (3)-(4). Keep the top end open.



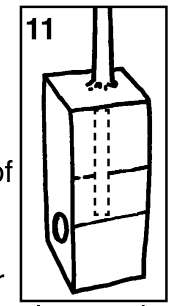


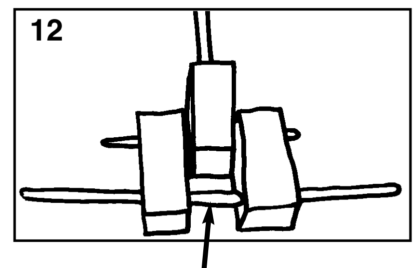
(9) The box now needs to have the second inner tab fitted. This one has a cross on it, which will need cutting. You need to glue the 2 sides and align them with the mark in the box.



(10) Bend the tabs outwards like in step (5) to complete the crank, which should now look like this.

(11) You now need to apply glue to the lower part of a length of barbecue stick. Push it through the top and inner tab stopping at the lower tab. A bit of glue around the top will give extra strength.





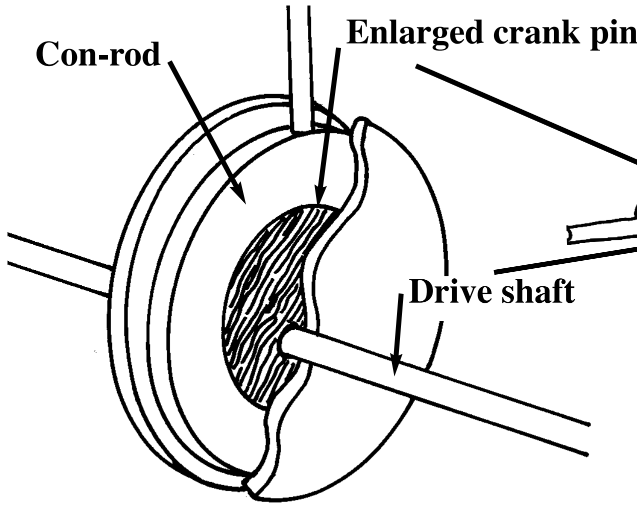
(12) Finally join up all the pieces. Make the crank in one piece and let it dry. You can then cut out the extra drive shaft when the glue is dry. This part is covered more thoroughly on page 75.

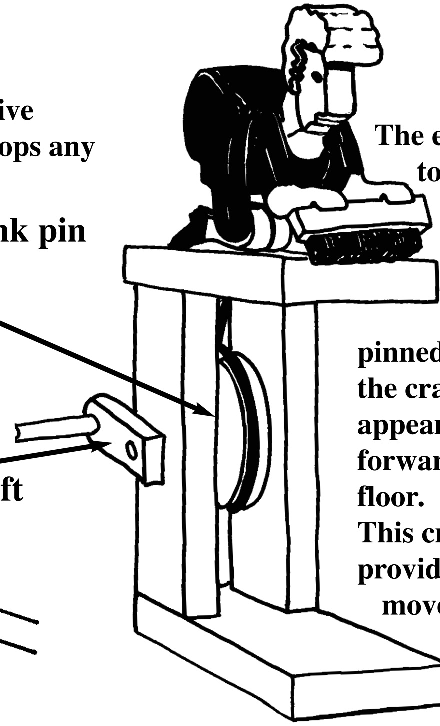
CRANKS

THE ECCENTRIC CRANK

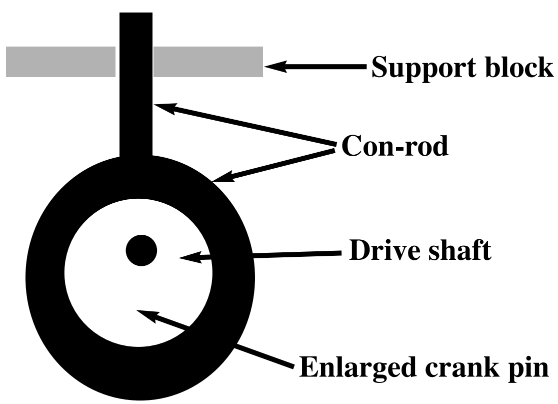
This next crank is known as an Eccentric Crank. The crank pin is greatly enlarged and sits within the con-rod (or eccentric strap). This crank will produce up and down as well as side to side movement. It also uses a straight drive shaft and is therefore stronger and easier to make. It is necessary to support the con-rod with two circular supports attached to the main shaft, in order to stop it falling off the crank pin.
The distance from the centre of the shaft to the highest point of the crank pin will determine the throw. When constructed this is quite an elegant looking mechanism. It's real advantages over the traditional crank is the straight drive shaft and ability to fit into tight spaces. Again this can be made out of thick card.

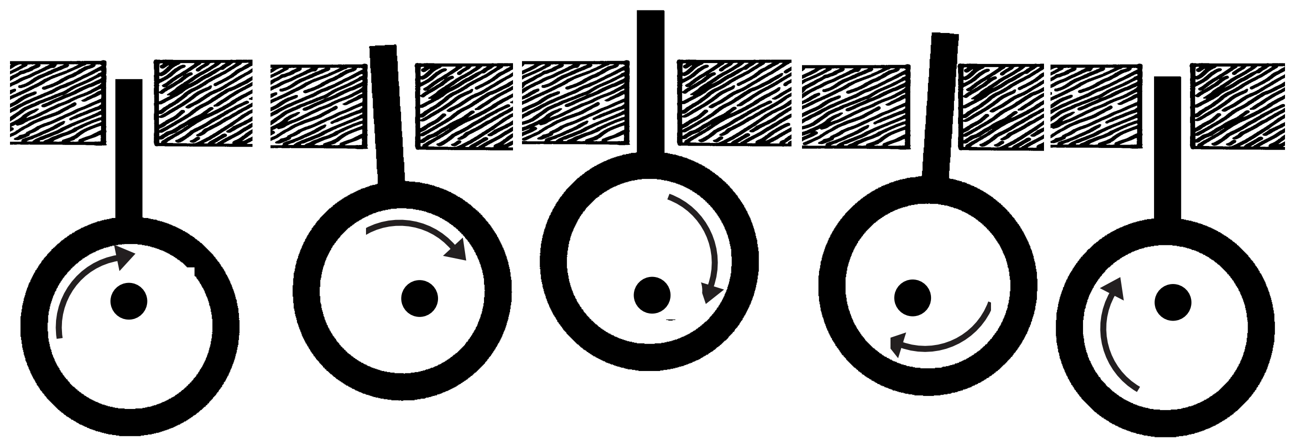
The side supports are attached to the drive shaft constraining the crank pin. This stops any lateral movement.





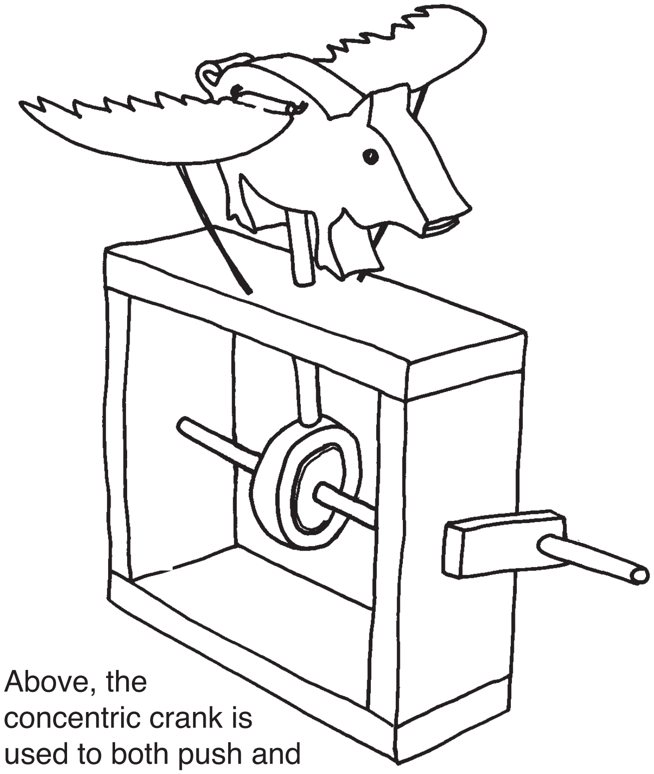
**The eccentric crank is used to push the cleaning lady up and forwards, then back again. She is pivoted at the knees and her arms are pinned and free moving. As the crank is turned she appears to scrub back and forwards furiously on the floor.
This crank is excellent for providing a slightly irregular movement when not constrained.**



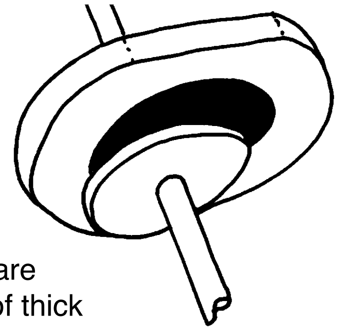


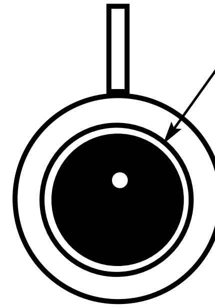
The concentric crank raises and lowers the con-rod as it rotates. Because the con-rod is free to rotate it can be constrained to a near vertical path. .

CRANKS



This illustration shows the concentric strap on a straight drive shaft. The offset crank-pin is in black and you can see the side supports holding it in place. The crank-pin and con-rod are made from two layers of thick card such as that found at the back of drawing pads. This sort of card is made from many layers and has a smooth surface when cut. Corrugated card, although nice and thick tends to jam and is best avoided for this crank.
The side supports should be larger than the crank pin. They are there to stop it dropping out and need to be a close fit.

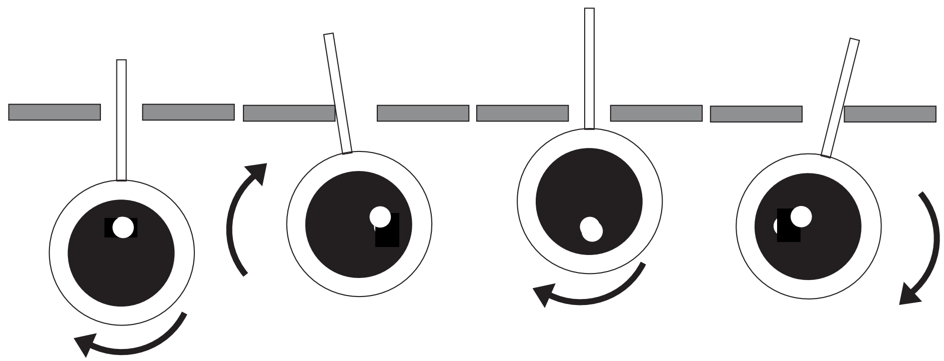




You need to allow a small gap between the crank-pin and the con-rod. Rubbing graphite from a pencil onto the crank will help it to rotate smoothly.

The most difficult part in constructing this mechanism is the cutting out. Because the card is thick and strong scissors won't work so you will need to use a craft knife. An alternative method is to use a hand drill with circle cutters normally used for wood. This should be done by a teacher.

Above, the concentric crank is used to both push and pull the pig. As it rises up and down, fixed linkages make the wings move in the opposite direction to the pig and it looks like it is flying. Another advantage of the crank over the cam is that being fixed to the crank shaft it does not cause horizontal rotation which happens a lot with cams unless the follower is sitting right in the middle.
This is a very adaptable mechanism and the flying motion can be applied to other designs such as aeroplanes, people, insects, fish and even birds!

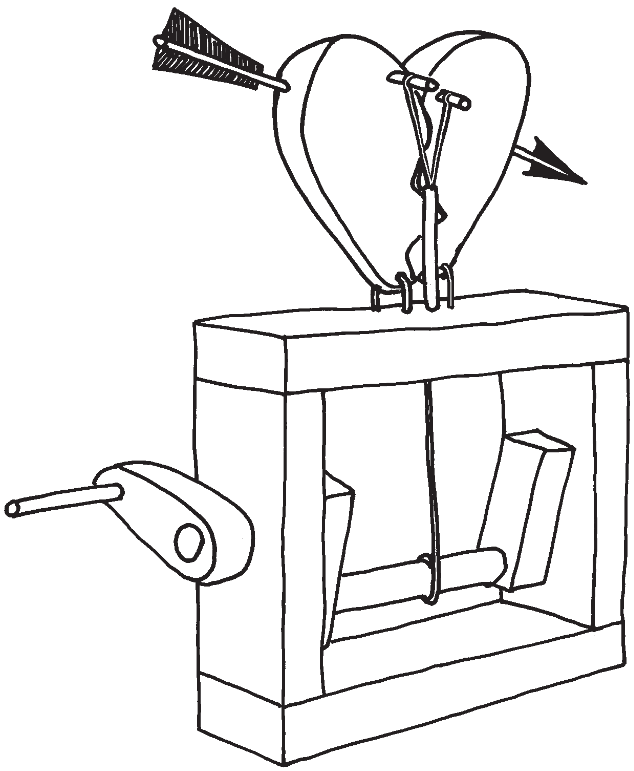


With a wider opening in the support block the concentric crank produces a more pronounced side to side motion. The diagram above demonstrates this. The same engineering principles also apply to the amount of lateral movement (side to side). So a bigger gap or longer con-rod will both have an effect. This is something you can explore.

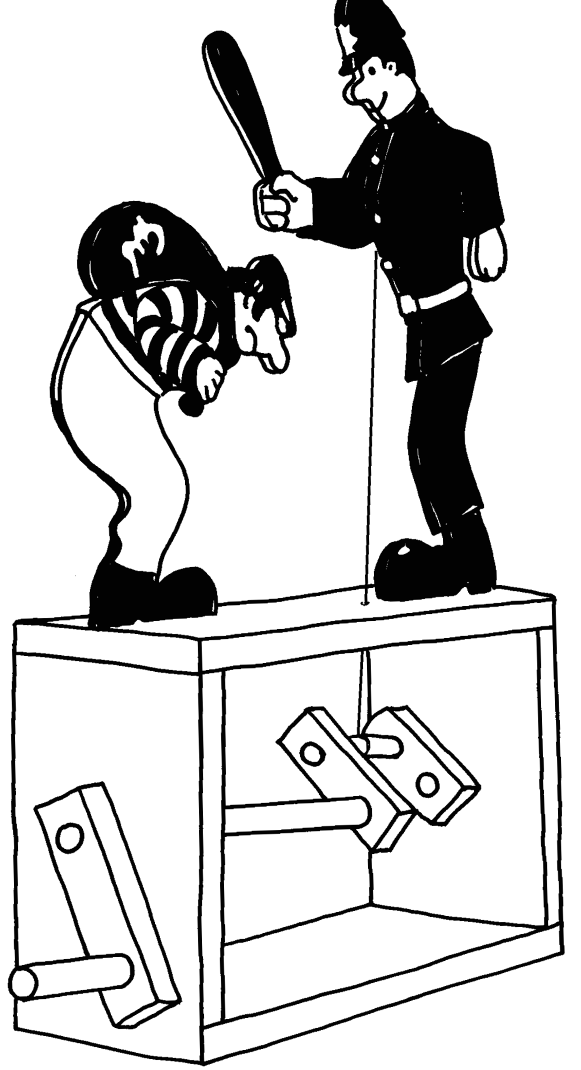
CRANKS

STRINGS ATTACHED

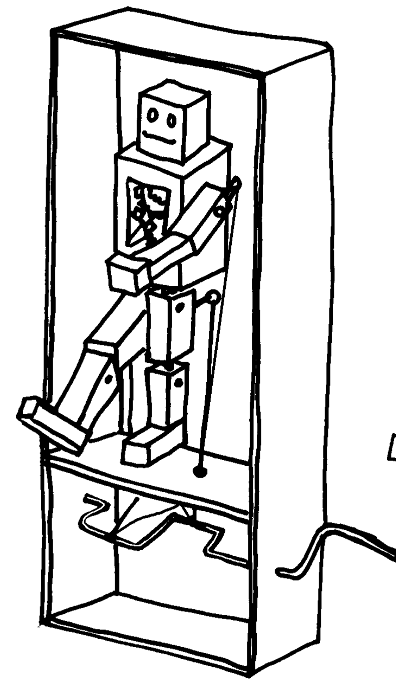
Most con-rods are made of resistant material such as metal or wood. A great alternative, in certain circumstances, is nylon cord. This method works best if you need to pull rather than push. The automata below and opposite rely on gravity as a secondary moving force.

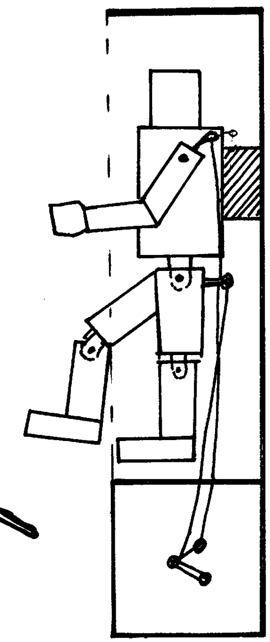


The two pieces of the heart fall apart helped by gravity and a weighted arrow. As the crank turns, it pulls the nylon cord which, in turn, pulls the two halves back together.

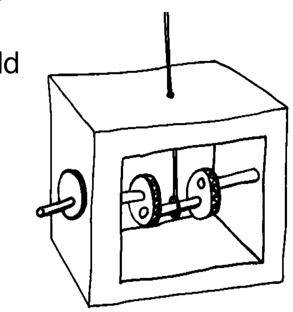


As the crank reaches it's lowest point the policeman's truncheon is pulled up by a nylon thread. When the thread slackens, gravity pulls it down.



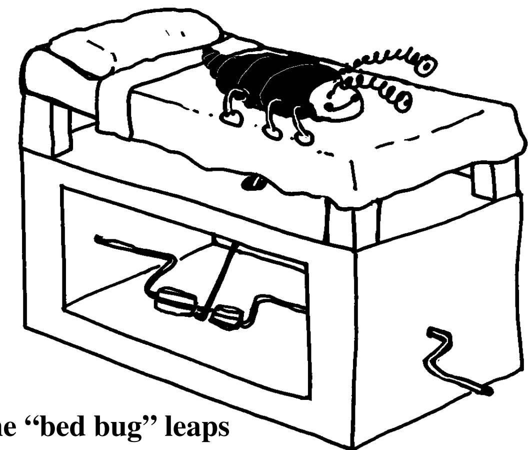


The above robot makes use of a cardboard box with a simple wire crank that lifts his arms and legs up to give him the appearance of walking. The robot is also made of card. This automaton could be adapted to other characters, and you could even have two or more figures moving. You can make a stronger crank out of thick corrugated card disks and use pencils for the shafts.

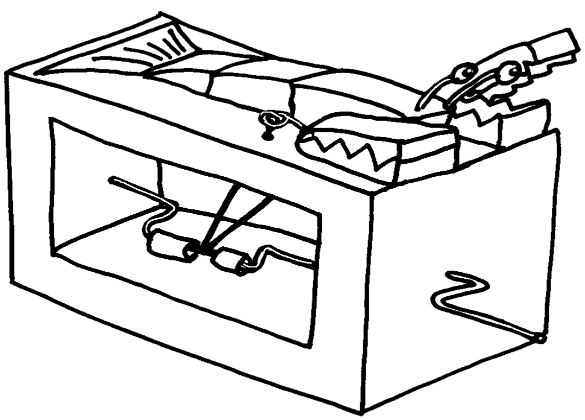


CRANKS

A simple wire crank is a good mechanism to start with. It can be adapted in many ways to produce exciting and lively movement. You can make all these automata out of card and wire.

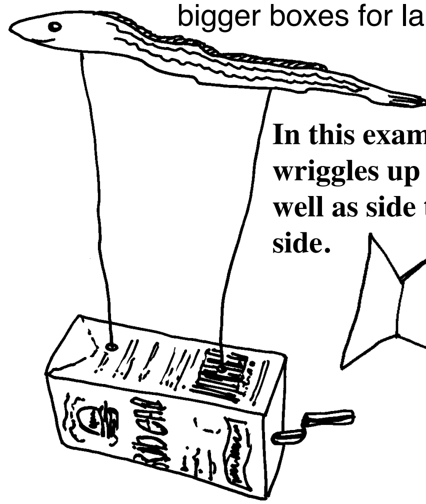


The "bed bug" leaps about on top of the sheets.

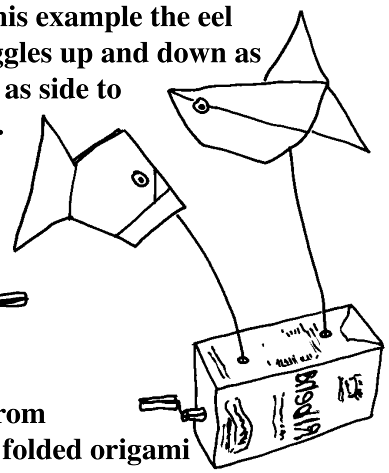


This snappy lobster makes use of two cranks that pull the claws open alternately.

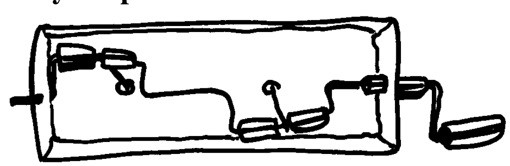
The recycling of household packaging can be a very positive aspect of making automata with children. The automata below use a small drinks carton to hold the mechanism. Florist's wire is used to make the crank and handle. A drinking straw has been cut for use as spacers to keep the crank-pins in place and make a handle. You can adapt this to use bigger boxes for larger automata.



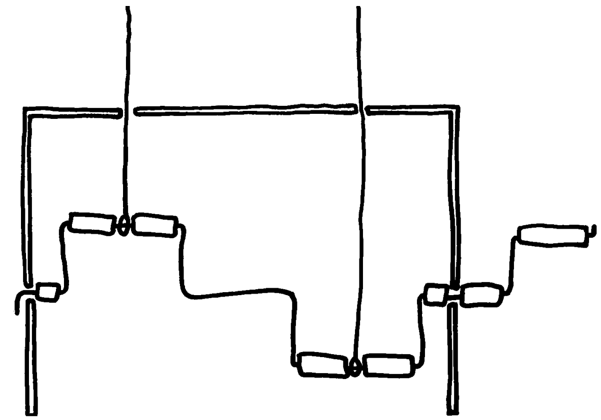
In this example the eel wriggles up and down as well as side to side.



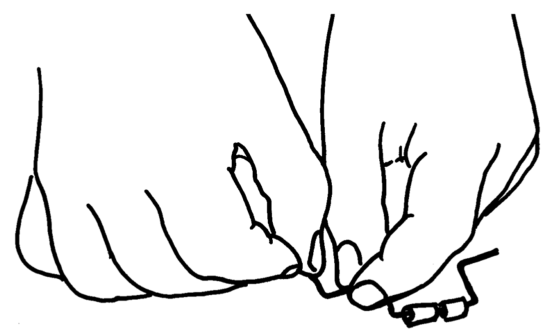
The fish are made from coloured paper and folded origami style. They bob up and down as well as side to side. Below you can see the mechanism inside the drinks carton. It is very simple and effective.



Below you can see more closely how the wire is bent into shape and how the straws help to keep the mechanism in the box as well as holding the con-rods in place.

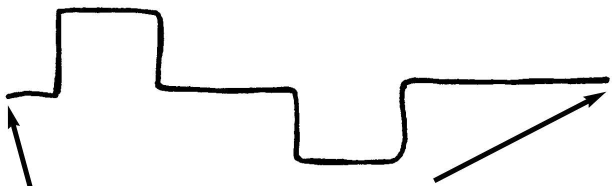


You can bend florist's wire by hand very easily. It is advisable to draw the shape of the crank on paper beforehand and follow the pattern as closely as possible. Remember to put the straw spacers in place as you go along.
The straws have to be quite narrow as the wire is thin. The straws that come with the drink work well and add to the recycling theme.



CRANKS

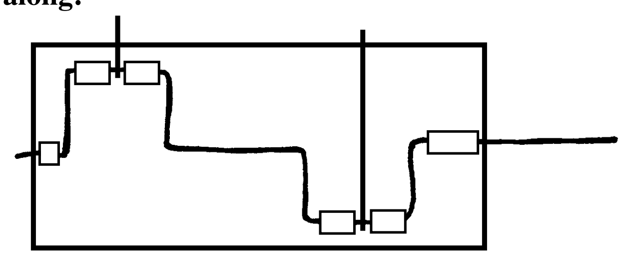
Fitting the crack mechanism into the box takes a little planning. The drinks carton is relatively flexible which helps a lot. The best method is to make up the crank but not the handle. Leave this as a straight length of wire and feed this through the hole first, making sure that there is a straw spacer on the inside. The back part is much shorter and squeezing the box together should give a little more room. Slide the wire through the hole, again make sure that there is a straw spacer on the inside.



If you slide the longest part in first.

Then the other, shorter end should go in quite easily.

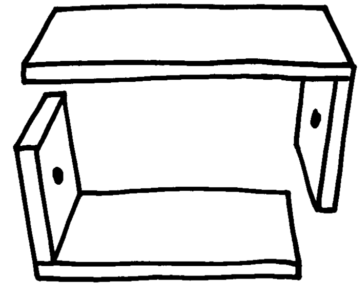
Don't forget to add the straw spacers as you go along.

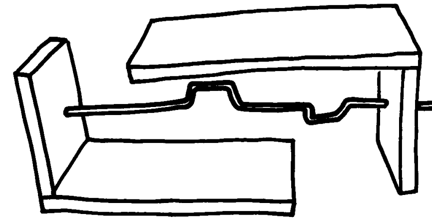


Once in position you can bend the short end over and bend the longer length into the crank handle.

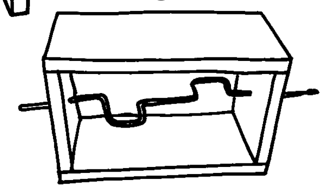
Larry the lizard, featured below, uses a corrugated card box with a wire coat-hanger as the crank. Larry the lizard is made from coloured card sections that are stuck together. This is a simple construction and gives flexibility. The wire coat-hanger is very easy to bend into position. It can be done by hand or with pliers. This automaton is about twice the size of the carton ones and so needs a stronger crank. Florist's wire is just too thin. You can adapt this mechanism for other projects. The children should pre-draw the crank and then try to bend the wire to fit the drawing.

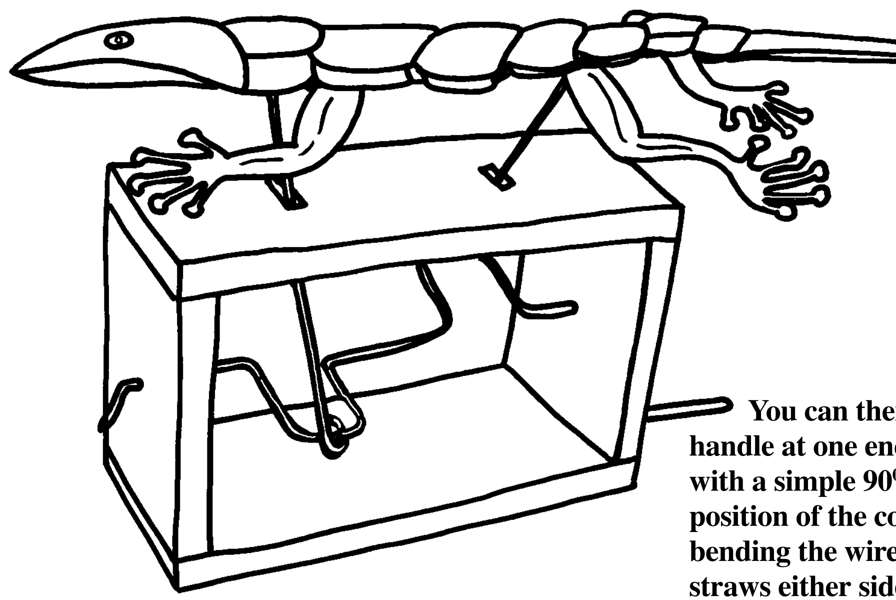
You will need to make the base in two sections. This will allow you to fit the pre-formed crank.

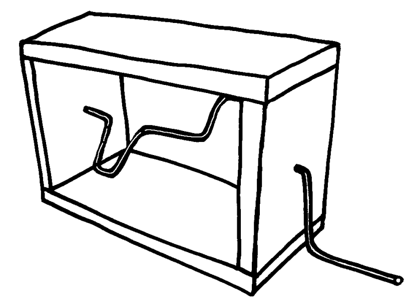




You can now fit the crank, and then glue the two sections of the base together.



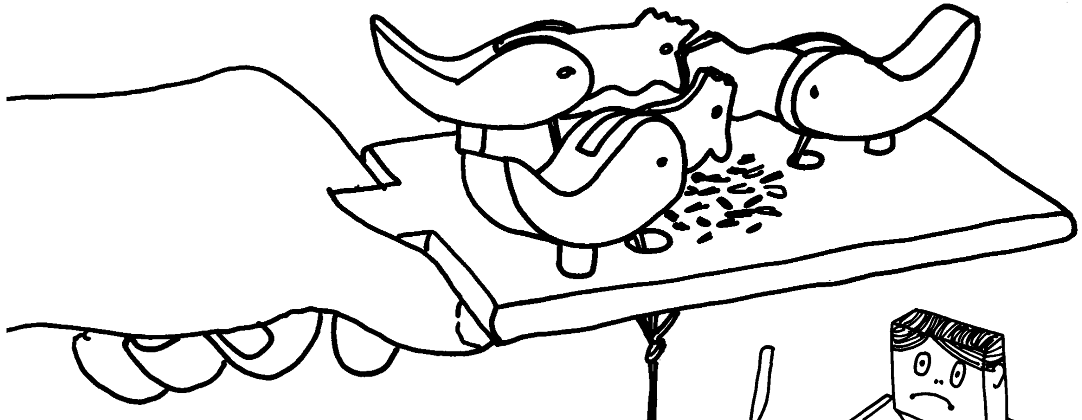




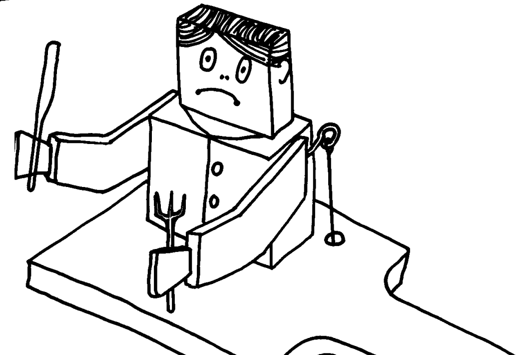
You can then bend the wire into a crank handle at one end and make it fast at the other with a simple 90^0 bend. You then work out the position of the con-rods and attach them by bending the wire into a loop. You will need to fit straws either side to stop them sliding sideways.

CRANKS

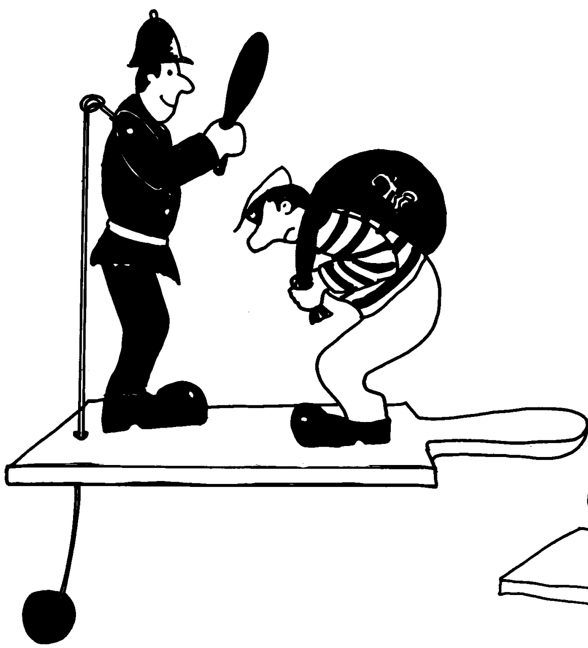
For some young children even simple cranks and cams may be too complex, so push-pull mechanisms can be used instead. Pecking chickens are an old favourite and rely on weight and gravity to produce movement. Pulling the string on a simple figure makes the arms and legs move and is a very easy way of producing and learning about movement. This is an area well worth exploring, and can easily be adapted for many things.
The following automata make use of linkages and levers to create movement.

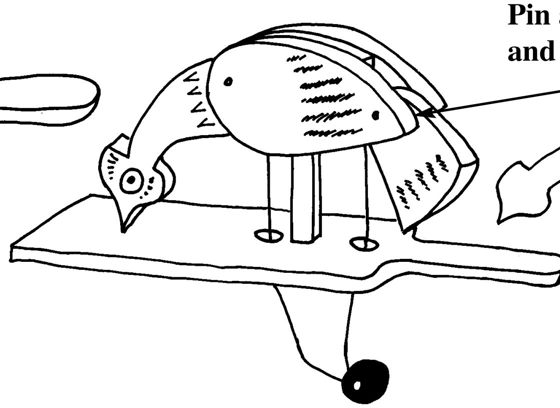


This simple mechanism is very versatile. As mentioned, the pecking chickens are an old favourite, but you can adapt the movement to most things. In fact, you can replicate the action of a simple crank, without having to make any mechanical parts. It is simplicity and adaptability which makes this a great starting point for young automata makers.

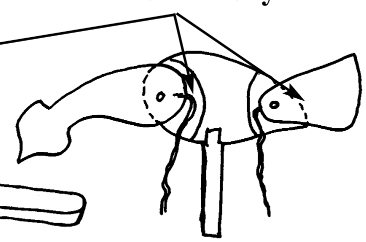


The hungry diner is thumping his knife and fork as he waits impatiently for his dinner.





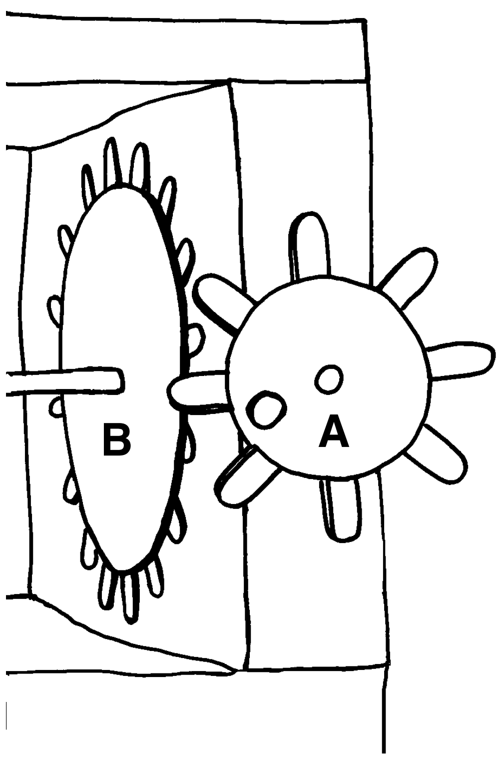
Pin attaching the neck and tail to the body.



When using this technique the knack is to make sure that the parts you want to move are pinned in such a way as to allow the weight to pull them down. It is also important that they can move freely. In the example to the left you can see that the pin is placed close to the string. The neck of the chicken is quite long and dips down, the swinging weight then pulls it up. The weight needs to be fairly heavy. A large metal nut or wooden ball work well.

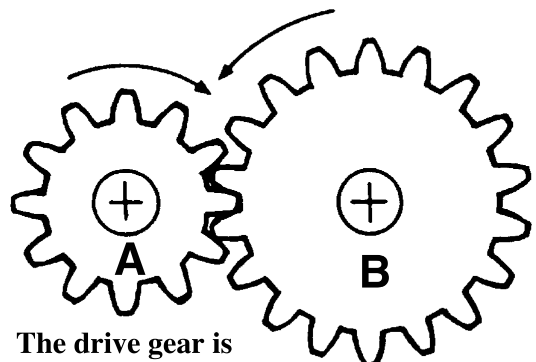
GEARS

Older children can be introduced to the principles of gearing. They can make very effective gears using lolly sticks, pencils or wooden dowel stuck to cardboard.



The example above uses a ratio of 2:1 The big gear wheel (output gear) has 16 lolly sticks whilst the smaller one (input gear) has 8. So things are slowed down, it takes 2 turns of the small gear **A** to make the big gear **B** turn once.

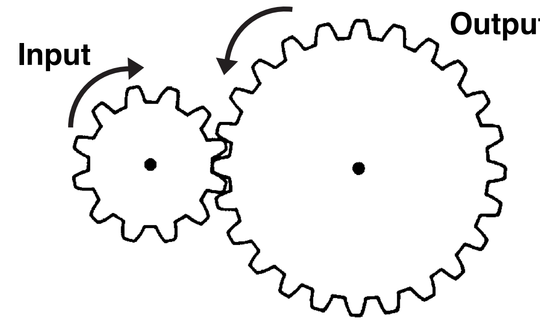
HOW GEARS WORK
Gears are very versatile and can produce a range of movements that are used to control the speed of action.
In basic terms, gears are comparable to continuously applied levers; as one tooth is engaging, another is disengaging. The amount of teeth on each gear wheel affects the action on the gear wheel it engages or meshes with. The gear wheel being turned is called the input gear and the one it drives is called the output gear.
Gears with unequal numbers of teeth alter the speed between the input and output. This is referred to as the gear ratio.



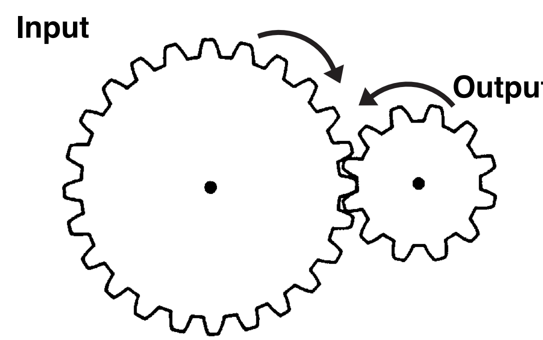
The drive gear is known as the "Input gear".

The gear that is being turned is referred to as the "Output gear".

Gears also alter the direction of rotation. In the above example gear wheel **A** is rotating clockwise, but as it turns, gear wheel **B** is moved anti-clockwise.



Stepping down has the advantage of producing more power although at a slower rate. This is often a big advantage with automata as some of the mechanisms can get stiff or are under tension. It makes turning the handle easier.

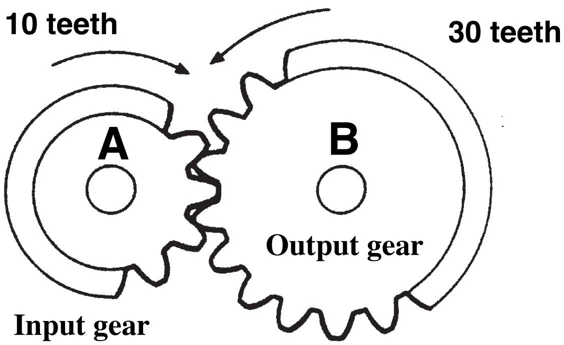


Stepping up produces a much faster output speed, but mechanically delivers less power. Be aware of this as you may find that your automaton does not work properly or the handle is very hard to turn. However, it is useful if you want something to move more quickly in relation to other components.

GEARS

CALCULATING RATIOS

The following example shows how the ratios are calculated;



If the input gear (A) has 10 teeth and the output gear (B) 30 teeth, then the ratio is termed 3 to 1 and is written down as 3:1

Ratio = $\dfrac{\textbf{No. of teeth on the output gear B (30)}}{\textbf{No. of teeth on the input gear A (10)}}$

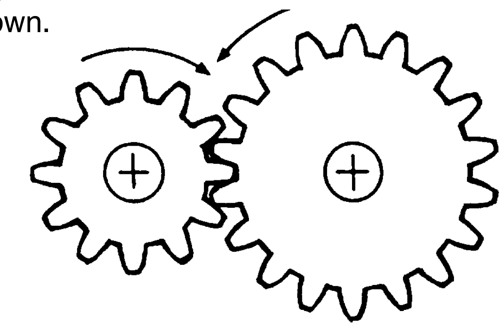
= $\dfrac{3}{1}$ **and is written down as 3:1**

Simply divide the amount of teeth from the output by the input gear to work out the ratio. In the above example, for every complete revolution of the input gear the output turns 1/3 of the way round. In other words it takes three turns of A to rotate B once. This means you are slowing down the action and is referred to in engineering terms as "Stepping Down". If B were the input gear and A the output gear, then the opposite happens and we "Step Up". Then with one turn of the input gear the output gear would turn three revolutions, giving a ratio of 1:3.

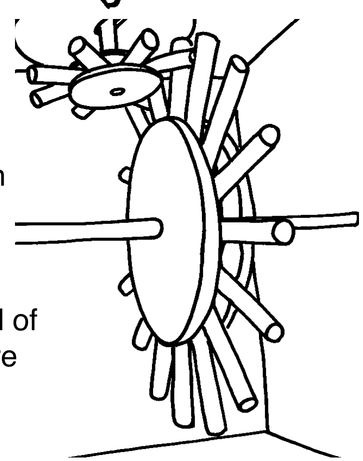
MAKING IT EASIER

That is some of the theory, happily the reality is far simpler. While it is important for children to have a grasp of the concept of gears, the practicality of making them needs to be obtainable. The best way of approaching this task is to take a look at the main gear variations.

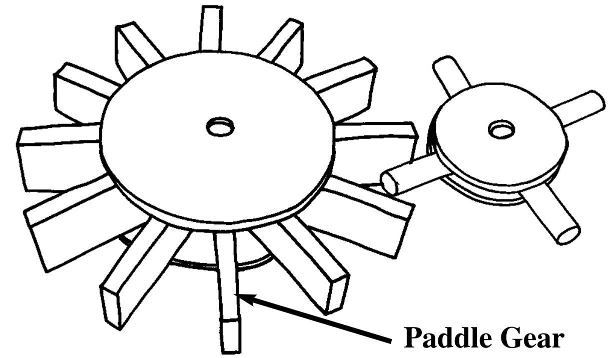
In this example you see what is referred to as "In line" gears. They have a number of teeth that mesh precisely. This type of gear is really beyond the young maker. You can buy plastic gears but it is better to let children make their own.



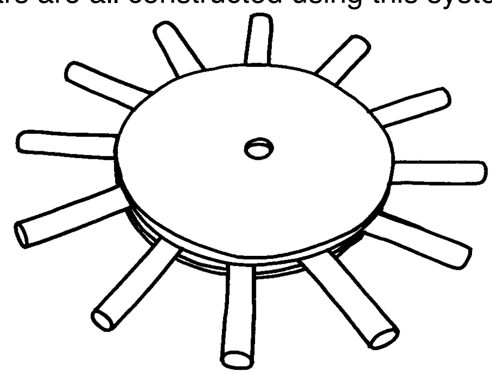
This example uses "Bevel" gears which run at 90^0 to each other. They can change both the direction and speed of movement. They are also easy to make.



This third set are referred to as "parallel gears". They work in a similar way to the "In line" ones but are much easier to construct. The larger one uses lolly sticks instead of dowel and is referred to as a "Paddle" gear.



The last two examples are the best options for younger children to make. Most educational D&T suppliers can offer assistance here. There is an excellent jig available that enables you to make perfect gear wheels using card and 5mm wooden dowel or lolly sticks. The following automata gears are all constructed using this system.



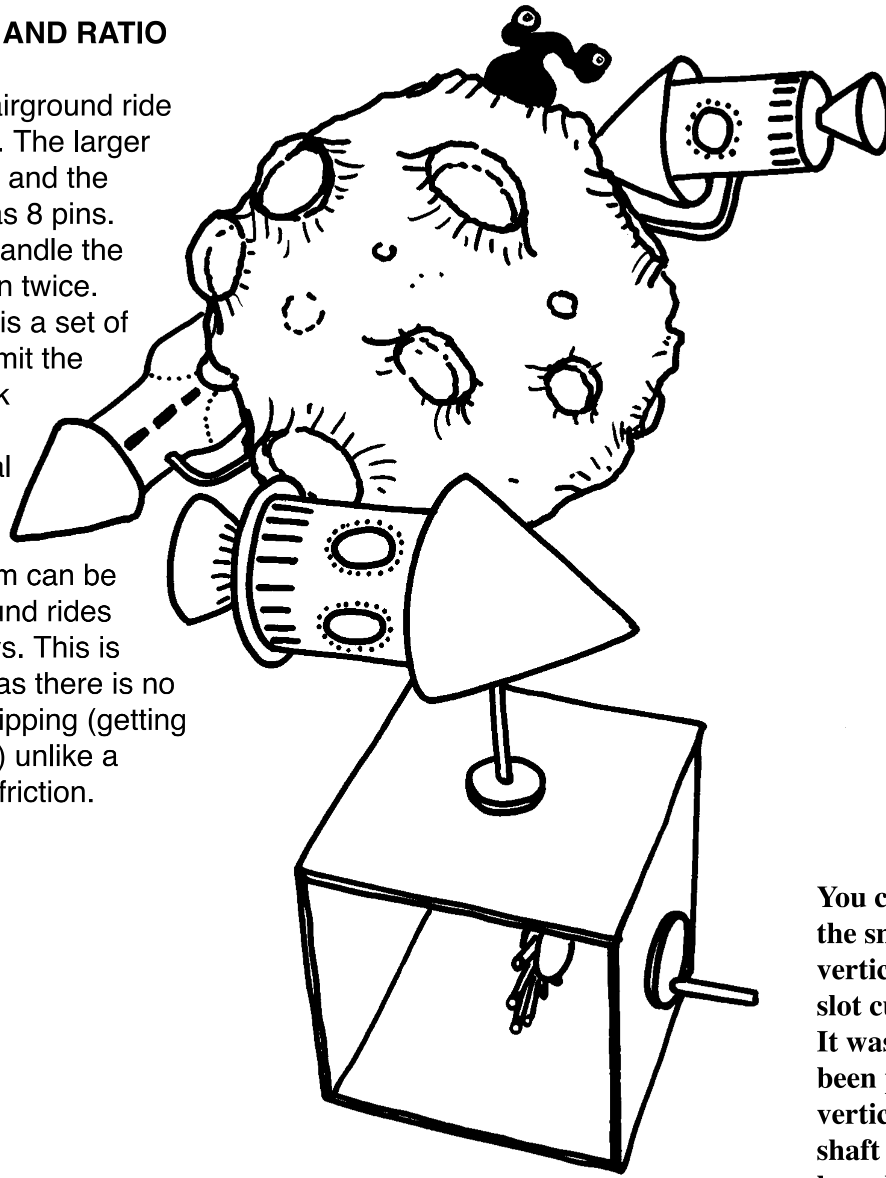
GEARS

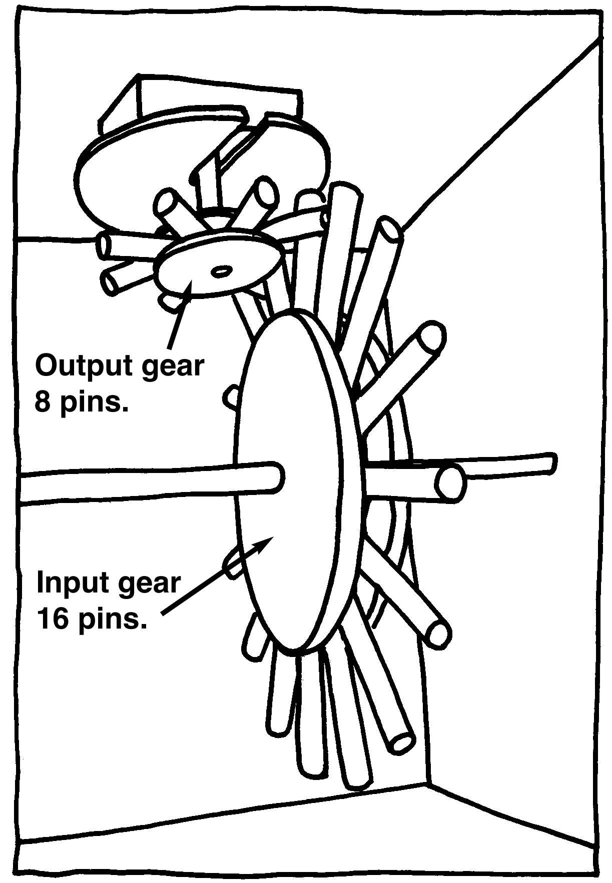
CALCULATING SIZE AND RATIO

This “Crazy Rocket” fairground ride has a gear ratio of 1:2. The larger input gear has 16 pins and the smaller output gear has 8 pins. For every turn of the handle the planet and rockets spin twice. The mechanism used is a set of bevel gears that transmit the movement of the crank handle by 90^0.

The gears serve a dual purpose to speed up and divert the drive.

This simple mechanism can be used to create fairground rides instead of using pulleys. This is called “positive drive” as there is no chance of the gears slipping (getting out of synchronisation) unlike a pulley which relies on friction.

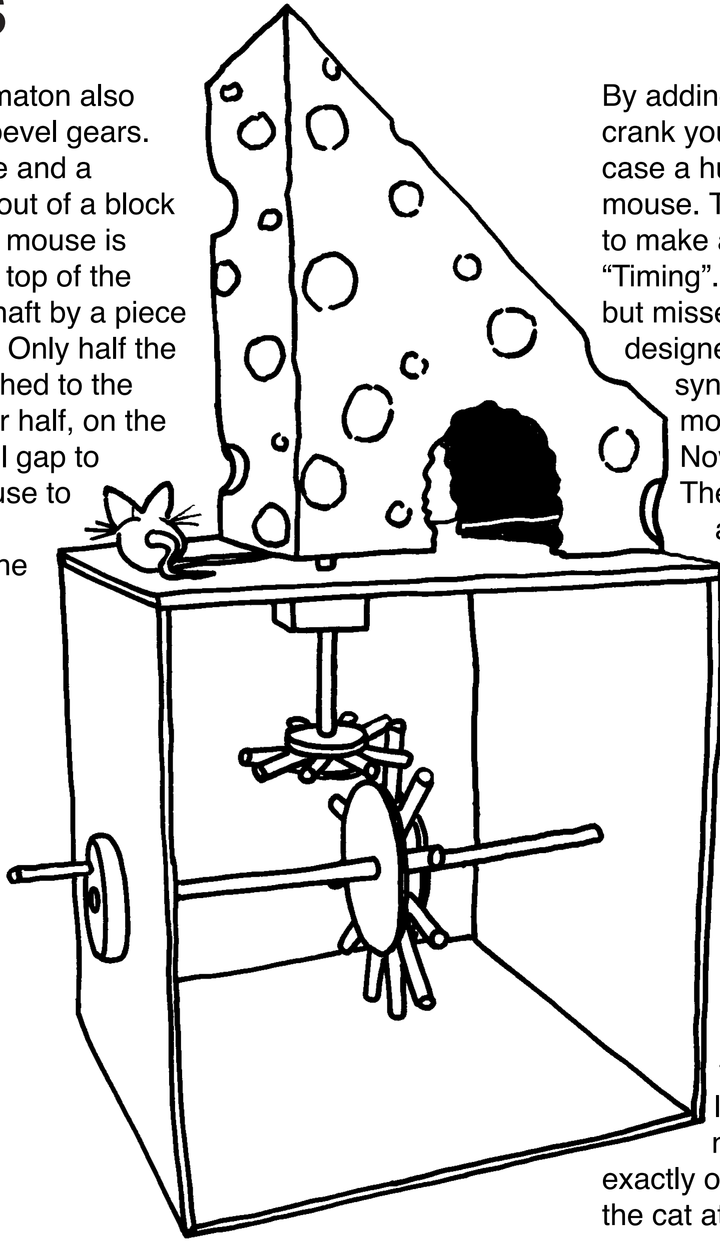




You can see the mechanism more clearly illustrated above. Note the small block of wood at the top. This helps to keep the vertical drive in an upright position. The circular card with a slot cut into it was used to stop the planet pulling the gears up. It was added after evaluating the automaton but should have been put in when inserting the gears. It was glued onto the vertical drive shaft and not to the block of wood. In fact the shaft was to thin to support the weight of the planet and should have been thicker.

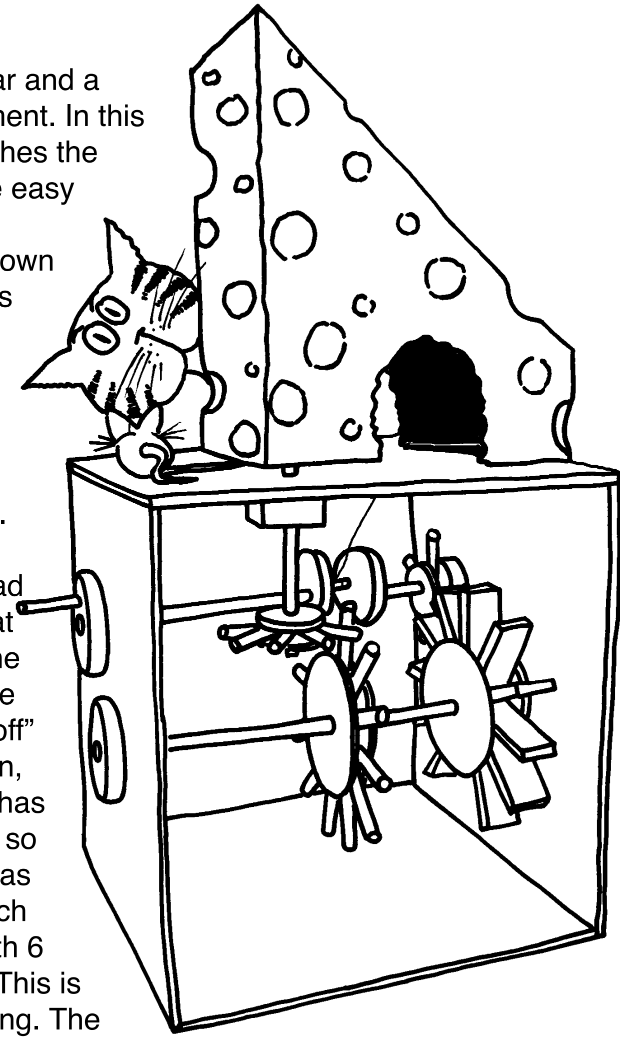
GEARS

This next automaton also makes use of bevel gears. Turn the handle and a mouse rushes out of a block of cheese. The mouse is attached to the top of the vertical drive shaft by a piece of clear plastic. Only half the cheese is attached to the base. The other half, on the left, has a small gap to enable the mouse to rotate. You can just make out the top of the drive shaft.

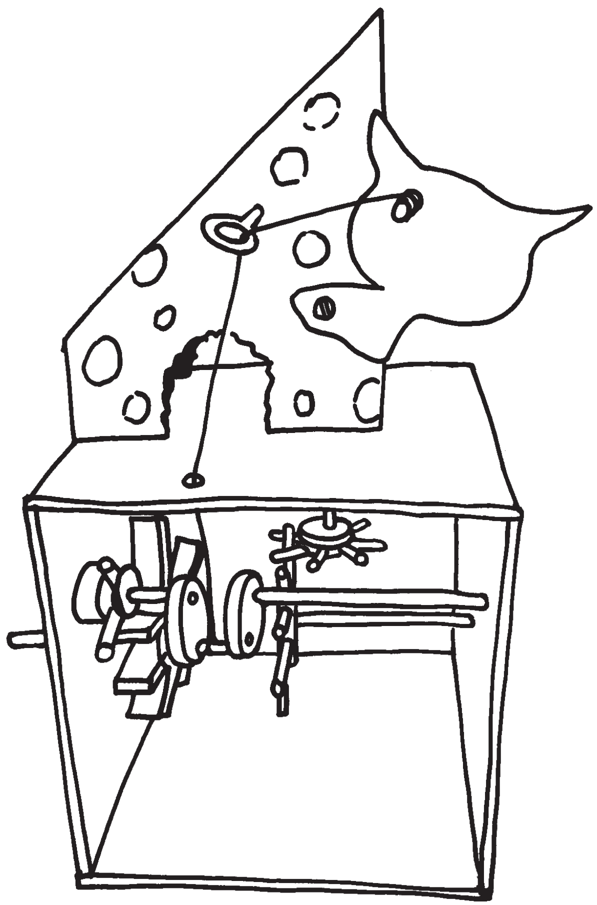


By adding a paddle wheel, an extra gear and a crank you can a introduce another element. In this case a hungry cat who never quite catches the mouse. The additional mechanisms are easy to make and introduce the concept of "Timing". The cat's head bobs up and down but misses the mouse each time. This is designed to happen. The gears are synchronised so that the cat and mouse never hit.

Now for some jargon and theory! The handle and main drive shaft are now positioned to the back. The shaft doubles up as a crank which pulls the cats head up and down. This means that for every turn of the handle the cats head will go up and come down once. There is a 'Take off" gear with 4 pegs which, in turn, drives the second shaft. This has a 12 peg paddle gear "in line" so the ratio is 3:1. This, in turn, has a second 12 pegged gear which turns the mouse on a shaft with 6 pegs this forms a ratio of 1:2. This is referred to as compound gearing. The final ratio of the mouse works out as 2:1. It sounds and may look, complicated but this really is a very simple automaton to make. For every two turns of the handle the mouse goes round exactly once. Because we know where the mouse will be, in relation to the cat at any given point, you can time the gears to create a near miss.

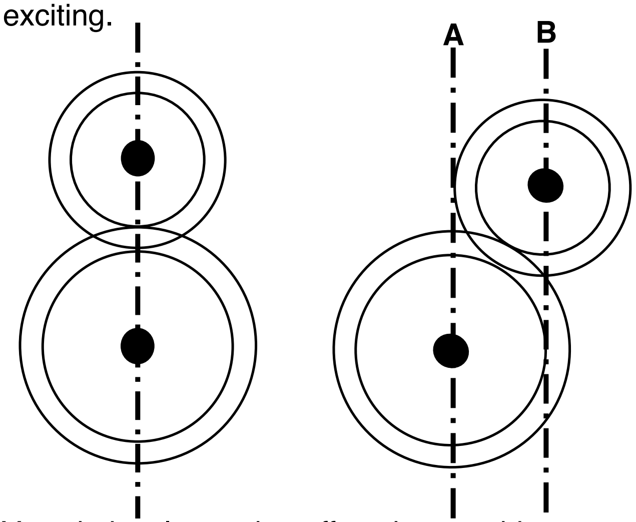


GEARS



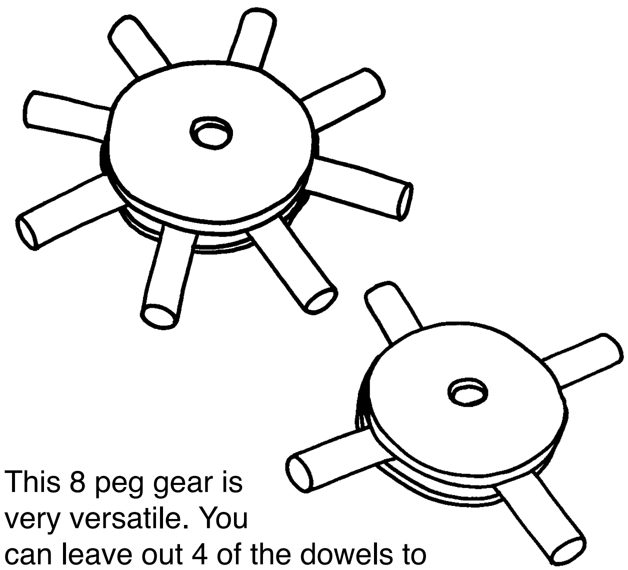
This back view shows the mechanisms for moving the cat's head. The crank pulls a string which runs through an eye-screw. This is attached to a short length of wooden dowel protruding from the back of the cat's head. The head pivots on a screw positioned on the cats shoulder. Gravity pulls the head down, the crank pulls it back up.

GETTING MORE FROM GEARS
A useful tip with gears is to offset the two supporting shafts so that additional mechanisms can be used, as seen in the cat & mouse automaton.
By offsetting the drive shafts you will be able to run cams or cranks at different speeds, without jamming or hitting other components. This can help to give your automata several speeds of movement and make things really exciting.

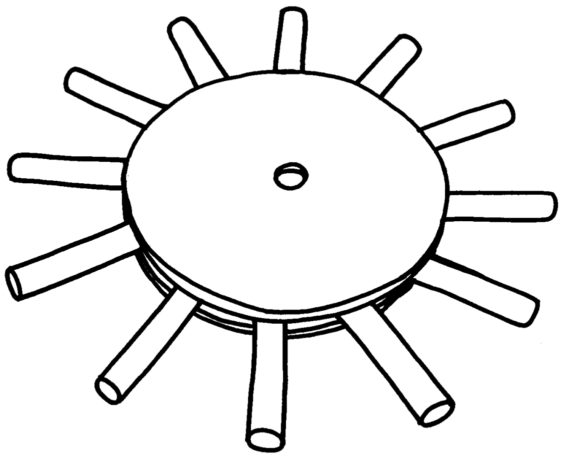


You obviously need to offset the two drive shafts, but the knack is to do it by just the right amount. This will enable you to drive other objects with cams, pulleys or even cranks. The amount you offset is limited by the physical space available in your automata housing (trial and error is the usual way of measuring). The distance between **A** and **B** is determined by the amount you offset.

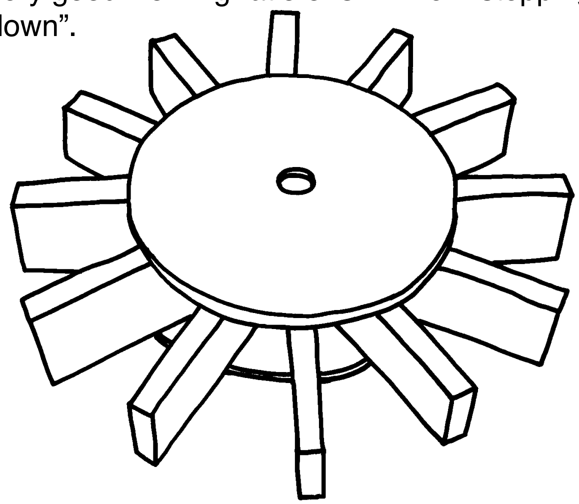
The cat and mouse automaton made good use of the two drive shafts. Because the peg and paddle gears were quite large the two shafts were offset much more than on the example to the left.
The use of a jig enables gears to be made very easily and incorporate them into Key stage 2.
Below are a range of examples that were used in the two previous automata. They are constructed from 5mm wooden dowel and sandwiched between two 2mm thick card disks. PVA glue was used to bond them.



This 8 peg gear is very versatile. You can leave out 4 of the dowels to produce a 4 peg variant giving a 2:1 or 1:2 gear ratio. These are a useful size, not too complicated and use less dowel to construct.



The 12 peg gear wheel works well with the smaller ones, especially the 4 peg. It gives a very good working ratio of 3:1 when “stepping down”.



The paddle gear is ideal for running “Parallel”. You simply replace wooden dowel with lolly sticks. The 12 paddle gear works best coupled up to the 4 peg one.

DESIGNING GEARS

When designing and making gear wheels you need to apply a little common sense. For example, the load or pressure put on the gears in automata are usually very small compared to that of a car gear box. This allows you to get away with things that you couldn’t in other machines. However, you still have to follow some simple engineering guidelines.

You will need to identify what you want to get from the gears. Try running through this simple check list;

1) Do you want the gears to step up or step down? (speed up or slow down the performance).

2) Do you want the gears to run parallel, or at an angle of 90° to change the direction of the drive?

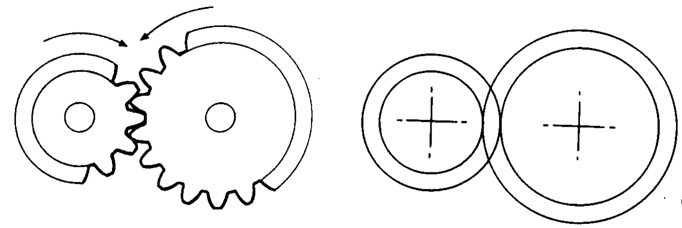
3) What size do you need to make them? (small space means making smaller gears and this can get tricky).

4) What is the best or easiest material to make them with? (this may well depend on how heavy a load you want them to drive).

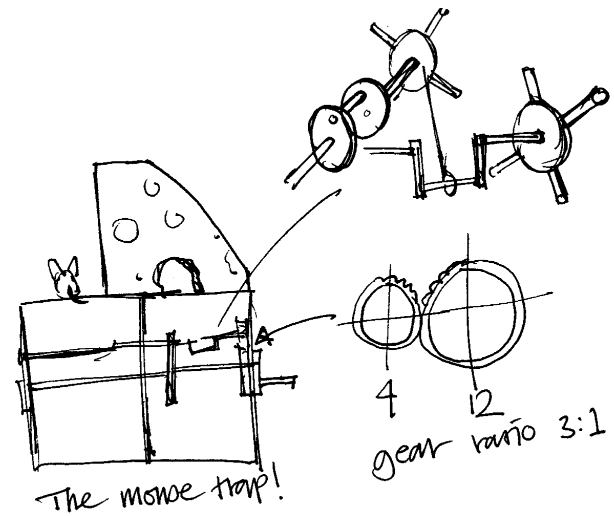
Each automaton made will have different design criteria to meet, but there are some common design and construction solutions which work well.

DESIGNING WITH GEARS

When drawing gears they are represented as either a circle with just a few teeth at the point where they mesh, or as twin circles denoting the teeth.



Although this may seem very technical it is good practice to visualise gear wheels like this, especially when it comes to drawing up plans for making automata.

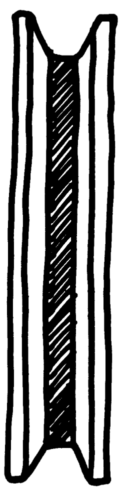


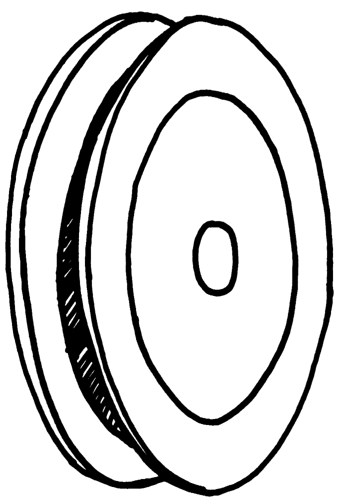
An example of the mouse mechanisms drawn as a rough plan in a sketch book.

PULLEYS

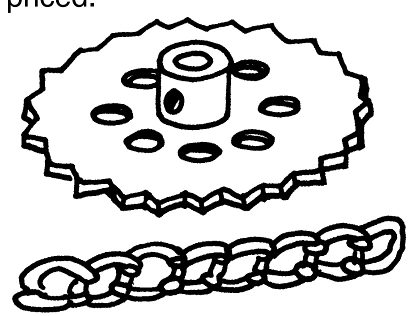
THE POWER OF THE PULLEY

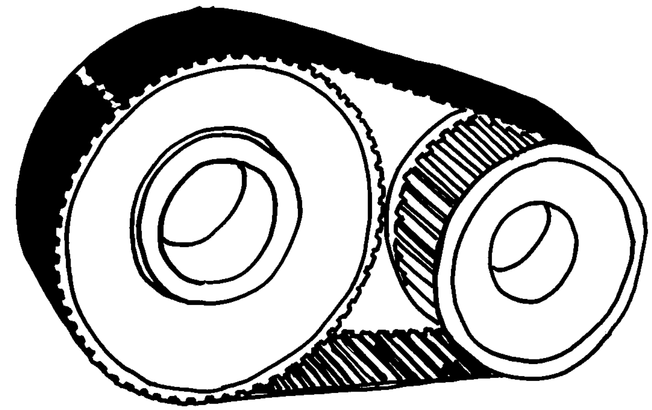
Pulleys work in a similar way to gears, except they are not directly joined but linked by a belt made from elastic bands, tubular springs or some other flexible but strong material.
A common example is the fan belt in a car that links a number of pulleys.
To stop the pulley belt slipping off, pulleys have grooved rims. This also keeps the belt running in a straight line.
Pulleys that use some form of belt drive are referred to as “Friction Drive” mechanisms.
A drive mechanism such as gears which physically make contact, is referred to as “Positive Drive”.



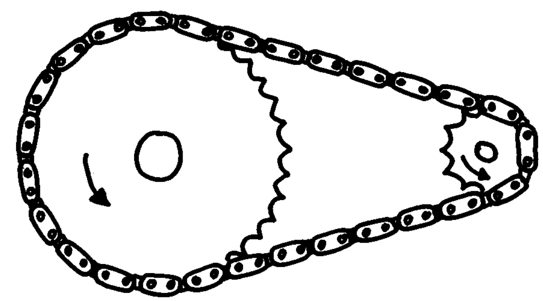


Pulleys have several advantages over gears, but also some disadvantages.
The main advantage is the fact that they are simple to make and can be used at a distance from each other, unlike gears that need to touch in order to work. The disadvantage is that they work by friction and so can slip, which could seriously upset the timing of a complex automaton.
You can get a toothed pulley and belt which eliminates any slipping or timing problems. Many cars have a cam belt that works on this principle. Some model suppliers sell special toothed pulleys but they tend to be very expensive and are rarely used in automata which generally have a “Friction belt” system. This is simple and very effective in most cases.
The belt can also be substituted by a chain. A bicycle is a good example of this system. Model suppliers often stock small plastic toothed pulleys or chain sets which are reasonably priced.

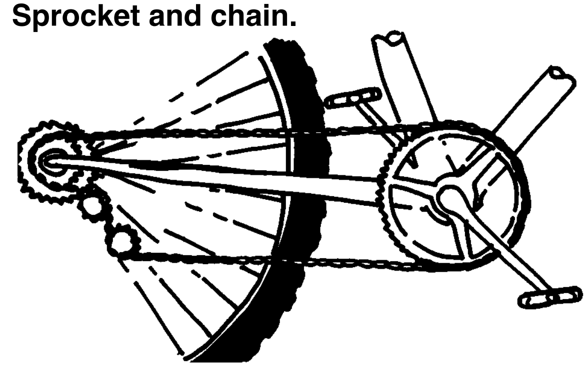




Toothed pulley and belt.



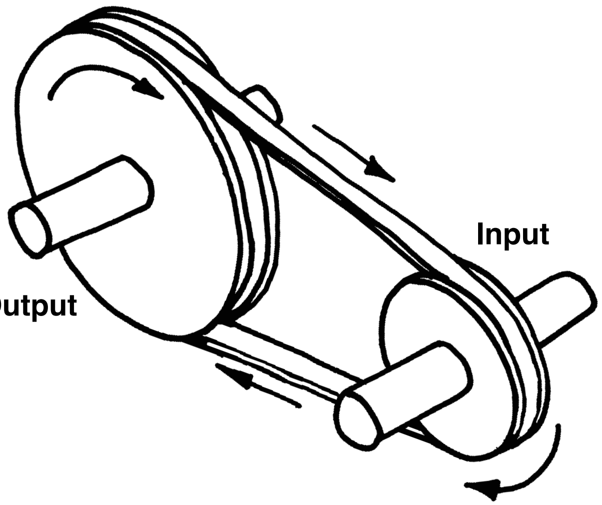
Sprocket and chain.



A bicycle chain.

PULLEYS

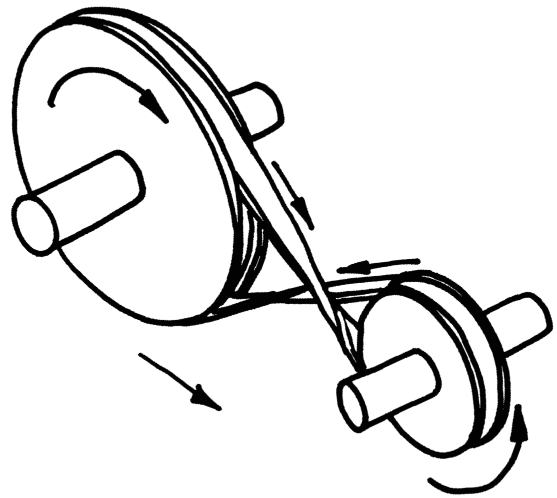
Like gears, you can use the pulley to either step up or step down the drive. But instead of counting teeth as with gears, you simply make the diameter of the pulley wheels larger or smaller.



Pulleys rotate in the same direction.

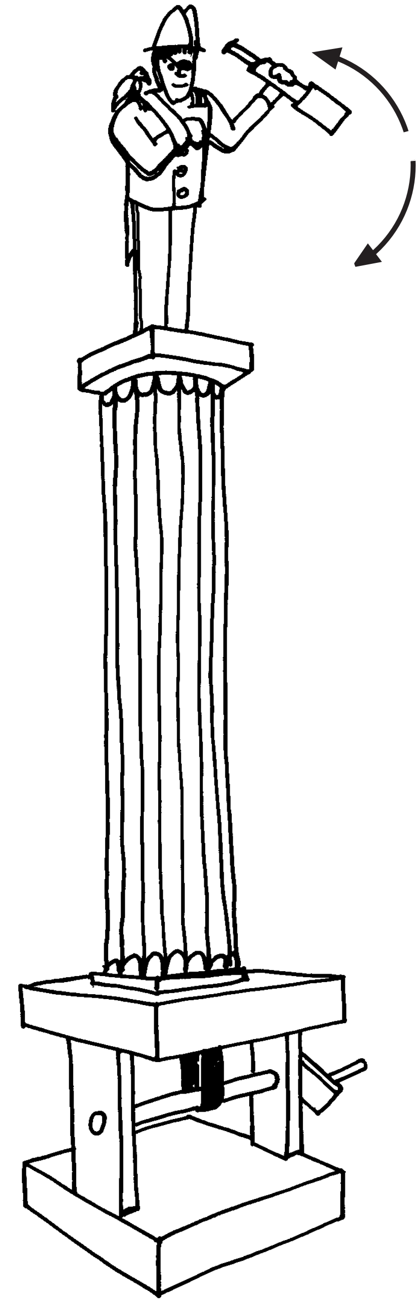
By dividing the input diameter by that of the output, you can workout a final ratio. In the above example the ratio is 2:1. This means for every two revolutions of the input pulley the output turns one full revolution. You could reverse the input and output pulleys.
You can see that pulleys rotate in the same direction (unlike gears which do the opposite).

Pulleys are useful for getting the drive action to happen in awkward places. You can use the drive pulley to transmit it's motion to the output pulley which may be some distance away.
We can also use pulleys to reverse the action by putting a twist into the belt. This makes the output pulley move in the opposite direction. Again this can be very useful.



A twist in the belt reverses the direction of the output pulley.

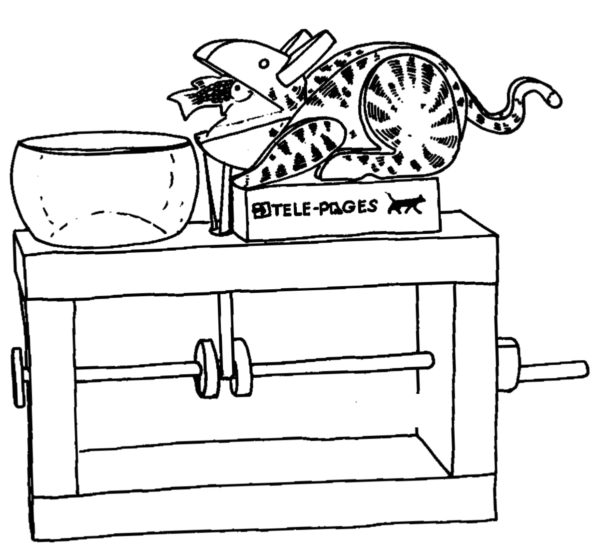
The automaton opposite uses a pulley to transmit the motion over a long distance. It also slows the action down and transmits it to the output pulley which is in a confined space (Nelson's body). Pretty good going for a simple pulley system!



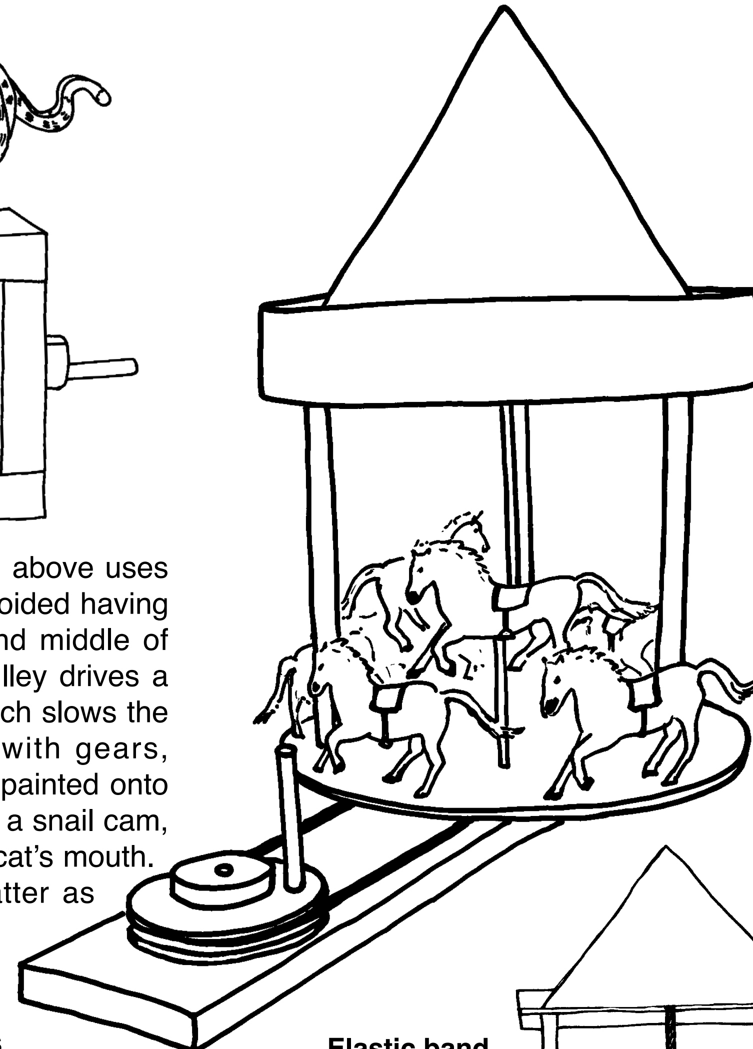
PULLEYS

APPLYING PULLEYS TO AUTOMATA

When you want to transmit the drive over some distance, pulleys are an ideal choice. As we have seen, they are simple to construct and take up comparatively little space. In fact, they share many of the virtues of gears, with the advantage of producing a constant and smooth drive force. But it doesn't stop there. The pulley can perform one other vital function, which is to change the direction of drive. This can be to any angle but the most common use would be to turn the drive through 90°. This same task could be performed by gears but would be significantly more complicated to make. When it comes to making automata, this easy way to change the drive direction can be invaluable for it's simplicity and effectiveness.

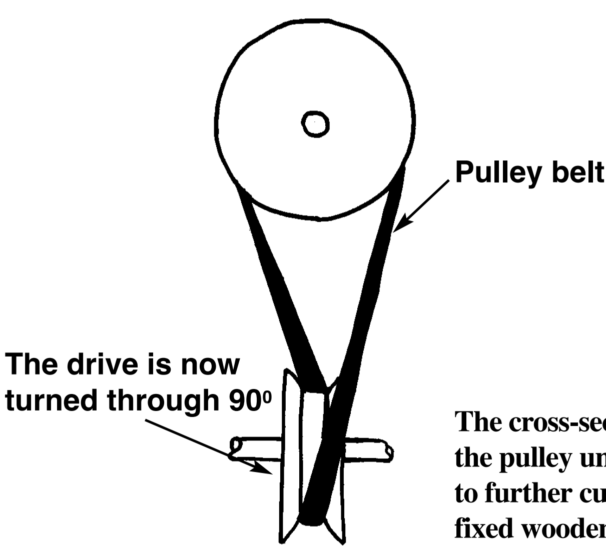


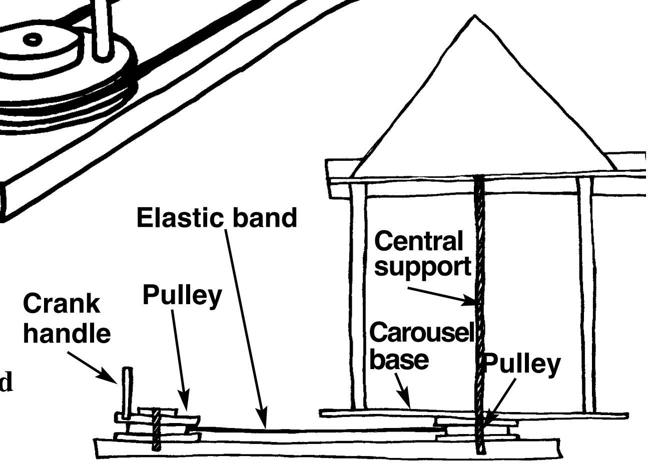
The "Cat eating Fish" automaton above uses the pulley twisted at 90°. This avoided having the crank handle at the front and middle of the mechanism housing. The pulley drives a larger one in the cat's mouth which slows the action down slightly and, as with gears, provides more force. The fish is painted onto clear plastic which is shaped like a snail cam, so as it goes round it opens the cat's mouth. If the pulley slips it doesn't matter as there is no special timing.



FAIRGROUND RIDES

This is a popular school project which is used to introduce pulleys to the students. The automaton opposite makes use of a simple pulley system.





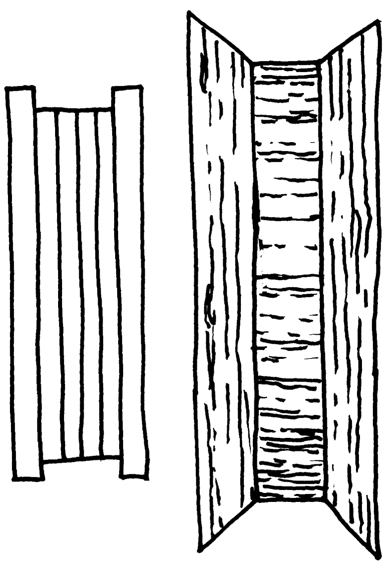
The cross-section of the Carousel shows the pulleys in position. Note the pulley under the Carousel also acts as a washer. Graphite was added to further cut down friction. The crank pulley is kept in position by a fixed wooden dowel. A washer is added to the top to keep it in place.

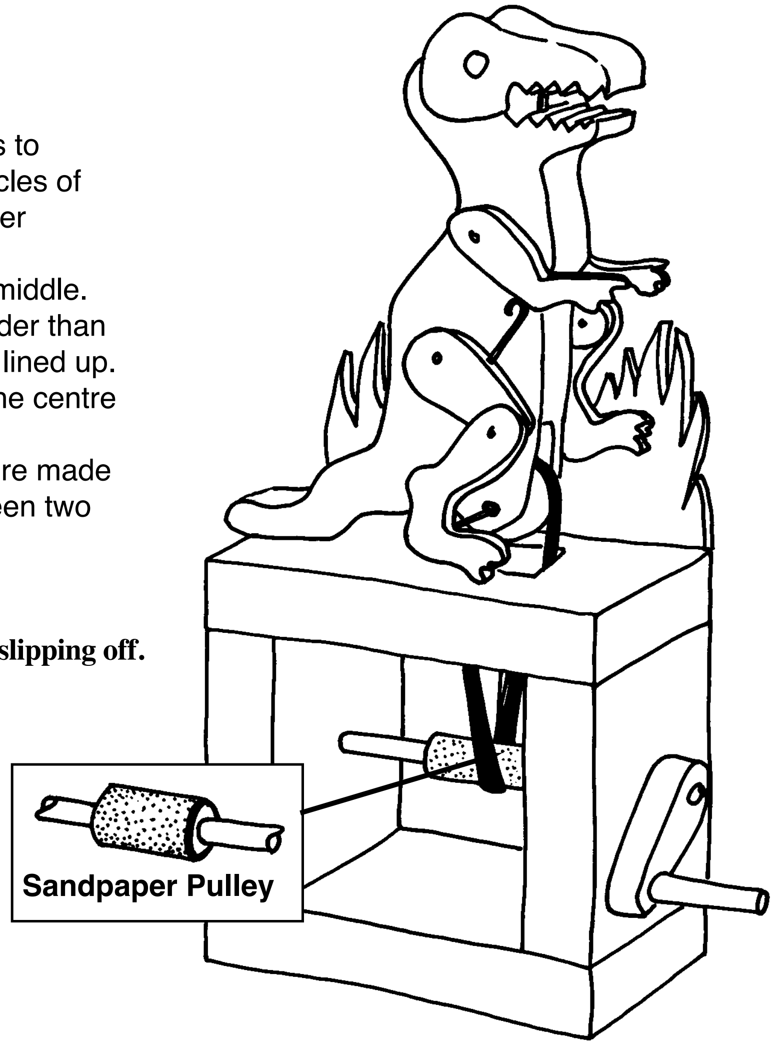
PULLEYS

CONSTRUCTION TIPS

Laminating is one of the easiest ways to make a pulley wheel. Use several circles of card making two of them slightly bigger (around 5mm). Glue them together, sandwiching the smaller ones in the middle. Make sure that the pulley is a little wider than your belt, and try to keep the centres lined up. When the glue has set you can drill the centre out to the size of the drive shaft.
The fairground automaton pulleys were made by sandwiching an MDF wheel between two card circles.

The lip of the pulley stops the belt from slipping off.

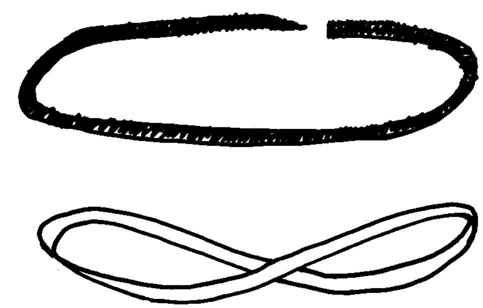




The running dinosaur above is driven by a pulley. The top pulley is also an offset crank which turns the legs. Because the pulley has a lot of work to do, it was geared down. Sandpaper is wrapped around the drive shaft, giving the elastic band much more grip.

PUTTING IT ALL TOGETHER

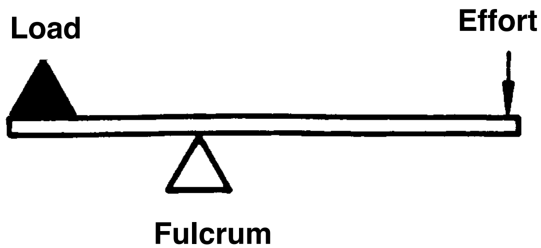
Fitting the elastic band is often the final part of the assembly process before gluing everything. Should you find that your elastic band breaks, you could substitute it for a flexible steel spring driving belt. These come open ended and can be cut shorter or extended by joining another spring. They can be purchased in most model shops and offer superior performance over elastic bands, which are prone to stretching and can disintegrate if left in direct sunlight.
Finally, make sure everything is strong enough to take the tension of the pulley. Remember you are dealing with a friction drive, so the tighter the belt the less chance you have of it slipping. Make sure that any axles are strong enough to take the load.



Elastic bands make good, cheap drive belts but have certain limitations. Flexible steel spring driving belts are excellent and much tougher.

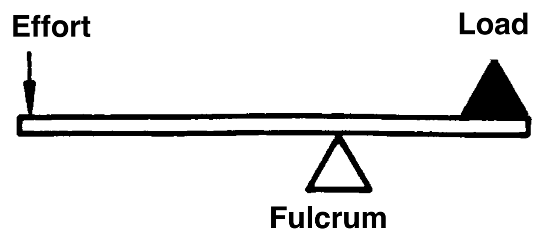
LEVERS

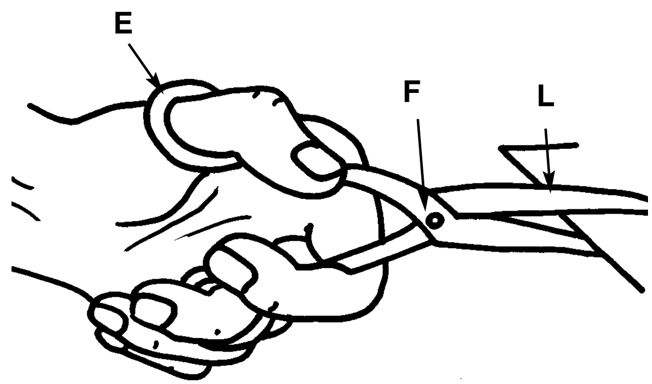
A lever is a device that applies or transfers force. It is a simple mechanism that usually consists of a rigid length of wood or metal, which pivots on a fixed point called a fulcrum.



Most machines employ some form of lever, and you will find that they are used a lot in automata. It is therefore useful to understand how they work and how to use them in your own designs.
Levers work on the principle of “mechanical advantage” which can be calculated by a simple equation, and is used to compare the effort applied to the load moved. We will look at this formula later.
Archimedes established the Law of the Levers in his book “On the Equilibrium of Planes”. He described the three separate types (or orders) of levers, which have their fulcrum, effort and load arranged in different ways.

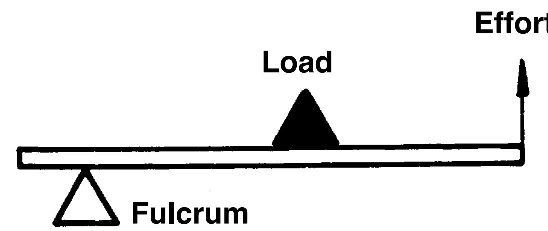
First order lever.
A first order lever has its fulcrum point between the load and effort.

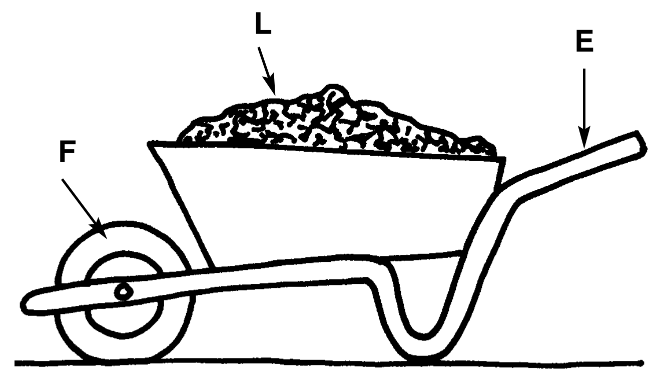




A good everyday example of a first order lever is a pair of scissors.

Second order lever.
A second order lever has its fulcrum and effort at opposite ends, and the load somewhere between the two.

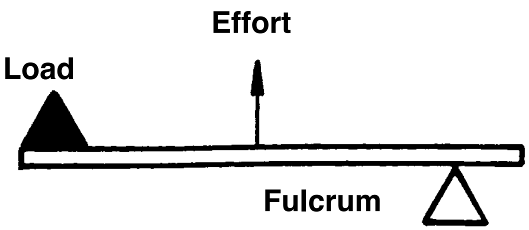


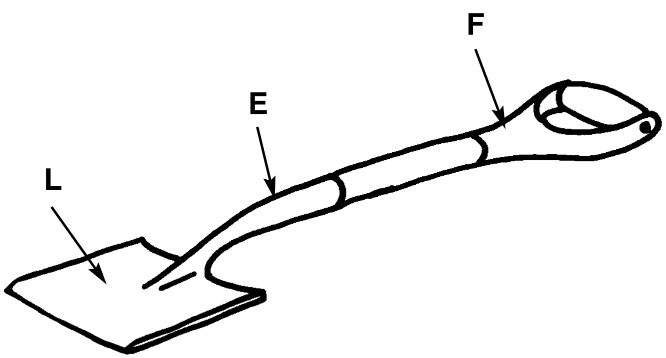


A good, everyday example of a second order lever is a wheelbarrow.

LEVERS

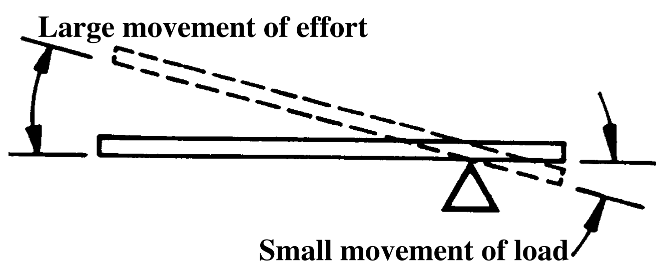
Third order lever
The third order lever has the fulcrum and load at opposite ends with the effort somewhere between the two.





A good, everyday example of a third order lever is a shovel.

A little bit of theory
A lever can produce a small output motion from a large input force, as when using a crowbar. A lever can also be used the other way round, where a small input movement can be increased by a lever to create a larger output movement such as a pair of scissors. Moving the fulcrum point, the effort or load points can change the effectiveness of a lever. For example if you move the fulcrum point on a first order lever towards the effort, the load travels further but takes more force to move it. The opposite happens when you move it towards the load.

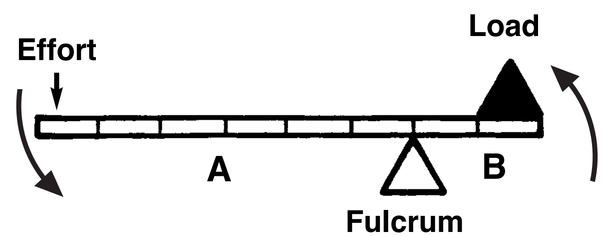


The important thing about levers is the way that they can be used to transmit, amplify or decrease movement. In engineering terms you are experimenting with the "Mechanical Advantage" of the lever. When a small effort moves a large load the effort has to move a much greater distance than the load. This is the price to pay for gaining mechanical advantage. However, at the scale we normally work with in automata, the effect of this will be negligible.

The formula for working out the ratio of a lever can also be used to work out the "Amplification" or amount of movement a lever will travel. Just like a cam, this is referred to as the "Throw" and can be used to great advantage when designing and making your own automata.

$$\text{Mechanical advantage} = \frac{\text{Load}}{\text{Effort}}$$

If we apply this formula to the example below you will see how to calculate both the ratio and the throw of the lever.



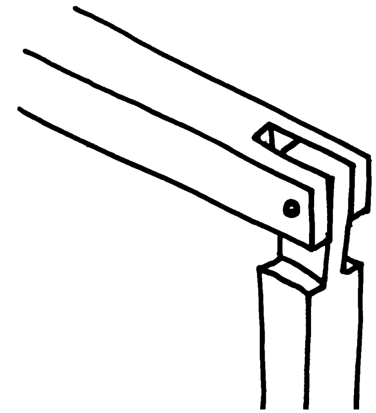
We can see that the ratio of A to B is 6cm to 2cm, so applying our formula we get a ratio of 3:1. This means for every 3cm of travel at effort (A) the load (B) will move 1cm. Reverse this by moving the fulcrum towards the effort and we magnify the movement for every 1cm of travel on the effort (B), so the load (A) will travel 3cm. It is also important to remember that levers travel in (describe) an arc and do not move in a straight line.

LINKAGES

WHAT IS A LINKAGE ?

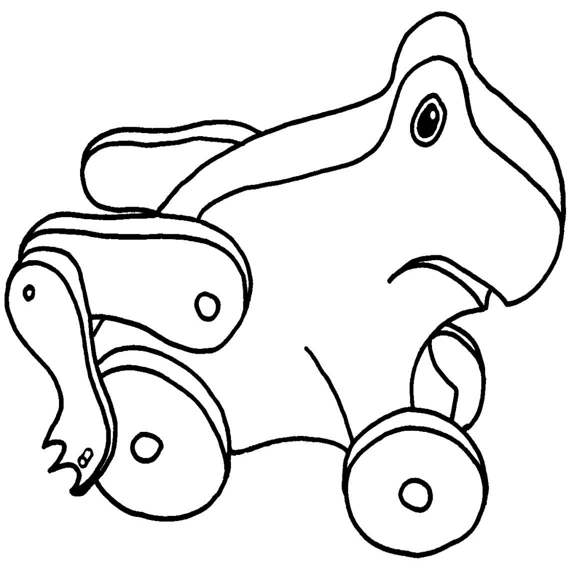
“Linkage” is the term applied to the parts of a machine or mechanism that connect moving parts together.
Many of the different drives that we have looked at use some form of linkage or con-rod to transfer the power and motion. Linkages can be used to control movement as well.
The frog below makes good use of linkages. It’s legs are attached to an offset peg. When pulled along it gives the illusion of the frog leaping.

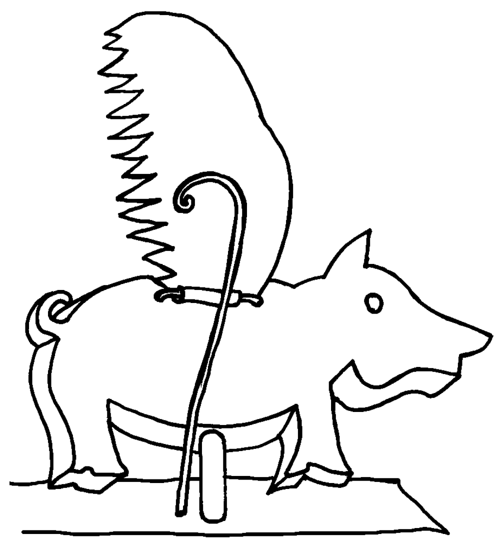
Linkages can be made from a range of materials, but wood and metal are perhaps the strongest and most commonly used.
It is important to note that where there is movement between materials there must be a bit of free movement otherwise the mechanism will jam.
Linkages are used to transfer motion, so they must be properly designed in order to function as intended. Although the mechanical stresses in automata are very low, you still have to apply good, solid engineering skills.

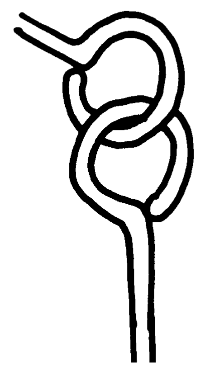


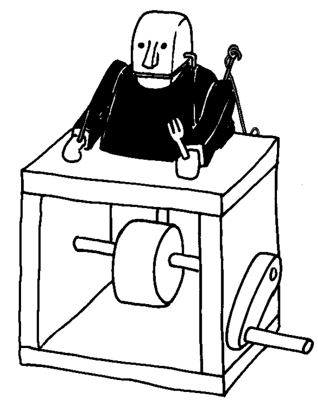
This mechanism is more complicated to make but is a much better design, as it only allows movement in it’s intended direction (up and down) not side to side.

The rings allow for movement in the required direction but also in unwanted directions.





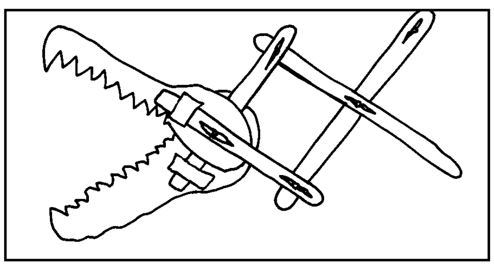


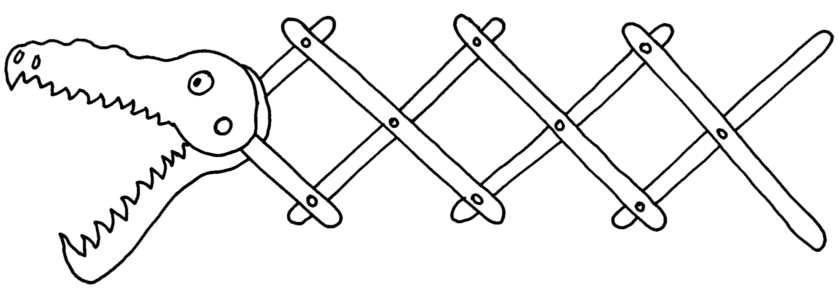


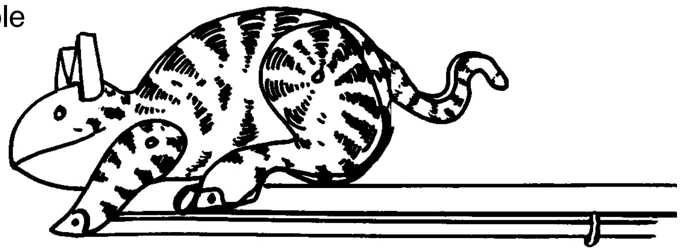
The pig’s wings are linked to the body and are pivoted, which allows them to move freely up and down, but not backwards and forwards.
As the pig is moved up and down, the wings are forced to either rise or drop. This can only happen if the linkages are not attached, otherwise the wings would not move.

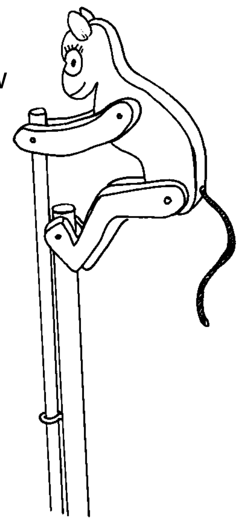
LINKAGES

Linkages can be adapted to make very simple yet effective automata. The following examples can be adapted and make great introductory projects.
Using lolly sticks or something similar, you can create a scissor-like action that extends when the ends are squeezed together and contracts when opened. This simple device is easy to make and is very effective. The more sticks you use, the greater the reach and more dramatic the action. The example below is made from lolly sticks that have been drilled to allow split pins to join the sticks together. Two separate jaws are centrally hinged and taped on each end. This mechanism creates a snapping action and can be modified for different creatures.

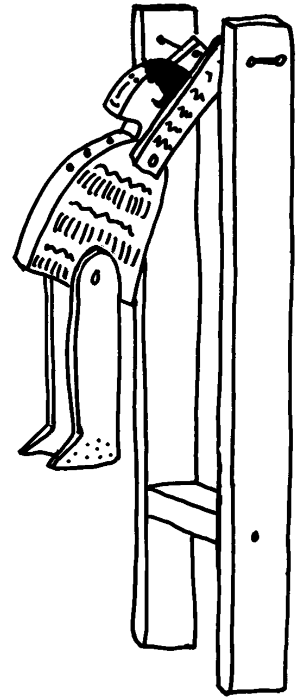


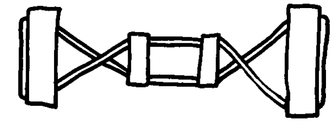




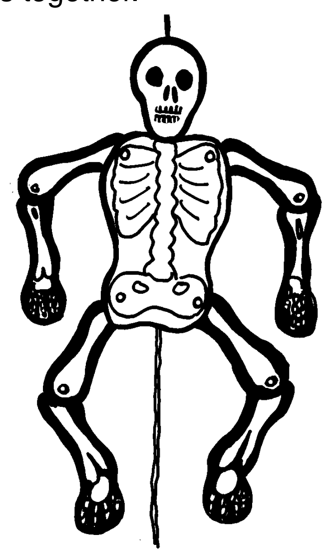


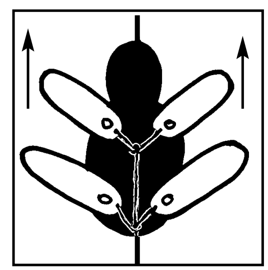
The cat and monkey work by placing two wooden sticks, of slightly different lengths, on top of each other. The characters are hinged at the ends and when you slide the sticks back and forth the animals leap up and down. A simple eye-screw is used to guide and hold the sticks together.

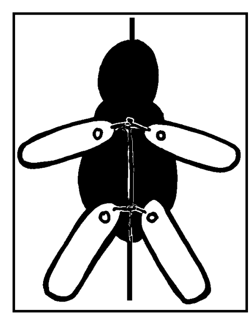




This toy uses elastic threaded through two sticks and then crossed through the character's arms (see above). When the lower ends of the sticks are squeezed together the elastic stretches and twists which makes the acrobat leap up and down, depending on the pressure applied.







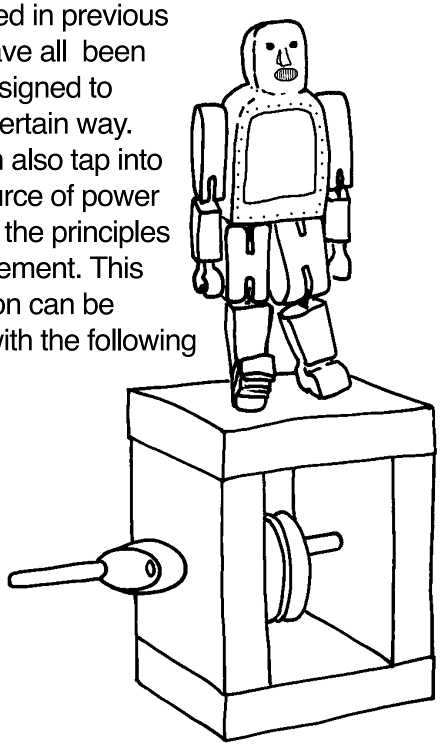
Jumping Jacks can be made from wood or card. When the string is pulled it makes a single jerky movement, pulling the limbs up, and then when you let go gravity pulls them back down. The simplest way to construct one is to use card and split pins, making sure that everything can move freely. The diagram on the left shows how to thread the string.

FREE MOVEMENT

GETTING SOMETHING FOR NOTHING

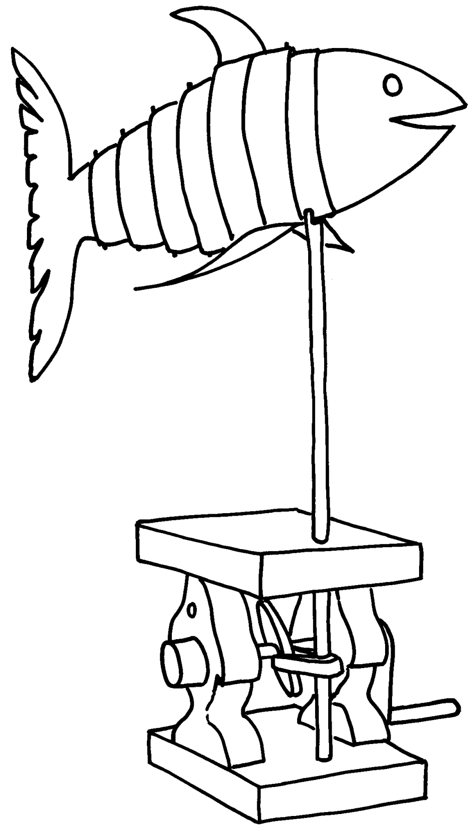
So far we have looked at a wide range of mechanisms and engineering principles. This section will show you how to get something for nothing!

The automata and mechanical principles that we have covered in previous chapters have all been carefully designed to move in a certain way. But you can also tap into another source of power by applying the principles of free movement. This phenomenon can be explained with the following examples.



The robot's body is fixed to a con-rod attached to a crank. As it moves back and forth the arms, legs and head flop about because they are free to move. This gives life and action to the automaton. The beauty is in the simplicity. There is no need to make complex parts in order to create the actions.

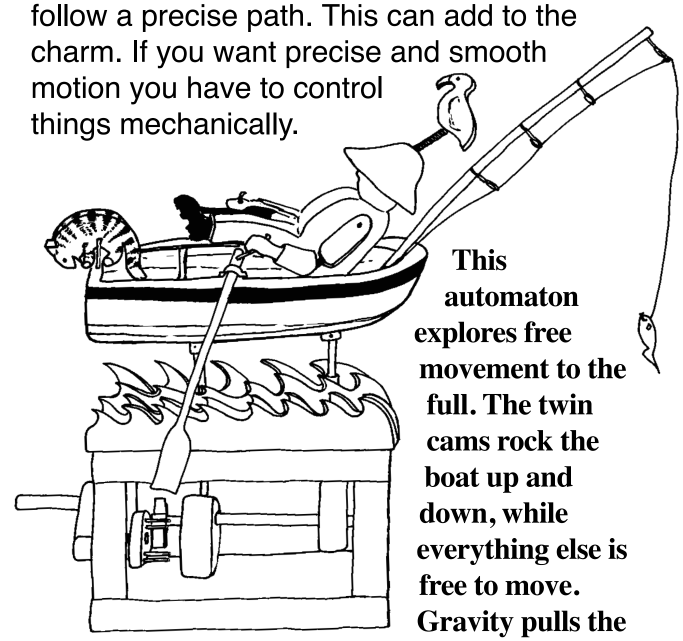
Try to explore and exploit "free movement" in your automata where ever possible. It is a great way of getting extra action without extra work.



The fish turns back and forth but, because the tail and head are free to move, they swing from side to side. This use of free movement makes the automaton far more exciting and life-like and does away with extra complex mechanisms.

The key to achieving free movement is enabling parts to be free to move. This may sound obvious, but you have to make sure that joints and linkages are designed to move freely. You also have to give thought to the designing of your automata and work out precisely what is going to happen.

Given the random nature of free movement it can often bring an automaton to life. Movements are sometimes jerky and may not follow a precise path. This can add to the charm. If you want precise and smooth motion you have to control things mechanically.



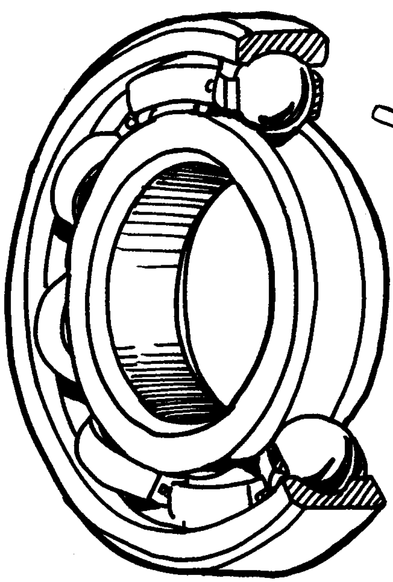
This automaton explores free movement to the full. The twin cams rock the boat up and down, while everything else is free to move. Gravity pulls the oars back and forth which in turn make the sailor rock to and fro. The cat rolls in and out of the boat whilst the sea gull wobbles about on a spring. Finally, the fish on the end of the line leaps about as if alive and jumping.

BEARINGS AND LUBRICANTS

LOW SPEED, LOW STRESS

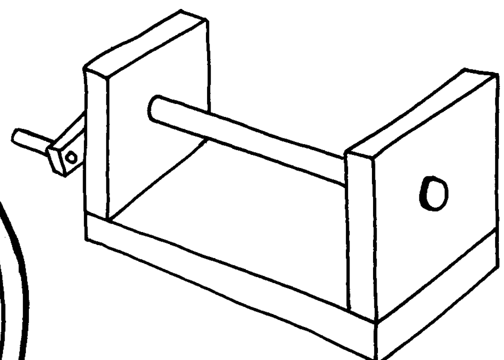
So far we have looked at very simple mechanical mechanisms which, when applied together, are capable of producing very complex automata. For the most part paper and card have been the most convenient materials to use.

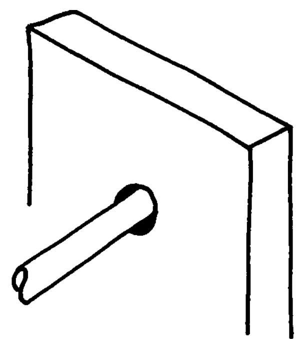
 All the automata we have looked at so far have several things in common in engineering terms. They can be described as working at slow speeds, under low stress and with low output. In practical terms this means you do not have to worry about special lubricants and bearings to keep things moving. However, here are some simple ways to keep things running smoothly if necessary.



BEARINGS

Lets start by looking at bearings. Bearings usually support a moving shaft and help it rotate freely under as little stress as possible. Many commercial machines have bearings. They use a metal case called a “chase” that houses hardened steel ball bearings. An inner case holds them in place and is attached to a rotating shaft. The ball bearings help spread the load and force of the shaft. They are usually lubricated to cut down friction. It is usual to construct an open box to house the mechanical parts of automata powered by a central shaft. This shaft sits within the outer walls and is free to rotate, so the box acts as the bearing supporting the shaft.

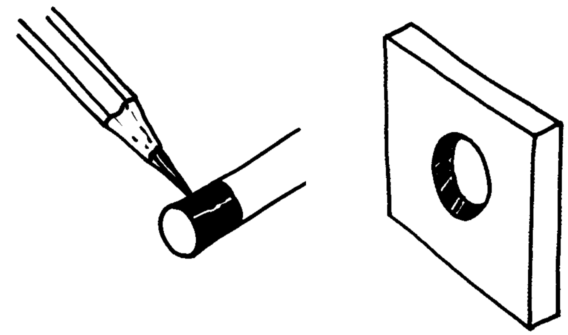




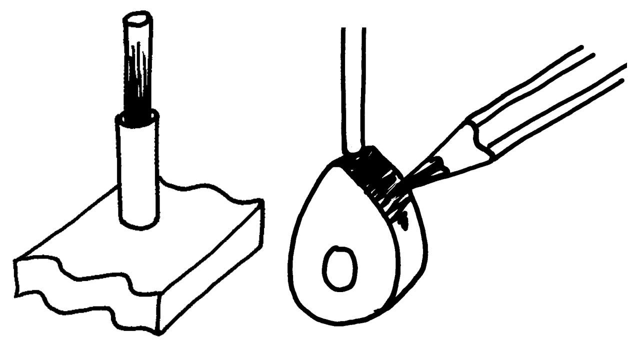
You need to make sure that the drive shaft is free to rotate and is not “sticking” as it turns. The hole it goes into should be slightly larger than the shaft itself but not so big as to give you too much play. This could cause more sensitive mechanisms, like gears, to jam.

LUBRICANTS

An ideal lubricant to use when working with wood, card or paper is graphite, which is found in pencils. When drawn onto a surfaces, it makes an ideal lubricant.



Apply the graphite from a pencil into the hole (bearing) or drive shaft to enable the shaft to turn more freely. Do not get it on any areas you need to glue. Use a soft 2B or 4B pencil.



Graphite works well on wooden or card cams and cam-followers. However, you may find that you don’t need to lubricate your card or paper automata at all.

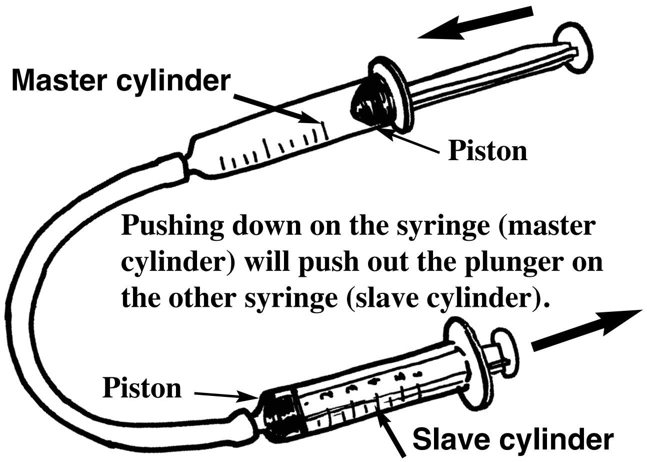
PNEUMATIC DRIVES

PNEUMATICS A SIMPLE THEORY

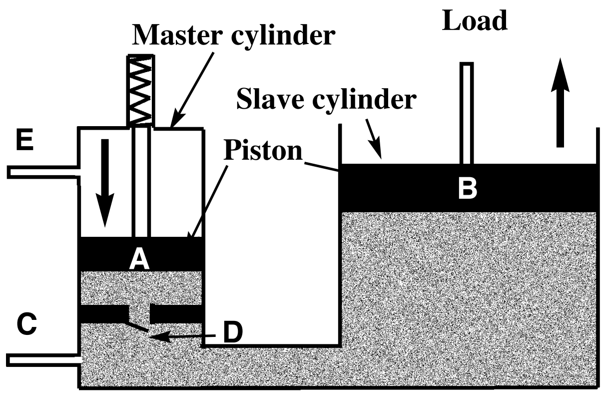
Pneumatics is all about using air or a liquid (Hydraulics) to make something move. Put simply: **Force that is applied at one end is transmitted to another point using non-compressible gases or fluids**. In the class-room it is probably better to work with air (a lot less mess).
A pneumatic system is comprised of two components;

Cylinders
Valves

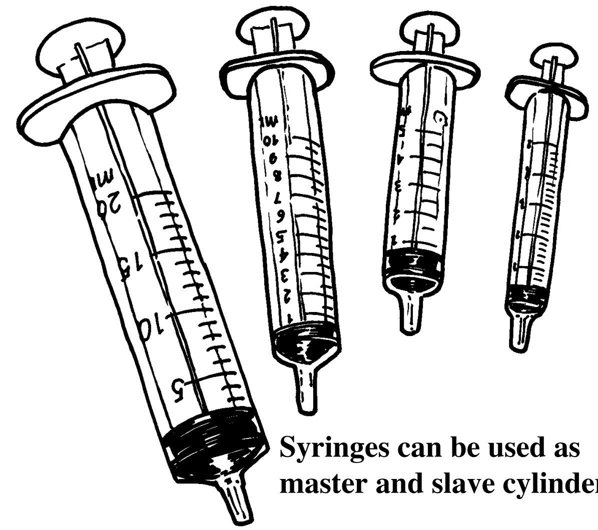
The cylinder provides the input force to create and transmit movement whilst another cylinder is used to convert the output force into a linear motion. The cylinder that does the pushing is referred to as the “Master cylinder” and the one being pushed as the “Slave cylinder”. They contain a “Piston” which either pushes air/fluid, or is pushed (slave cylinder). Syringes make good master and slave cylinders. To “transmit” the energy from one to the other you can connect them with a tube. Pushing the plunger down forces the air out of the master cylinder and because it cannot compress very much it pushes the slave cylinder. This is a very simple pneumatic system. The second component the valves would usually let the air out of the system and provide a new source of compressed air to drive the master cylinder. In our syringe set up, pulling back the master syringe draws the slave plunger back down, and so acts as the valve.



Hydraulic/Pneumatic lift.



The above illustration shows a typical pneumatic/ hydraulic lift. Master cylinder A is pushed down by compressed air. In turn it pushes the air or liquid which transfers the force to slave cylinder B which is 10 times larger in diameter. Valve C lets the air/liquid out of the system. Valve D stops any return pressure. Valve E is the compressed air input.

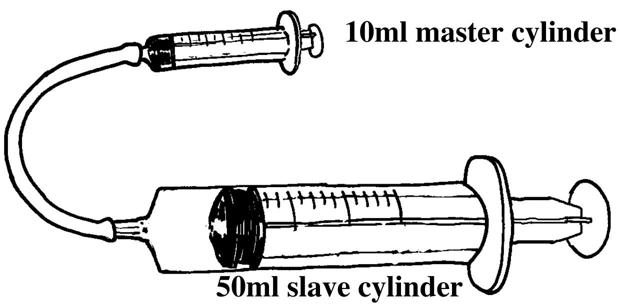


Syringes can be used as master and slave cylinders

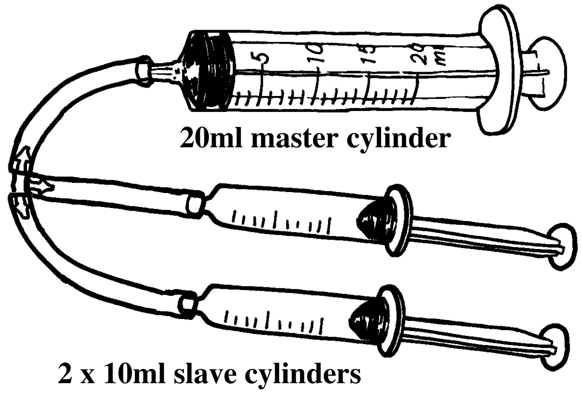
Syringes are available in a range of sizes. They are usually marked by the liquid capacity that they can hold ie. 5ml, 10ml etc. We can use this to translate into air capacity as a guide to the amount of “Work” we can get from a syringe. Like gears and levers you can also get “Mechanical Advantage” or “work” from pneumatics and hydraulics. In fact they are often used to lift very heavy loads, such as car jacks, hoists and even crush garbage! So a little more theory: If you push down on a 10ml master syringe it will the push a 10ml slave right to the end. So no mechanical advantage here, just a simple transmitting of force. This 1 to 1 set up is probably the best for making working models in the classroom where movement is more important than mechanical advantage.

PNEUMATIC DRIVES

If you have a 10ml master and a 20ml slave, syringe, then one full push will only move the 20ml slave half way, but it will have twice the force. It can be said to have a mechanical advantage in the ratio of 2:1. Try this by coupling up to a 50ml syringe. Now with a mechanical advantage of 5:1 it will only travel one fifth of the way out but is very powerful. To see for yourself, try and stop it moving. This is a good demonstration of how pneumatics and hydraulics are used to do hard work for us. The system can also be reversed, where a small push on a big syringe will make a small one travel a long way. Be careful a 50ml one will send a smaller one flying out very fast!
Now to drive two 10ml syringes together you will need a 20ml master giving a ratio of 1:1.

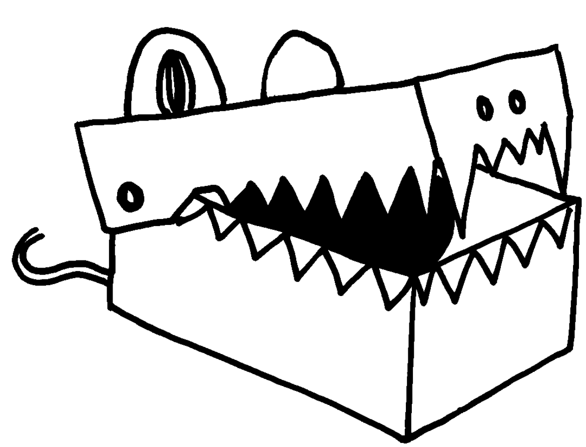


Experiment with your class using different sizes to see the effects of mechanical advantage as well as exploring firsthand the way pneumatics work. If the children log the results they can use them to help to get the best out of their “Moving Monster” project unit 3C.



Because air can be compressed it creates a light spongy feel when encountering any strong force. Water does not compress as much and so produces a smoother and stronger action.This is why commercial hydraulic and pneumatic systems use liquids and gases that are non-compressible. Compressed air is our normal air squeezed into a smaller space so it is under pressure. Because it is pressurised it possesses “potential energy” which can be released to produce energy, or work. A balloon is a good example. If you inflate it, and let go, it flies around the room, releasing all the air and “potential energy” (it is also acting as a jet engine). A balloon pump acts as a simple pneumatic cylinder with the balloon as the slave cylinder. The balloon blower has a valve to stop the air escaping back into the pump.

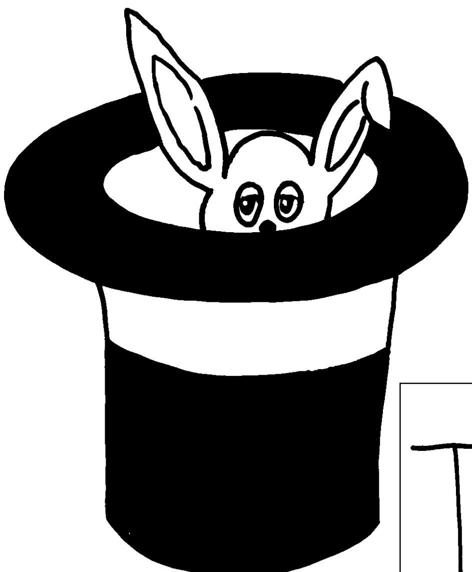
Below is a simple crocodile made out of a shoe box. Hinge the lid with either tape or brass paper fasteners. Make an 8mm hole at the pivoted end and push through a length of tubing, fastening it to the balloon with tape, now pull it back and fix about 20mm of tape to the bottom of the box, Connect the tube to a balloon pump or foot pump and blow up the balloon. It will lift the crocodile’s jaws open. Releasing the air makes them shut. The balloon is acting like a slave cylinder and can be used to create movement. Firemen use the same principal to lift heavy vehicles.

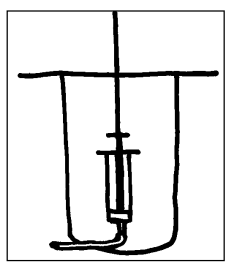


You can covert an old shoe box into a monster. The jaws are hinged with paper fasteners and can be opened with either a balloon or a syringe.

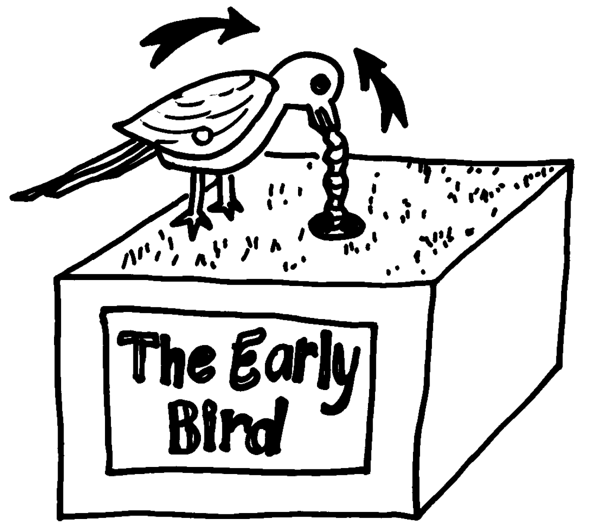
PNEUMATIC DRIVES

The following automata all use pneumatics (or hydraulics) to make them move. A simple 10ml syringe 1:1 ratio has been used in most cases. These can be used as a starting point for your pupils work and for QCA, Key stage 2, unit 3C moving monsters.

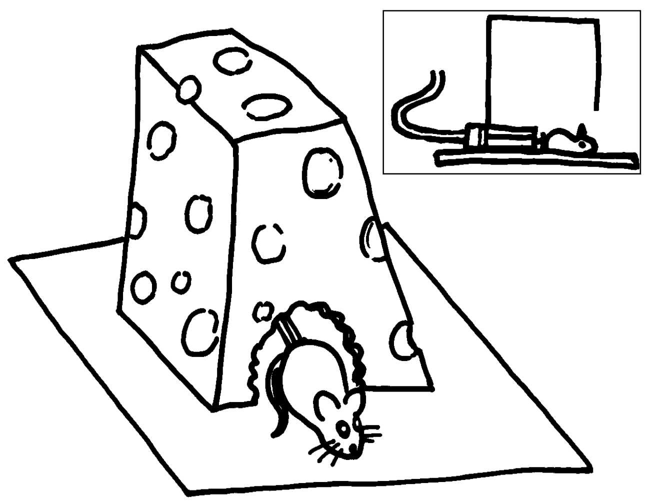




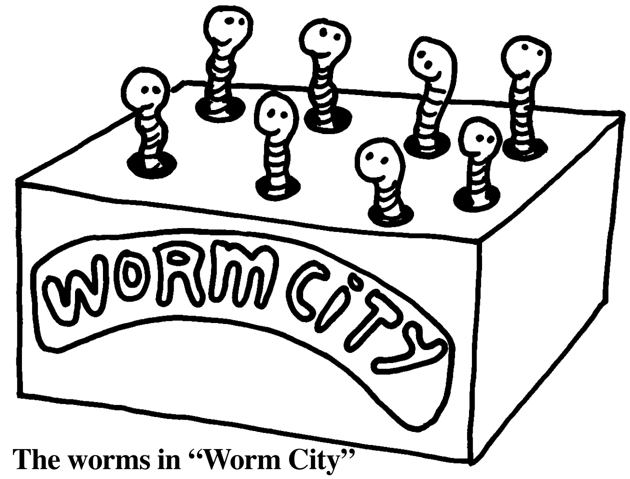
The rabbit moves up and down in the magician's hat. The cardboard cut out of the rabbit is stuck to the syringe plunger with a blob of glue from a cool-melt glue gun. The syringe is taped to a small block of wood that has been glued to the bottom of the hat. The hat itself is made out of card.



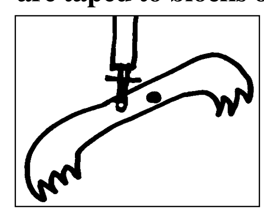
The early bird is made from card and is pivoted above his legs. The worm, which is pivoted on the birds beak, pushes and pulls. It gives the illusion that the bird is doing all the work.

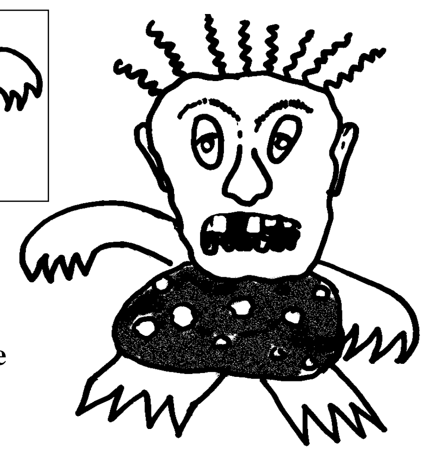


The mouse goes in and out of his home made of cheese (cardboard).



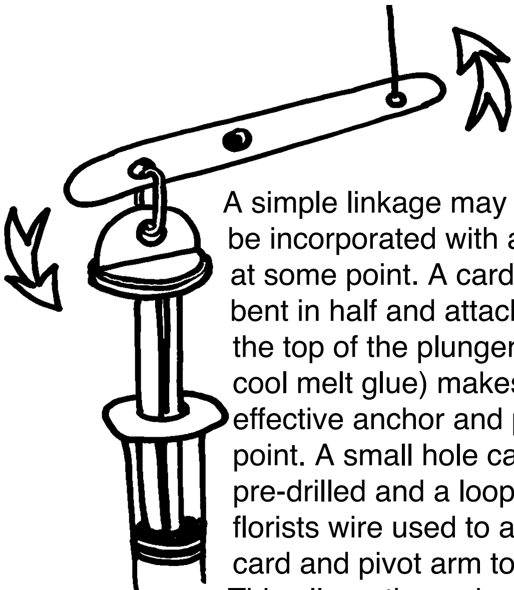
The worms in "Worm City" are made from modelling clay,. Each one is stuck to the plunger of a 2.5ml syringe. The master cylinder is a 20ml syringe. The pipes are split by 3 way connectors and keep splitting to provide further connections. It looks a bit like a tree. The worms all move at different speeds as the air takes slightly longer to reach certain syringes. The slave syringes are taped to blocks of wood in the cardboard base.





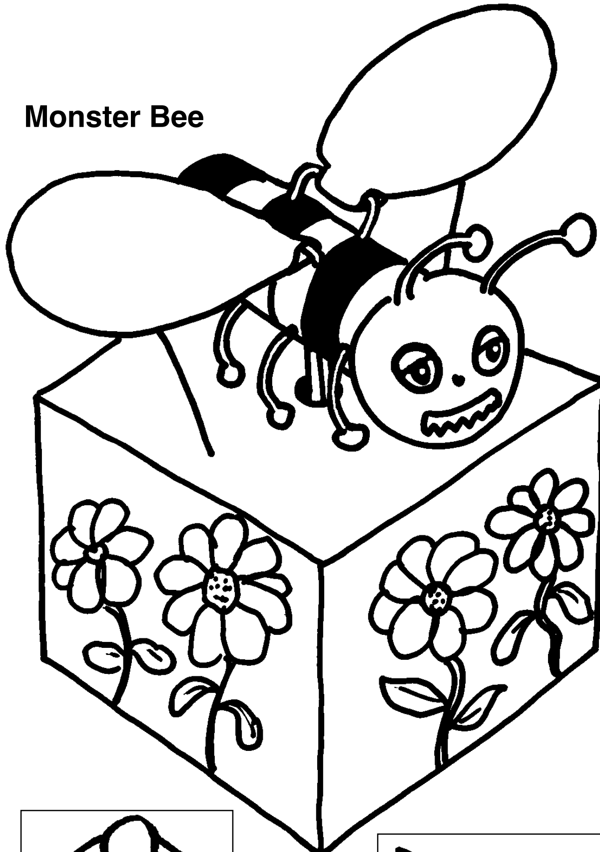
The angry troll waves his arms up and down. A syringe at the back is attached to one side of the pivot (paper binder) to produce the action.

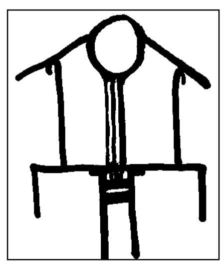
PNEUMATIC DRIVES



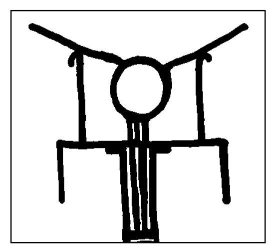
A simple linkage may have to be incorporated with a syringe at some point. A card disk bent in half and attached to the top of the plunger (using cool melt glue) makes an effective anchor and pivot point. A small hole can be pre-drilled and a loop of florists wire used to attach the card and pivot arm together. This allows the syringe plunger to move and not jam. Wire twisted into a figure of **8** works well. Alternatively a paper fastener can be used to join them. The other end of the pivot must be free to rotate (see linkages). Because the pivot is acting like a lever it can amplify movement. This can be used in project work to demonstrate the action of levers. It is worth spending a little time on the linkages to see why it is so important to have free movement and the way a pivot arm moves or “Describes” an “Arc”. The children could make up a model to demonstrate this. It may seem trivial but some of the most common engineering faults and problems are associated with moving linkages. This also applies to automata!

Monster Bee





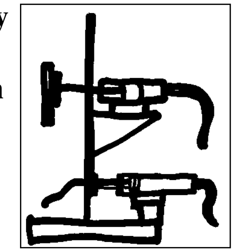
A

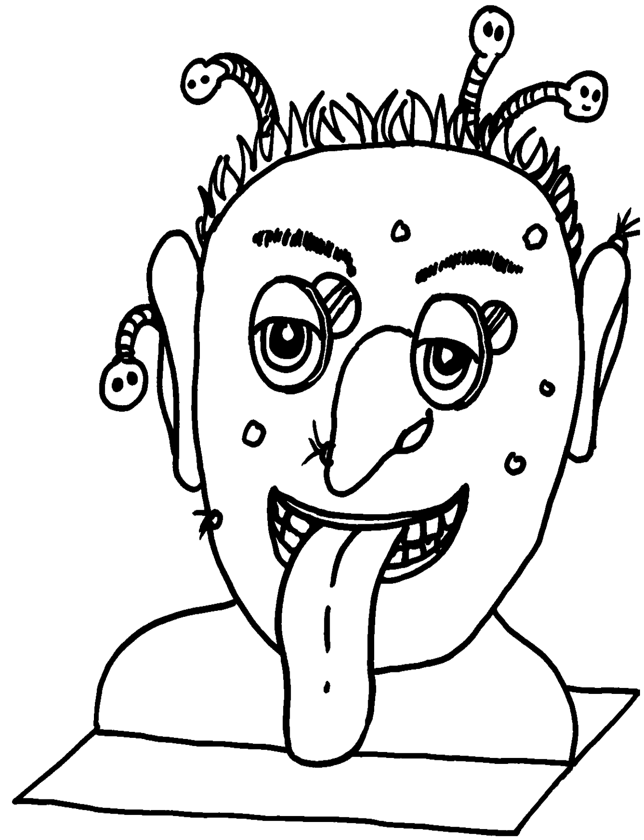


B

The Monster Bee uses a simple up and down motion like the flying pig automaton. It makes use of the same pivoting wing mechanisms shown in diagrams A & B above. This simple automaton can be easily adapted.

The Monster’s eyes pop in and out and he also sticks his tongue out. This automaton contains 3 syringes utilising a straightforward push and pull movement. This can easily be adapted to other projects. In fact all the automata shown in this section can be modified or used as a starting point from which to base your classroom work.





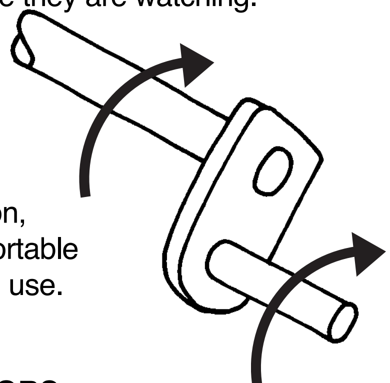
DRIVES

HAND POWER

There are two main ways of powering your automata. One is to turn by hand and the second is to use a motor, the most practical being a small electric one.

A hand driven automaton helps bring the mechanism to life and makes the user feel part of the performance they are watching.

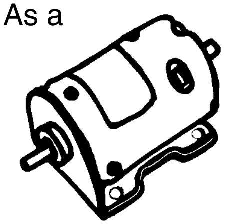
Power is transmitted through a crank, which is more than sufficient to work an automaton, and is quite comfortable for the operator to use.



ELECTRIC MOTORS

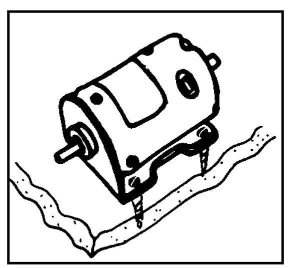
The advantage of electric motors is that they give a constant output, so the automata are less likely to be damaged.

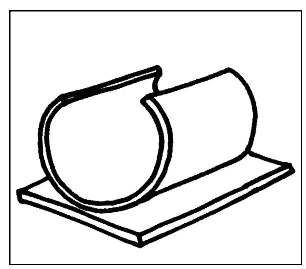
Most electric motors turn at very high speeds. The typical revolutions per minute (or rpm) of a small 12 volt motor is between 200 and 12,000 rpm, so you will usually have to slow the speed down. Most hand-cranks rotate between 30-50rpm, which is a good speed to aim for. The best options for stepping down speeds are either gears, pulleys or a combination of the two. Many electric motors come with a small gear wheel, which is a good starting point. If you decide to use a motor there are a few things to consider. Firstly, what voltage does it run at? Most cheap motors run at between 1.5 to 9 volts. As a rough guide, the higher the voltage the more powerful the motor. Even a small 1.5 volt motor can give a lot of power when stepped down.



The second consideration is how easy the motor will be to attach to a board, or anchor down. Better motors have two lugs with holes to allow them to be screwed or bolted down. You can also get a motor mounting clip that uses a sticky fixing pad to adhere it to plastic, wood or card.

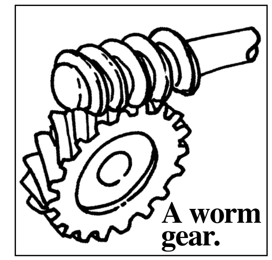
An electric motor is an option in the fairground project Unit 6C. Educational suppliers offer a range of suitable motors. The better ones have both a small pulley and gear attached, giving greater versatility. They can be linked to special gears and pulleys which fit 5mm dowel. This makes construction a lot easier.



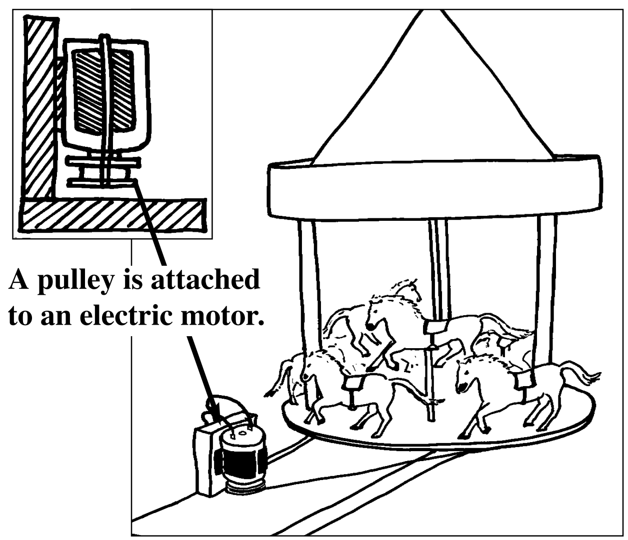


You can attach an electric motor with screws if it has fixing lugs, or with a special motor clip.

The main consideration is the gearing down and drive application. Pulleys are best as the mechanics of linking up are the most simple. Experimenting with pulley ratios in order to find the best solutions makes a good classroom activity. The fairground model will probably require a fairly large out-put pulley. Gears are another option. Electric motors can come with a small input gear in order to get a good slow final output. The main problem to overcome is the connecting of the output gear to the fairground model. The 5mm dowel gears offer the best solution. A motor with a worm gear is another option. Again, you can get commercial motors which come with one in a simple gearbox.



A worm gear.



A pulley is attached to an electric motor.

THE DESIGN PROCESS

INSPIRATION

Mechanical toys and automata often appear to have a life of their own. The simple mechanical parts seeming to produce an almost magical response in the figures that they move.
Automata come in a vast range of sizes and varying degrees of complexity. Some may keep your interest for several minutes whilst others you may just pass over.
What makes an automata "good" is very subjective. We all like different things and we do not all find the same thing funny. As the old saying goes "You can't please all of the people all of the time." So where do you start?
The check list below gives some simple suggestions to test your ideas against;

1) Will it be visually exciting?

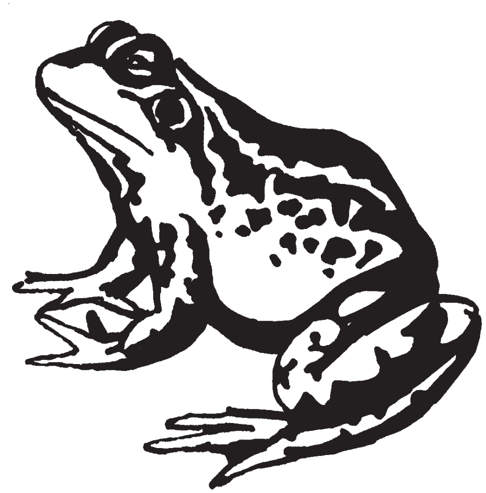
2) Will it interest the viewer?

3) Will it hold the viewers attention?

4) Is it too complex?

5) Will I enjoy making it?

This is just a general check list, and is by no means a fool-proof system for producing the perfect automata, but it will help to weed out good ideas from the bad. Children will develop good design skills and practices if involved in the process from the start. Begin by basing ideas on something that they are interested in, such as a sport or a hobby. Animals can provide a wonderful subject on which to base a theme for automata or you could use characters from a favourite story.
As with any creative process, coming up with the idea is often the hardest. It is probably fair to say that most children have to work hard at the inspirational or ideas stage. However, you could be lucky and your pupils may be full of ideas, every class is different.



RESEARCH

Once an idea has been decided, the next stage is to research it. The purpose of research is to get as much information as you can about your subject. This helps to work out how something moves, the colours, the scale etc. Research can be broken down into two areas;

1) Primary research: where you make drawings of your subject from life.

As an example, drawing a camel at the zoo. You do not have to be a great artist, it's more about looking and observing to help understand the subject. It may not always be practical to draw from life, and the temptation is always to work from the easiest sources. However, the best and most creative works evolve from good observation. This is true for all arts and crafts, and is the reason why many artists spend so much time drawing.

2) Secondary research: refers to the use of things such as photos, pictures, photocopies etc.

This is usually the most accessible material to get hold of. The library is a good place to start, you can also photocopy relevant pages from book sand magazines.

THE DESIGN PROCESS

MOOD BOARDS

Designers often put together a “Mood Board” or “Ideas Sheet” which is made up from a range of materials that reflect the theme.
It can include colours, textures and surroundings. They are often used in the fashion industry yet are of great benefit to any designer. In it’s simplest form you could paste up all your research material onto A3 or A2 paper. The ideas sheet is there to inspire, so try and make it varied and interesting.
Children love this stage, sticking, colouring, and writing notes. It creates a clear focused classroom activity.

DESIGNING

When you have your research material, the next stage is to begin developing it into a working solution. Start by writing a short “Statement of Intent”. This is simply a few sentences about the automaton you want to make. It is a great way of focusing thoughts and forms the basis for a design brief.
The following headings will help as a guide to the sort of things to think about;

1) **Who is my automaton intended for? A young child, a teenager or an adult etc?**

2) **What size will it be? Automata can range from miniature pieces for dolls houses, through to hand held ones or large scale works.**

3) **Simple or complex? Will I use cams, gears or cranks or a combination of them?**

4) **What materials do I want to work with? Automata can be made from paper, wood, or metal. Often you will work with a range of materials.**

5) **Deadlines: How long have I got to make it?**

Work will need to be completed within a certain time. So careful planning is necessary. Once a basic working brief is established you are ready to start. Begin by thinking about the movements needed to make it behave realistically, and then try to match these to the mechanisms covered in the first part of the book.
Sketch out ideas. For more complex automata, it is often easier to break down all the movements and design the mechanisms individually. When this is done you can then work out how to join the whole thing together.
The actual design process is both exciting and frustrating.
When you have solved the initial mechanical problems, it is often helpful to ask pupils to evaluate their work and see if anything can be simplified. It is vitally important to keep sketching ideas. It is helpful to make accompanying notes as well. The reason for this is that what appears to be very simple and straightforward can often turn out to be confusing and complex when looked at a week later. Pupils and teachers may think they understand drawings at the time, and all the mechanisms make sense, but things do not always stay clear. A few accompanying notes can help to explain and make sense of a drawing. They can also jog your memory.

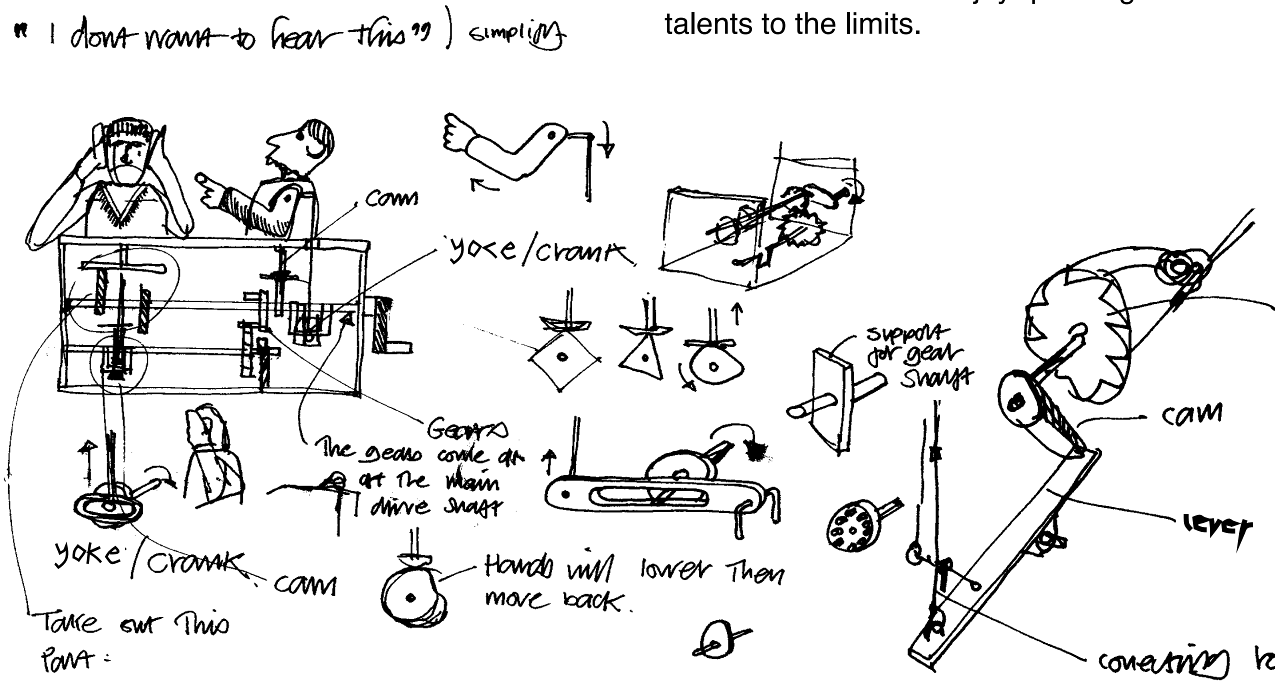
THE DESIGN PROCESS

DESIGN NOTES

It is a nice idea to work in black felt tip or handwriting pen which makes a committed and more permanent mark and will help you to draw and sketch in a clearer, more simplified way. (Try it for yourself and see). Pencils are often the preferred media of children as they are comforted by the thought that mistakes can be rubbed out. This is fine, they can always outline in pen afterwards.

DEVELOPMENT

Ideas need to be taken through to a final design and eventually drawn up in full detail, showing how all the mechanisms and moving parts will work.
You may find that none of your initial ideas were suitable, in which case a modification or combination of ideas can be put together to provide a workable solution.
Developing the work is a vital part of the design process. Taking an idea and developing it into a final solution is the very essence of the design process. So keep it fun. Children should enjoy “pushing” their talents to the limits.



WORKING MODEL

Making the working model helps to highlight any design and construction problems. It can also save you a lot of time and effort later on. At this stage the design can be modified and construction details finalised. It is also a vital part of the design development process, as the working model helps to evaluate ideas and pinpoints where to make changes. In some extreme cases it can show that the automaton just will not work as intended and a major redesign is called for. This is where the phrase, “back to the drawing board” originated from, and it happens to all of us at some time or another. Timely advice and supervision should avoid this happening.
The working model or prototype is best made with card, wood and string as they are flexible and quick to modify. Card is surprisingly strong and can be used for the final automaton. Working models or prototypes play a big part in the evaluation. At this stage the practicality and feasibility of a design can be assessed. There is almost always something that needs changing in order to make things work, you will often discover an even better way of construction. It is also a good point at which to evaluate work, and make sure that it still fits the original criteria, ie: intended use.

THE DESIGN PROCESS

FINISHED AUTOMATON

With the working model complete, functioning properly and evaluated, it is time to start on the finished piece.
The choice of materials to work with should logically come from the design process and working model. Wood, metal and hard plastic, termed “ resistant materials”, should be used if any parts need strength, otherwise use card, paper or a combination of the two.
The working model can form a template from which to make many of the mechanical parts such as cams, gears and pulleys. Be prepared for some things to need modification.
Resistant materials are less tolerant than softer ones, and whereas a card gearwheel may work, a wooden one may jam or stick if not properly designed.

EVALUATION

The final evaluation is used as a guide with which to test the success of a design against the original intentions.
Every stage of the design process will include some form of evaluation. Indeed, designing is really a continuous process of evaluation.
The evaluation may just be a process of making mental notes about what did, and did not work. Alternatively, children could be encouraged to write up notes in a sketch pad. This is the best method to adopt as it forms a valuable source of research material to refer back to, especially if they encounter similar problems. For schools it also provides evidence of achieving a unit of work.

Below is a flow diagram of the design process;

INSPIRATION

↓

RESEARCH

↓

DESIGN

↓

DEVELOPMENT

↓

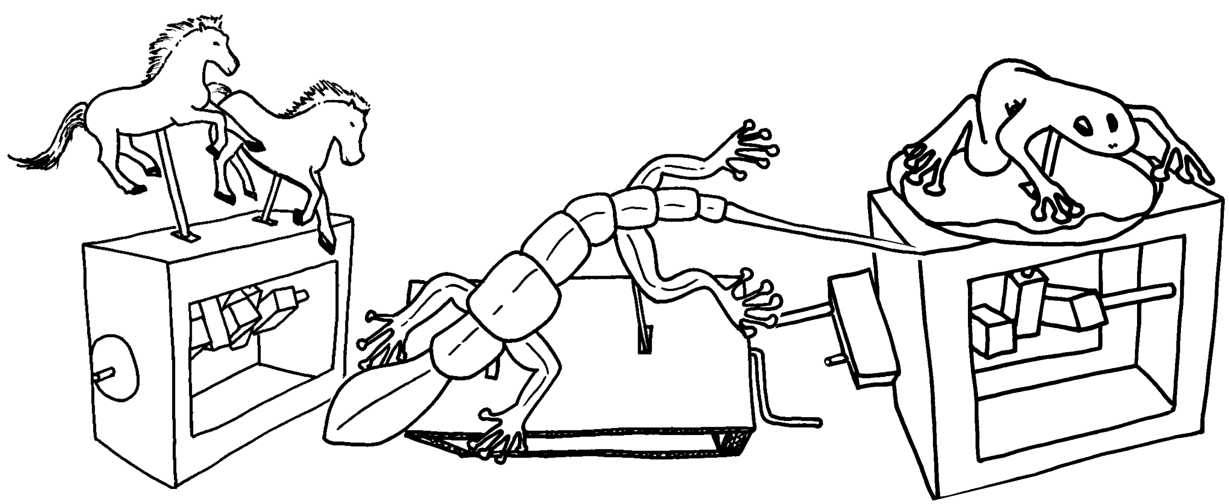
WORKING MODEL
& PRELIMINARY EVALUATION

↓

FINAL OUTCOME

↓

EVALUATION



THE DESIGN PROCESS - SUMMARY

Two golden rules to keep in mind when starting are;

1) KEEP IT SIMPLE

2) MAKE IT INTERESTING

When you have come up with an idea for an automaton run it through this check list;

1) Will it be visually exciting?

2) Will it interest the viewer?

3) Will it hold the viewers attention?

4) Is it too complex?

5) Will I enjoy making it?

You will then need to do some research about your subjects, trying to get as much visual information as you can. There are two main types of research;

1) Primary research: where you make drawings of your subject from life.

2) Secondary research: refers to the use of things such as photos, pictures, photocopies etc.

The following headings should help as to the sort of things needed to be thought about when starting to design;

1) Who is my automaton intended for? A young child, a teenager or an adult etc?

2) What size will it be? Automata can range from miniature pieces for dolls houses, through to hand held ones or large scale works.

3) Simple or complex? Will I use cams, gears or cranks or a combination of them?

4) What materials do I want to work with? Automata can be made from paper, wood, or metal. Often you will work with a range of materials.

5) Deadlines: How long have I got to make it?

After making the initial working model, it is useful to evaluate its effectiveness and highlight any design problems that may still need to be resolved;

1) Does it work the way it was intended?

2) Can anything be improved or simplified?

3) Is it going to be reliable?

In the final evaluation you need to test against your original intentions. Below is the procedure you run through;

1) Does it appeal to it's intended user?

2) Does it work as intended?

3) Is it safe for use by the intended user?

4) Can it be improved in any way?

5) Is it going to be reliable?

6) Will any of the parts wear out too soon?

7) How easy will it be to repair if something goes wrong or breaks?

8) Were suitable materials used for the final construction?

9) Could alternative materials be used (recycling)?

10) Can it be adapted in any way?

DESIGN & CONSTRUCTION

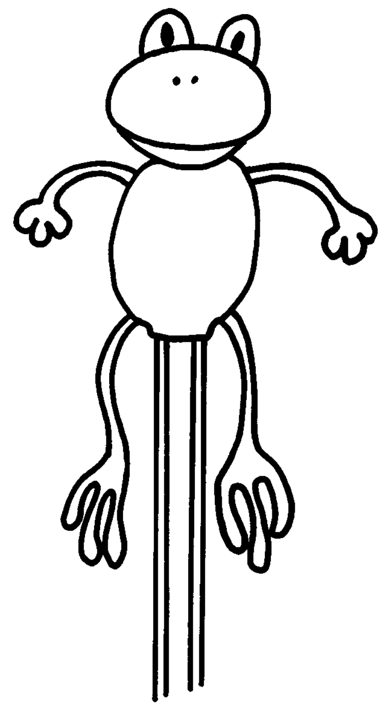
WHERE TO START
Knowing how mechanisms work and what movements they are capable of making is of great importance when it comes to designing automata. So just how do you come up with ideas and make them work?
This section looks at the design process and gives suggestions and ideas on which to base work.
It is a considerable challenge to design and make automata, so keep in mind the two golden rules;

1) KEEP IT SIMPLE

2) MAKE IT INTERESTING

These two design criteria are useful to base all work against. If designs pass this simple test then go on and make them.
You can look for inspiration from the people and things around you. The animal kingdom is a very rich source of ideas, and can be a good point from which to start a project for making simple automata.
The following section runs through the complete process of designing and making a simple automaton (moving toy unit 5C). This will give an insight to the principles to follow, the problems that may be encountered and ways to find solutions.

THE FROG
Stage 1) Inspiration
The inspiration for this automaton came from a rubber toy that fits onto the end of a pencil. Frogs have interesting features as well as an exciting way of getting around which is very distinctive and relatively simple to emulate.



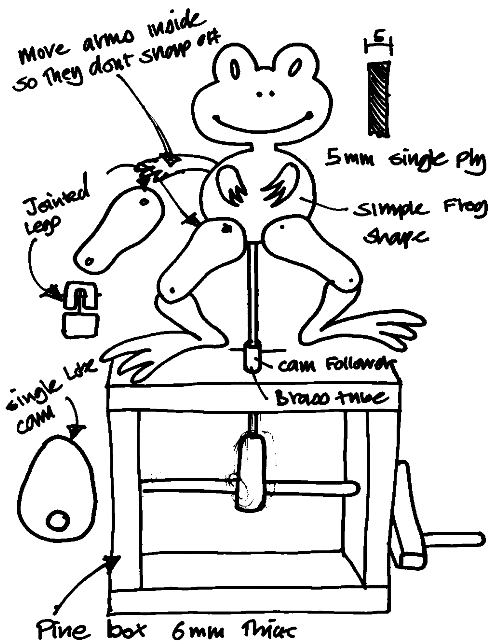
Inspiration - a tree frog toy

Stage 2) Research
This is one of the most important processes to go through in order get the best out of an automaton.
Begin by producing “Ideas Sheets”. Images can range from simple cartoons to drawings, paintings and photos. Magazines are a good source of material. Take photocopies from books and, if possible, take your own photos. A group discussion will help to focus on ideas as well as inspiring others in the group. It will also help to focus on what is needed and expected of the project.
From the ideas sheet begin to make simple line drawings to determine the best shape and angle to work from. Simplify the shapes as much as possible as they need to be re-created in wood or card eventually. Try to find the key features of shape and form that make the subject recognisable.
The next objective is try and simplify the movement. Look for characteristic actions. In the case of a frog, hopping or jumping.
Finally, choose the main colours to work with. In this case it was easy - green.

DESIGN & CONSTRUCTION

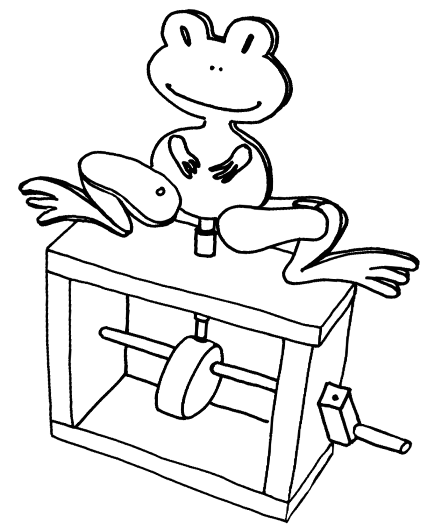
Stage 3) Design
This is the stage where final decisions are made on actual size and specific colours. Also to devise the simplest mechanism which will make the automaton work.
Introduce the concept of a “User Profile”. Simply put, decide who the automaton is intended for, children or adults. The frog automaton or mechanical toy is intended for young children aged 3 upwards. This now means designing something which is strong, durable and with no sharp edges or small pieces that could break off. It also needs to be colourful and slightly cartoon-like (whimsical).
With this information designing can begin.
The frog needs to move up and down, which means a choice of two mechanisms - a cam or crank. In this instance a cam seems the best choice. The crank could be adapted but would make the mechanism complicated.
The next decision is what sort of cam to use. A single lobe would give one big jump, a triangle or square would give a faster action. Earlier research showed that frogs jump in big leaps, so it makes sense to go for a single lobe cam. Small children should be able to follow the action better if it is slower.

The next task is to finalise the design as a working drawing. At this point decisions about the mechanisms, the box they are housed in and the materials to work with should be made. Next the design of the frog is developed. A “working drawing” will contain all the information needed in order to construct a “working model”. At this stage everything is theoretical and it should work, but problems can still arise.



The basic design may look like this. There are still a lot of problems to resolve, but drawing ideas helps to clarify the design process.

Stage 4) A Working Model
Using the design sheets, a working model can be made from a mixture of card and wood. This is the exciting part of the process where drawings come to life. It is also the time to discover what does and does not work. A lot of time and energy can be saved by producing a working model even though the temptation is to go ahead and start on the final one. In many cases the working model will evolve into the final work.



A number of things came out from this working model that were not apparent in the drawing. One is that the crank handle needed to be bigger so that a child with small hands can turn it easily. Secondly the frog should be double sided. This will enable both right and left handed children to use it.

DESIGN & CONSTRUCTION

Stage 5) Evaluation and Development
After making the initial working model it is useful to evaluate it's effectiveness and to highlight any design problems that may still need resolving. Try working to a simple check list;

1) Does it work the way it was intended?

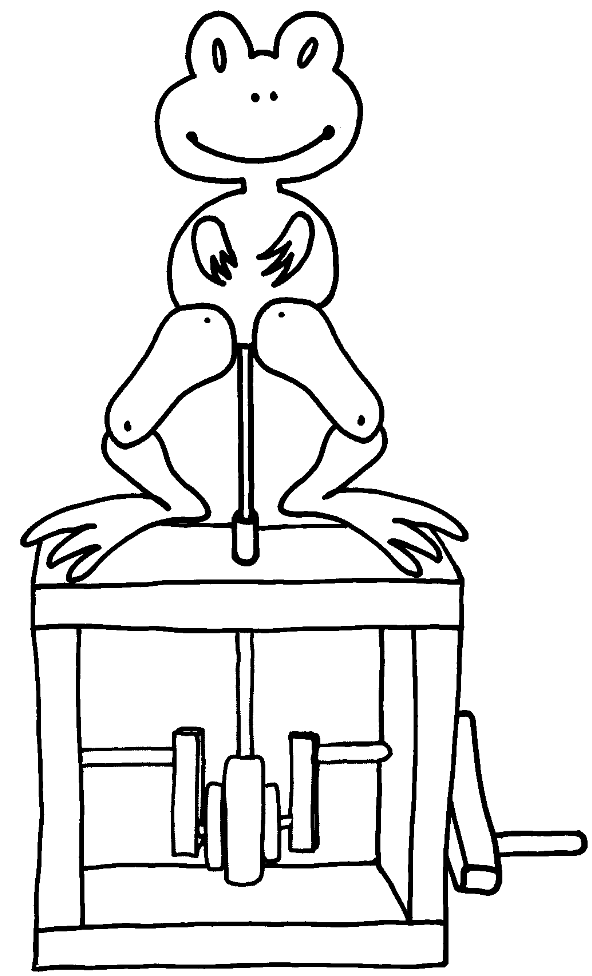
2) Can anything be improved or simplified?

3) Is it going to be reliable?

4) Does it look and move in a frog-like manner?

Inevitably, some aspect of the design will need to be adapted as with the frog. Apart from a larger handle and the need to paint the frog on both sides, a much larger problem was highlighted. The frog's legs were too long and do not leave the base when the frog was at the top of it's travel. The cam was just about as big as it could be so a major re-think was called for. One possible solution was to shorten the legs slightly and make the cam larger. The most practical solution was to replace the cam with a crank, and the scotch yoke crank made a good choice as side to side movement could to be avoided. This made it more complicated than originally planned.

Stage 6) Final automata
All the design problems should, in theory, have been ironed out, so the final stage is to make the automaton.
The final automaton is assembled and painted. Most of the parts are made directly from patterns that were produced for the working model and have been tested so should work without any problems. The scotch yoke has been substituted to provide more lift. It worked well in card. Because of the new design, the frog is attached permanently to the rest of the automaton which makes it safe for young children. In this case switching mechanisms has proved useful, and shows how easily things can be overlooked.
Now finished and working as intended, there was a final problem with one of the legs sticking. This was due to paint reducing the free play in the joint. A bit of vigorous push-pulling soon bedded it in.
Several problems were highlighted when designing and constructing this simple automaton. Encourage children when they encounter problems because there is usually a way to overcome the setbacks they are bound to meet.



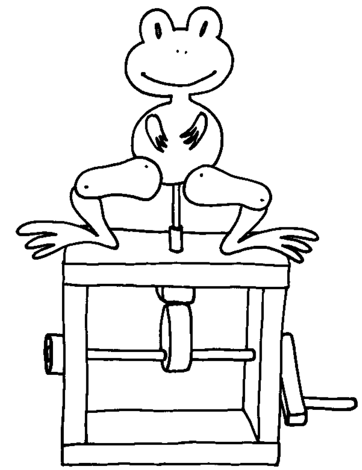
The final automaton works as intended and has evolved into a more practical toy for the children who are likely to play with it.

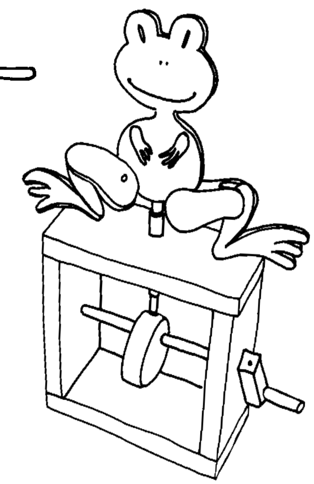
DESIGN & CONSTRUCTION

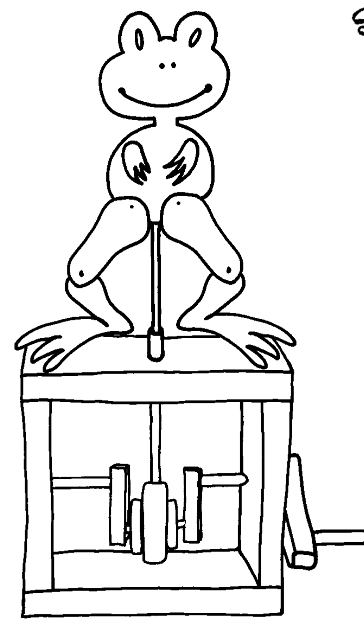
Stage 7) Evaluation
This final stage is very important. You now test the finished automaton against the original intentions. Below is the procedure to follow;

1) **Does it appeal to it's intended user?**
2) **Does it work as intended?**
3) **Is it safe for use by the intended user?**
4) **Can it be improved in any way?**
5) **Is it going to be reliable?**
6) **Will any of the parts wear out too soon?**
7) **How easy will it be to repair if something goes wrong or breaks?**
8) **Were suitable materials used for the final construction?**
9) **Could alternative materials be used (recycling)?**
10) **Can it be adapted in any way?**

The procedures that are followed are common to most designers. It is important to work in a clear and methodical manner. This does not have to be at the cost of creativity but, if anything, should help channel ideas and energies towards a successful solution.
It is important to remember that you face two challenges when trying to make automata. The first is what to make, the second is how to make it.
The design process is essential in order to produce a working solution. Making automata is not easy, but it is a rewarding and satisfying thing to do, especially when they work!
As you can see from this example, things do not always go to plan. However, a thorough approach to the design process will help to make successful and exciting automata.
This is quite a stringent process that has been outlined, it will need to be modified or simplified for young children. However, it underpins all design and technology activity. It also broadens out the activity into art, literacy maths and science.





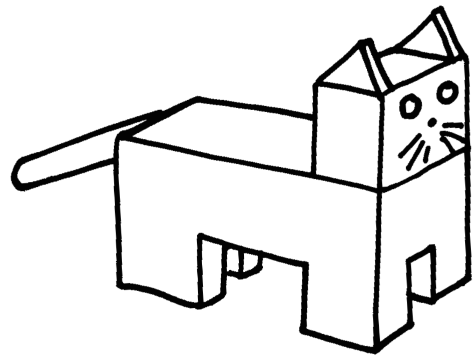


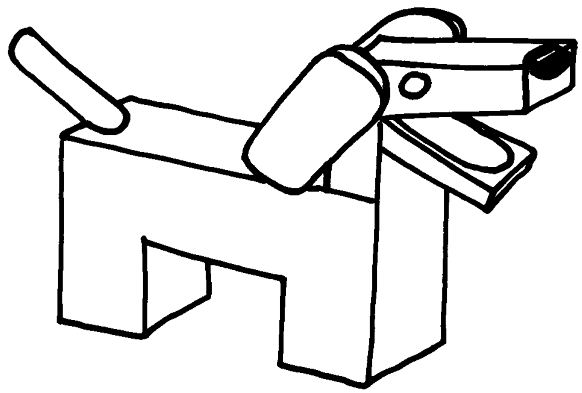
Be prepared to make and modify several versions in order to achieve a final working automaton.

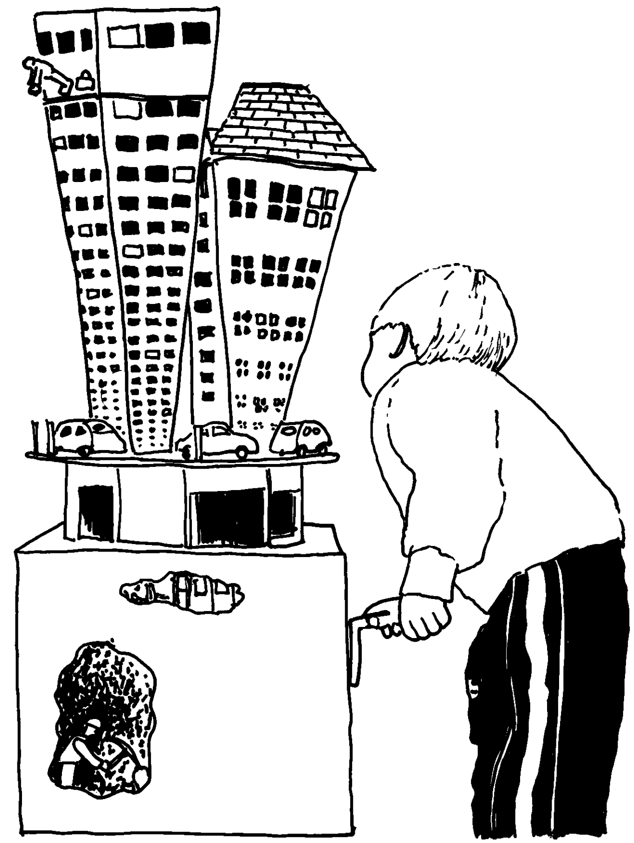
DESIGN & CONSTRUCTION

INSPIRATION AND RESEARCH

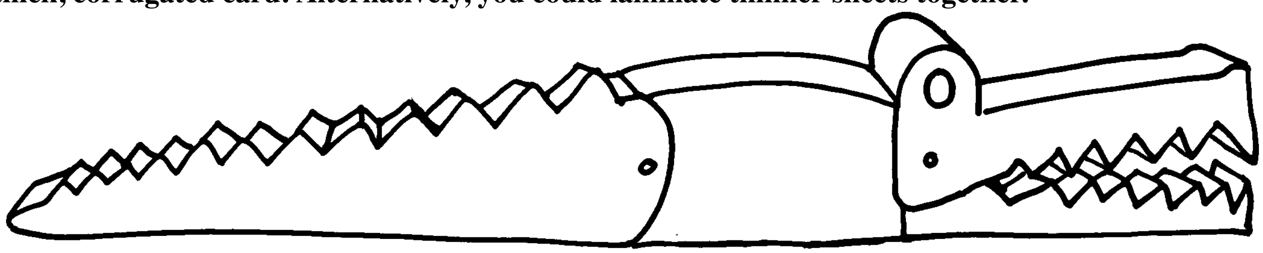
Animals are a great source of inspiration and research for children. They can begin by cutting out pictures of animals from magazines and sticking them down on an ideas sheet. You may want to theme this i.e. farm animals, dogs, cats, or be able to coincide this with a trip to the zoo. The best approach is to focus on some aspect of the animal kingdom and then look for key movements such as a snapping crocodile, kitten chasing it's tail or frog jumping.
When it comes to designing, stick to the very simple mechanical movements such as cams and cranks. These will still produce a range of exciting actions. Making the animal forms should also be simplified and either be kept flat or constructed from simple shapes. This method will work for most subjects including people.







Simple shapes are the key to success. A lot of objects can be constructed by combining box shapes. Colour and pattern can also help to identify things. The cat and dog above are a good example of this. More complex shapes can still be used and cut out of card. The crocodile below was cut from thick, corrugated card. Alternatively, you could laminate thinner sheets together.



The automaton above was made entirely from card using simple shapes, and household items like cereal boxes. Scale is something else to explore. As you can see this was fairly large.

TOOLS & EQUIPMENT

You can use card to make both working prototypes and finished automata. Below is a list of equipment you will find useful;

Large and small pair of scissors

A scalpel or craft knife

A steel rule, with a handle that keeps your fingers away from the edge

General items you may find useful:

A compass

2B Pencil

Rubber

Masking tape

Rubber bands

Sellotape

Wood glue (this can also be used on paper and card). PVA glue is better for children to use

Mitre square

Protractor

SAFETY FIRST

When making automata or engaging in any D&T activity children will have a need to use or have access to various pieces of equipment. Common sense and school policy are obvious guidelines to follow. But the fact remains that in order to deliver the curriculum certain tools and equipment will have to be used by the class.

The most common concern of teachers is the use of cutting tools, saws, craft knives, drills etc. Supervised instruction goes a long way to help avoid accidents. If possible have a classroom assistant (nice thought!) dedicated to working either 1 to 1 or with a small group of children. They can help with and supervise the difficult cutting activities.

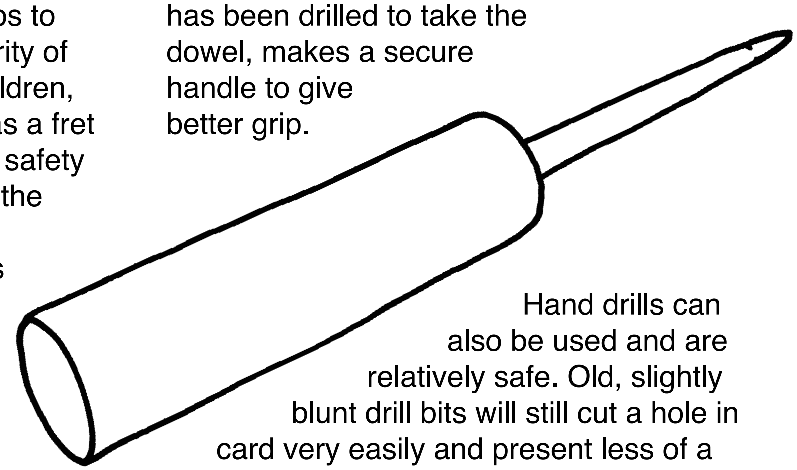
If necessary some project parts can be pre-cut or cut to order.

Working predominantly with card helps to overcome many problems. The majority of cutting can be done safely, by the children, with scissors. Most hand tools such as a fret saw and hand drill also minimise any safety problems. Part of the remit of D&T is the introduction and use of tools so a compromise needs to be reached. As a rough rule of thumb the older the child, the more responsibility they can have (that's the theory)!

One of the problems encountered in the D&T classroom is the making of holes in card. Ideally a craft knife should be used but this is often not practical. From personal experience they are frighteningly sharp, and the disposable type with break off blades are particularly dangerous. I have seen the blades snap several times whilst being used to cut card.

One solution is to make your own tools.

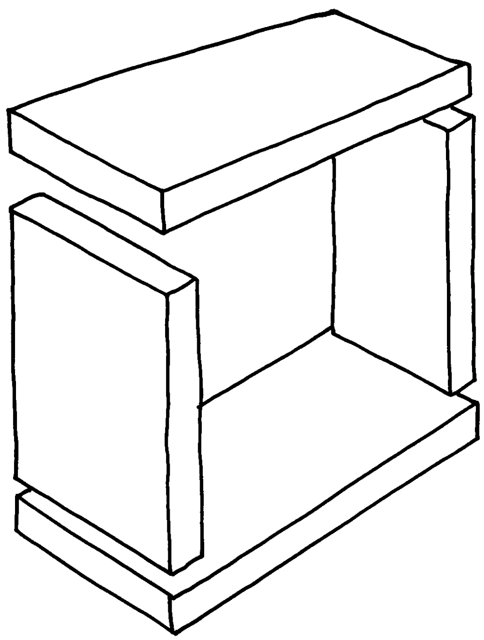
A piece of 5mm wooden dowel sharpened in a pencil sharpener makes an ideal hole cutter. If the work is placed over a piece of polystyrene or corrugated card it facilitates the piercing acton and stops the point breaking. Once a small hole is made it can be enlarged by pushing the dowel through. A short length of broom-stick which has been drilled to take the dowel, makes a secure handle to give better grip.



Hand drills can also be used and are relatively safe. Old, slightly blunt drill bits will still cut a hole in card very easily and present less of a danger to children.

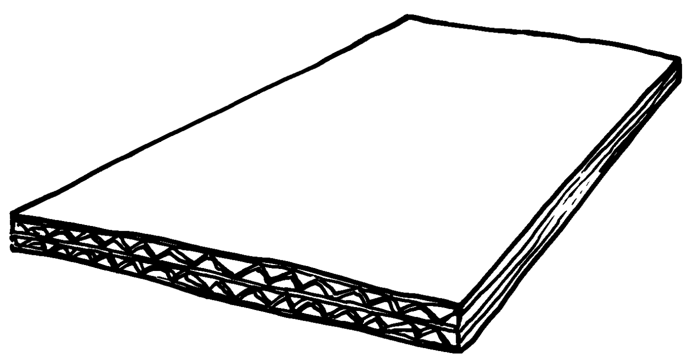
CONSTRUCTION TECHNIQUES

An open sided box is an ideal housing for automata mechanisms and is simple to make. You will need to work out the length and depth needed, then construct it from card. Alternatively, you could make use of existing things such as cereal boxes. Recycling offers the opportunity to be very creative with household rubbish. You can make art and help save the environment at the same time.

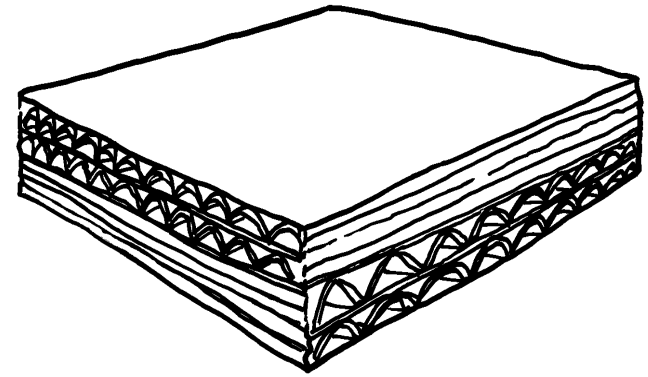


A simple four sided box makes an ideal housing for automaton mechanisms. You can make them from a range of materials such as cardboard or wood.

Corrugated card is an excellent material to work with. It is readily available and has a good residual strength. It is also easy to make holes in and bonds well when glued. Fruit boxes, computer boxes, in fact, anything designed to carry a heavy weight is usually made from thick, strong cardboard and is the best type to use as it is constructed with several layers or laminates. You can make super strong card by gluing two or more thinner pieces of corrugated card together. Placing them at 90° will add more strength. Put a weight evenly spaced on top while the glue dries. You can then cut it to the required size. This should be done by an adult using a steel rule and sharp knife. Children can then make and glue it together. Always make your drive shaft holes prior to gluing the box. It is a lot easier done flat, also they line up better if done simultaneously.

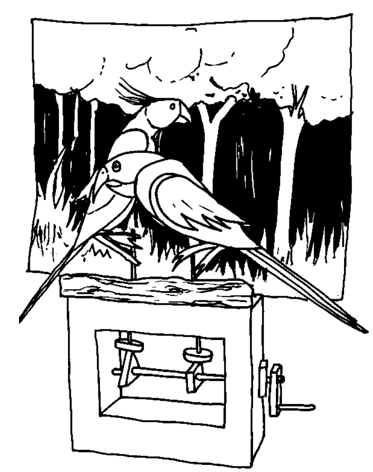


Good quality, strong corrugated card is made up from several layers or laminates.



You can make your own strong card by laminating two or more thinner pieces at 90° to each other. This makes a cheap and effective base to make automata housing and parts from.

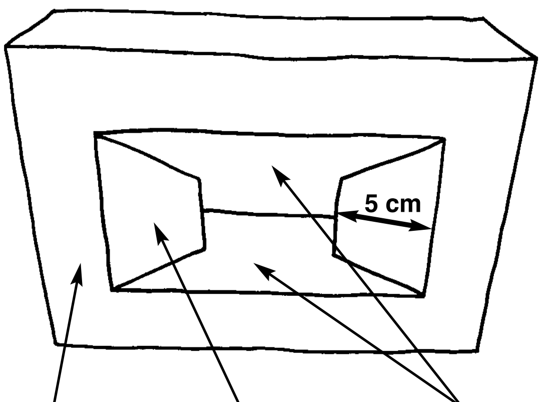
Cereal boxes make good housings. If cut correctly there will be little waste and they can be structurally strengthened. It also promotes recycling and they are free!



The housing and backdrop for this automaton was a cereal box.

CONSTRUCTION TECHNIQUES

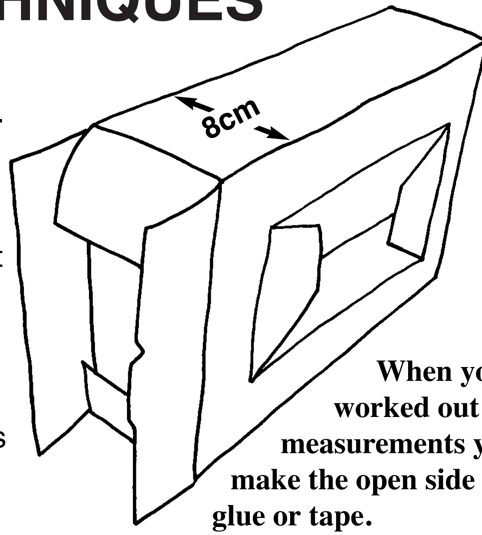
To make the housing you first need to measure your cereal box and work out a few dimensions. In this example the box has been turned on it's side. The inner shape and flap folds have been drawn on both sides. The basic side shapes were achieved by eye, look for a proportion that gives a good working size yet keeps the box strong. The inner side flaps were drawn with extra length for gluing. The depth of the box was 8cm so the flaps were drawn to 5cm each. This gives an overlap to glue. The same applies for the top and bottom flaps. You will notice the side flaps are much bigger. This is because the drive shaft will be running through them so they need to be strong.



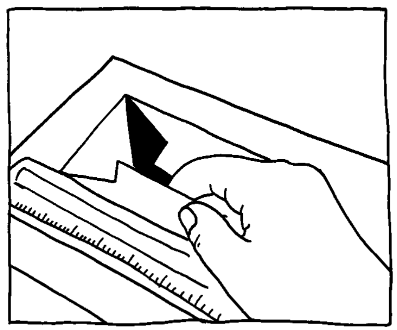
Side shape is equidistant all round.

The side flaps are measured so that they will overlap when folded, an extra 1cm was added.

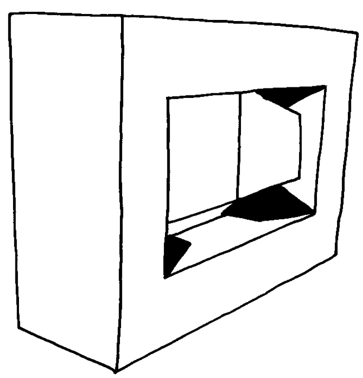
The top and bottom flaps should also overlap.



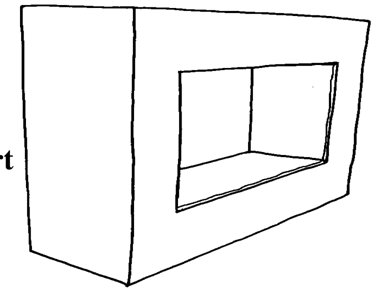
When you have worked out the measurements you need to make the open side secure using glue or tape.



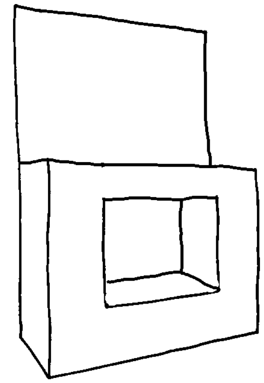
Next cut out the flaps. They can be folded in more easily if they are first folded outwards. Using a ruler helps fold them in a straight line.



The final box should be quite strong when the flaps are glued or taped into position.



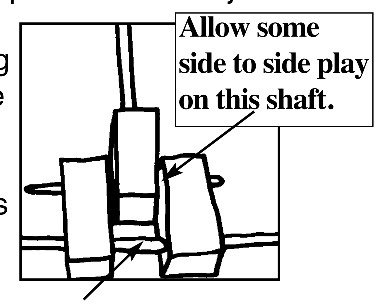
Extra card panels can be stuck on top of the flaps to give even greater support and strength.



By cutting and folding the box on it's base you can use the complete back panel to create a back-drop for the automaton. The front panel is used to create the top.

CRANK SHAFTS

It is advisable to make crank shafts in one long length. When the glue is completely dry, saw off the unwanted parts with a fine junior hacksaw blade. This helps keep everything in position. Extra glue can be added to give more strength on the cut parts. Twin cranks can only successfully be made this way.



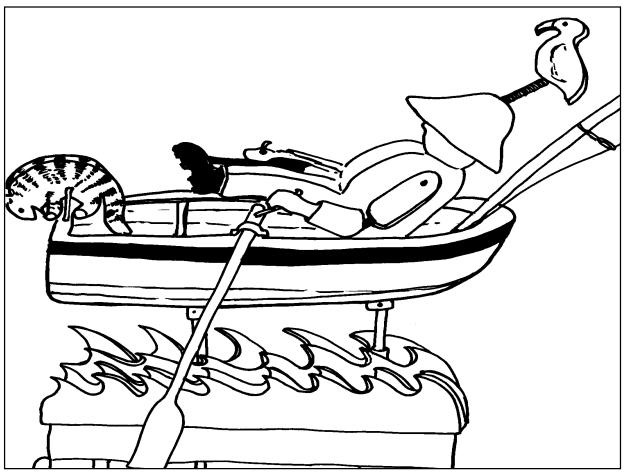
This part will need to be removed when the glue is dry. A blob of glue can be added to the ends for extra strength. Allow a little play at the crank follower end so that it can clear the lower supports.

CONSTRUCTION TECHNIQUES

CAMS, GEARS and FIGURES

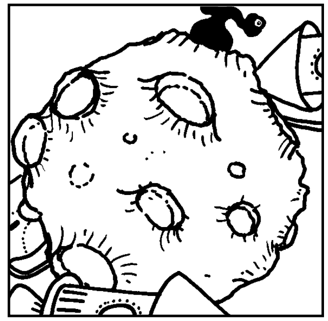
Probably the best materials to use are the pre-cut card circles that are available in a range of sizes, usually with a 5mm centre hole. They can be cut to shape and even sanded. They are very stiff and strong and are highly recommended for use in the D&T classroom.

If using MDF make sure that you wear a mask as it produces a very fine dust when sanded or cut.

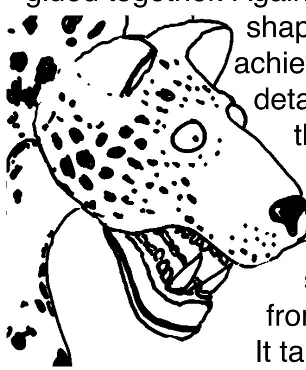


More complicated figures can be made from modelling clay then painted with neat PVA glue, finally a topcoat of paint mixed with PVA will give a good finish. The PVA makes the figures very strong and sets the shape. This technique allows quite complicated figures to be modelled and is strong enough to make moving, jointed figures like the one above.

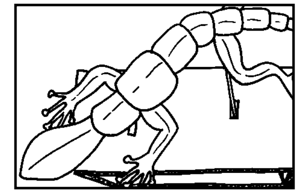
Paper mache is another good modelling material as it produces a lightweight, strong finish. It can be a little more difficult to make realistic figures with but is excellent for simple shapes. The planet for the space ride was made with papier mache.



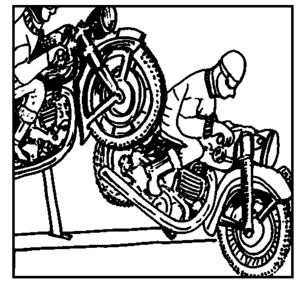
Paper pulp is another cheap and effective material. Paper is put in a blender with a quantity of water, then pulped down. When reasonably fine yet still sightly lumpy it can be strained and then used to model with, squeezing the desired character into shape. It is a bit messy and takes a few days to dry out but the results are great. A little PVA glue can be added to the pulp mix to help it to bond. Various parts can be made and then glued together. Again, it works best with simple shapes, although you can achieve a surprising amount of detail. The leopard in the“Jungle Jimmy” automaton was made entirely from paper pulp. Origami offers another solution for making things, from animals to people. It takes a bit of practice to achieve good results.



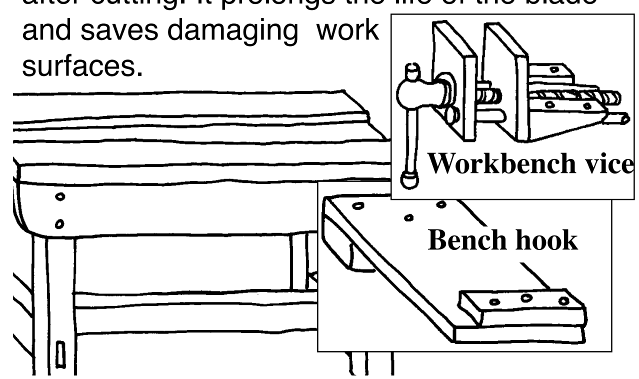
Coloured card is another good material to work with as it is both flexible and strong. Many of the automata creatures in this book were made with card. “Larry the lizard’ is a good example of card being used to construct a creature.



Photocopying pictures and drawings, then colouring them in or taking prints from a computer are all good ways of achieving the desired end result. These images can be stuck to stiff card to give them strength.



If you are cutting wood then make sure that you always cut away from yourself and hold the work squarely in a vice or bench hook. Card and paper are best cut on a “cutting mat”. This is made of semi hard plastic that heals up after cutting. It prolongs the life of the blade and saves damaging work surfaces.



CONSTRUCTION TECHNIQUES

GLUING

There are a number of different glues available that work well for various requirements.

Wood to wood, cardboard or paper

Wood glue is a great all round adhesive. It dries clear and sets fairly quickly. Paper and card are wood in origin, so it works well with them. There are many different brands on the market . They all seem to do a good job and are readily accessible from most hardware stores and schools suppliers. If you can find it, professional wood working glue (which is often yellow, and sometimes referred to as aliphatic resin) gives excellent results. There is a range from America which is non-toxic and safe for classroom work.

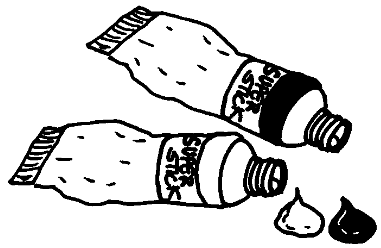
Wood or metal

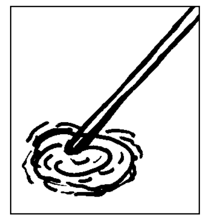
A two-part epoxy resin is very useful as it dries in about 10 minutes and sets clear. You mix two equal parts thoroughly. When first mixed, the glue is fairly runny. As it begins to set, it gradually becomes stiffer until it eventually starts hardening, When stiff, you can place it on the objects that need bonding. Be watchful, as the glue turns very quickly from stiff to set. Give yourself enough time to work, and only mix up as much glue as you need at a time.

Warning: Two-part epoxy resin glues contain harmful chemicals. They should be used with care, and if you get any on your skin, wash immediately with soap and water. Do not allow children to use it.

Two-part epoxy resin glue is incredibly strong, dries quickly and sticks most things. It works very well on metal and wood, and is an invaluable aid to the automata maker.

It should only ever be used by an adult. It is the perfect glue for sticking things that require a lot of strength.





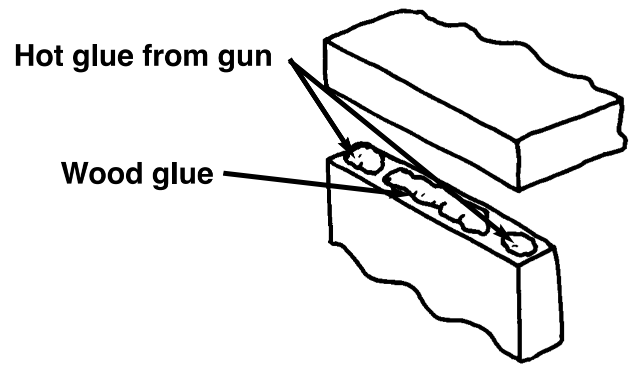
The secret to using epoxy glues, is to mix both parts thoroughly and in even amounts. (Always follow the manufacturer's guidelines).

Glue guns

Glue guns are very useful. They use sticks of ordinary or wood working glue. Be warned the glue is very hot when it comes out and burns, if touched. This also applies to the cool melt guns which supposedly run at a lower temperature. However, it does cool quickly. It will bond most materials together, although it does not form such a strong bond as wood glue or epoxy resin.

You do not have much control over the spread of glue, so a trigger type of gun is recommended. This enables you to control the flow of glue and can be operated with one hand. A glue gun will work on metal, wood, card and paper.

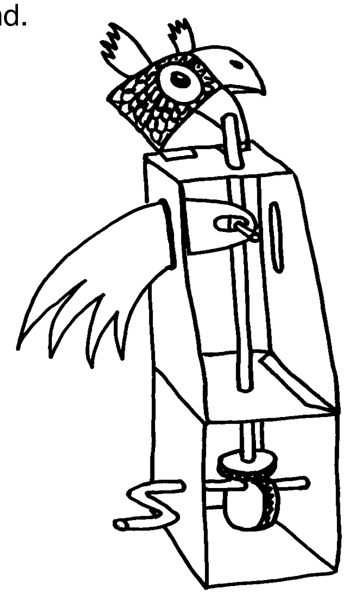
A handy tip for using glue (to make a base for example) is to put a few spots of glue down with the glue gun and then use traditional wood glue or PVA. The hot glue will dry in about a minute and hold the work whilst the glue sets in about 15 - 20 minutes. This will avoid you having to clamp the work.



A cool-melt glue gun with trigger.

CONSTRUCTION TECHNIQUES

Paper and card glues
Wood glue is excellent for bonding paper and card but may not suitable for children to use (check the label for a safety warning). PVA glue is a good alternative. It takes a little longer to dry, but is relatively harmless and safe for young people to work with under supervision. All-purpose adhesive is excellent in it's solvent base form. It dries very quickly and makes a strong bond, but this is not suitable for children. However there are solvent-free, all purpose glues available that children can use. They dry fast and produce a strong bond.



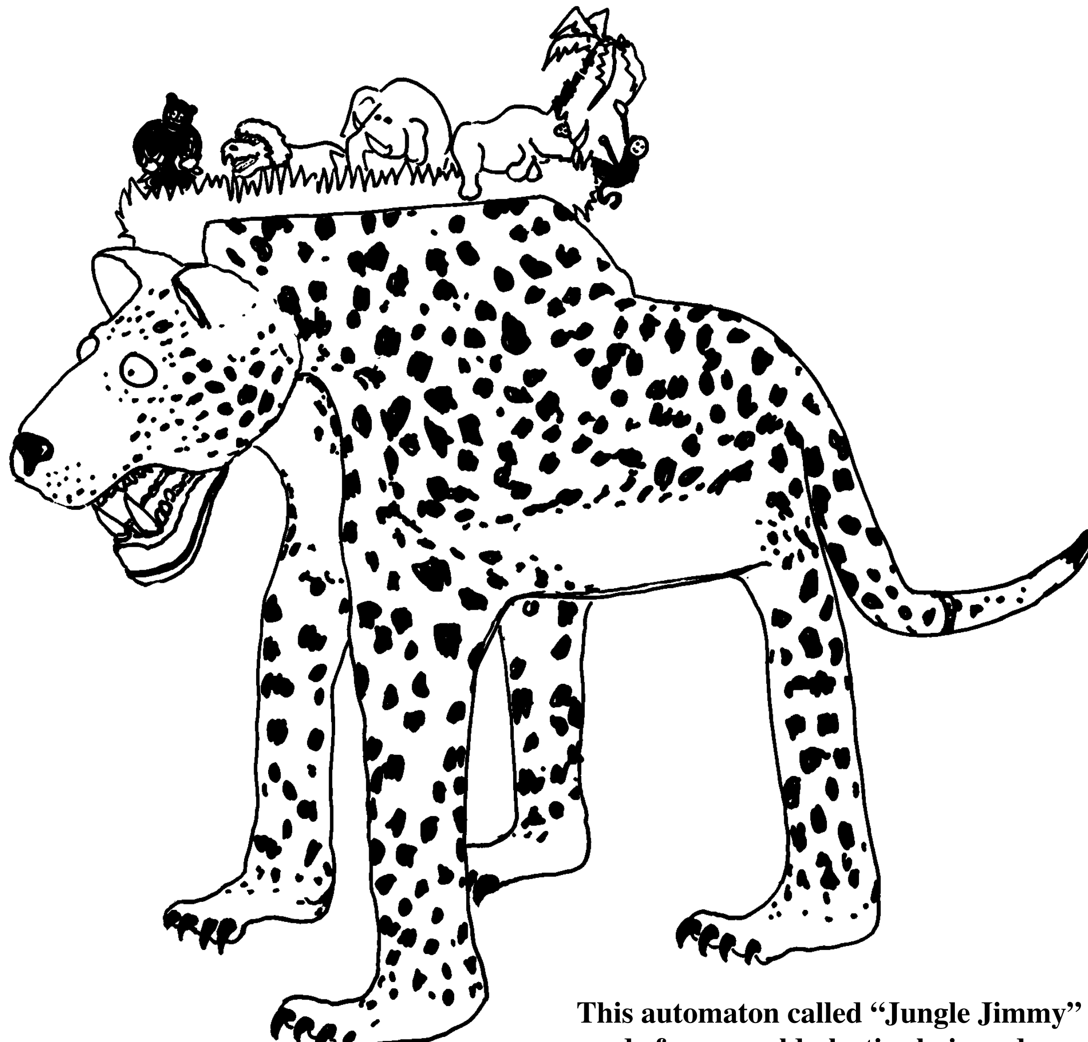
If you are working with card or paper then there are several glues you can use that are safe and solvent-free. You could also use sticky tape.

Keeping the cost down is always a problem. PVA glue is used because it is relatively cheap and will wash out of clothes. It is also non-toxic (I wouldn't want to put that claim to the test). All these factors make it an obvious choice but there are a few drawbacks. It is water based so often cockles paper and thin card. It takes quite a long time to dry and finally it is not very strong. Whilst it will suffice for about 80% of gluing jobs, you should consider using specialist, stronger glues for work that need more strength or a quicker drying time. Some of these, like solvent free UHU, can be used safely by children. This type of glue has a very fast setting time or "grab time". For example, if the class were making the cat from the net on page 19. They could cut out and glue most parts within a two hour session. Because UHU holds within 15 to 30 seconds (full setting is about one hour) the parts can be assembled fairly rapidly. PVA just can't match this as its grab or sticking time is about 3 minutes. Setting time is about 3 hours. Whilst this is fine for many applications it does slow things down. There are also some wood glues that dry very fast, with a strong bond and are certified non-toxic. It's worth exploring some alternatives that will help save time in the classroom or to salvage work where parts needs extra strength. Finally, glue sticks like prit-stick are very useful they produce a good strong bond on paper and card, instantly.

Painting and Finishes
The final finish of any automaton can have a tremendous affect on how it looks. Working with coloured card is an alternative to painting. It comes in various weights and colours and can give a very uniform, professional look.
Painting poses a few problems, water based paints will swell paper or card fibres. This can cause moving parts to stick and not move properly. Too thick an application can also stop parts from moving freely. Acrylic paints give the best overall finish and flatness of colour but are expensive. You can add PVA glue to poster paints. This will help them flow a little better as well as leaving the dried paint with a gloss finish. An alternative is to use felt tipped pens, again these are water based and although fine for small areas are not practical on larger areas.
Another alternative is to produce work on the computer and get a colour print. This can then be stuck down with a glue stick, like prit-stick, which will not cockle the paper and gives a very strong bond.
Children enjoy painting and colouring. It is an important area of the project and should be considered as part of the design process.This could be used as a classroom activity, investigating paint finishes by producing test strips.

SUMMING UP

Making automata can be challenging, frustrating, and fun. Sometimes mechanisms work well initially, but the next day they don’t work properly. Bits drop off or they fall apart. On other days everything works well and keeps on working, so you know you are having a good day!
It is easy to be dismissive of automata as just whimsical toys, but they are much more than that. Even the simplest piece of work can encompass a whole host of artistic and craft skills, not to mention engineering theory and practices. When you turn the handle something magical happens as the work comes to life. People love movement and in this modern age we are bombarded with it, yet it still captivates us.
There will be triumphs and tragedies. Many professional automata makers who have been working over a period of time have a collection of odd mechanisms that are a testament to their failures. The parts still maintain something special, which is enough to keep them, and they can often be recycled into other automata.
As a classroom activity making automata has a lot to offer. Encompassing art, design, craft, technology as well as numeracy and literacy. Parts of Key stage 2 can be accomplished in an exciting, creative and innovative way. It will also open up the children's eyes to all the everyday mechanisms we take for granted and pay so little attention to. Even the humble toaster could take on a new light!



This automaton called “Jungle Jimmy” was made from an old plastic chair and covered with paper pulp to form the shape. When you turn his tail the animals on his back jump about.

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