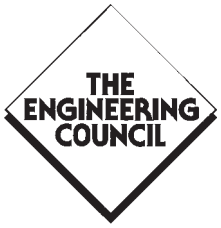
TEP
TECHNOLOGY
ENHANCEMENT
PROGRAMME

SHADOW AIR MUSCLE
14 - 16

Version 1



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Original contributions by:

The Shadow Robotics Project

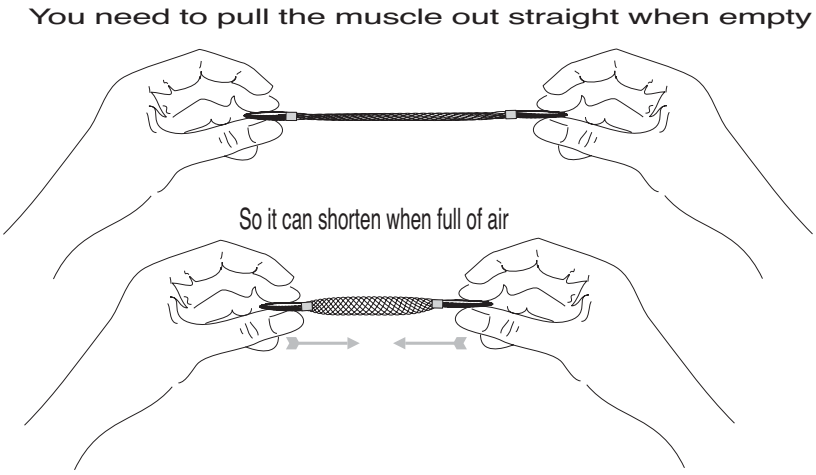
The air muscle illustrated here originated with the Shadow Robotics Project and the idea remains its protected intellectual property.

Series Editor

John Cave
Middlesex University

THE SHADOW AIR MUSCLE

The Shadow Air Muscle is a new kind of device for producing movement. This is what it looks like:



Pull it out hard.....then fill it with air, and feel it pull your hands together, no matter how hard you try to stop it.

Test the strength of your friends...

The strength of an air muscle

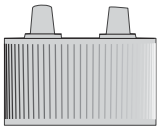
1) Make sure that the muscle is empty.
2) Set up the kit as described in the next few pages.
3) Pump up the reservoir until the bottle is quite rigid.
4) Get your friend to try and stretch the muscle.
5) Now open the valve to the muscle.
6) The muscle will contract whether your friend likes it or not!

The Shadow Air Muscle Low-Tech Sample Pack consists of the following...

1) One standard 15 cm air muscle.

2) Three-way-valve for controlling the air flow.

3) Bottle cap adapter for attaching an air reservoir.



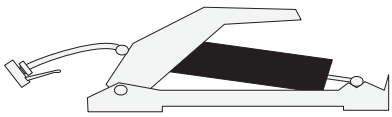
4) Fizzy drinks bottle to be used as the air reservoir.

5) Footpump adapter for connecting a footpump to the 3mm air line.

6) Tee piece, in case you want to connect one footpump to more than one system.

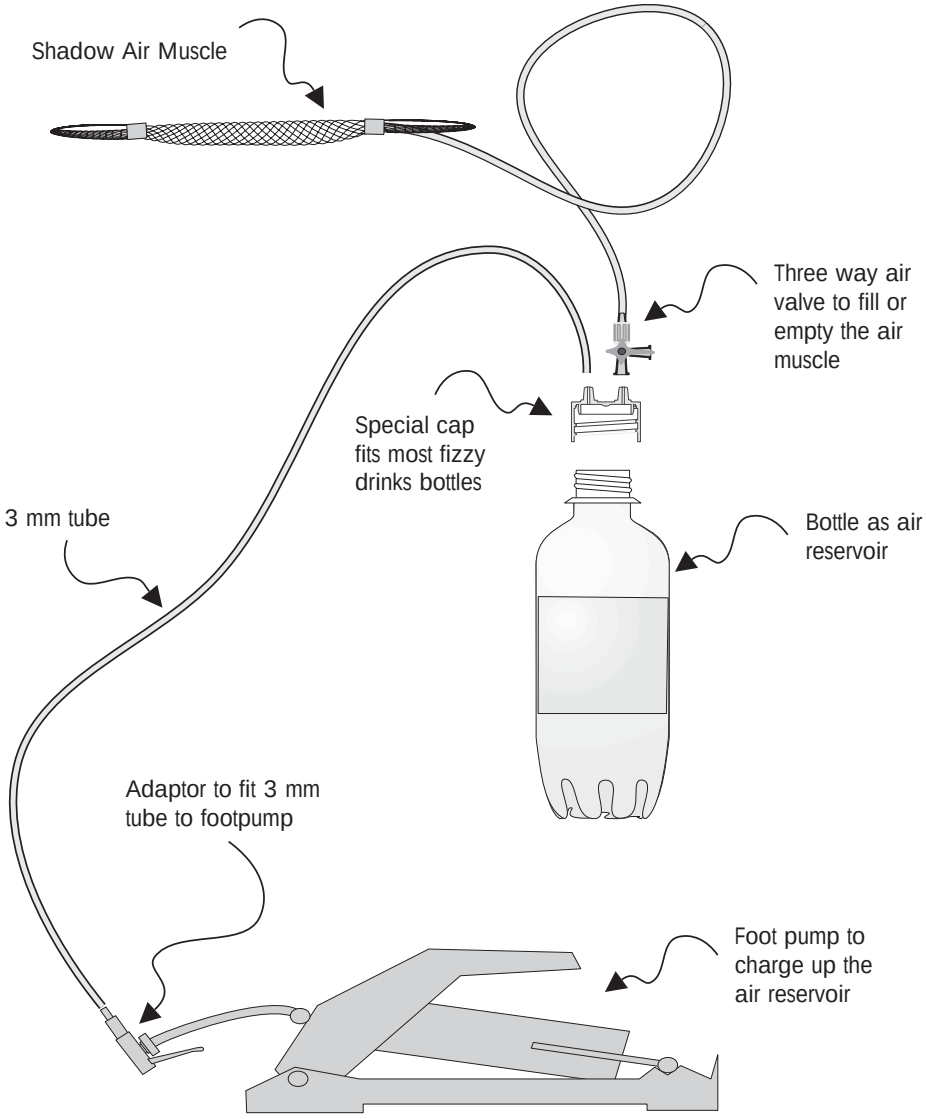
7) Two releaseable nylon cable ties, to attach the muscle to your device.

8) Plus a length of 3mm air line which can be cut and push-fitted into the other components.



NB You will need to supply a foot pump for charging the reservoir. *(If you can't get hold of one, a cheap one can be purchased from Middlesex University Teaching Resources.)*

This is how they all fit together..



KIT ASSEMBLY

You can cut the clear 3mm PVC tube with scissors. It is then simply pushed onto the foot pump adaptor and one of the nozzles on the special cap. To avoid the tube pulling off the special cap, use a rubber band or adhesive tape to fix it to the fizzy drinks bottle. Push the three-way air valve onto the other nozzle (it's called a Luer nozzle, which fits quite a lot of medical apparatus) and give it a slight twist as you do so, to attach it firmly.

Push another length of 3mm clear PVC tube onto the three-way air valve, as shown, and connect it to the short length of 4mm air line on the air muscle. The bottle supplied as an air reservoir is a standard fizzy drinks bottle made of PET (Polyethylene Teraphthalanate). You can use a larger, or smaller, bottle such as those used for sparkling mineral water.

IMPORTANT - AIR MUSCLE SAFETY

- Wear goggles during prototype work.
- Never connect a fizzy drinks bottle to an air compressor or air line.
- Do not pressurise glass bottles.
- Never use a bottle larger than 400 ml.
- Do not put your finger over the end of a tube or nozzle to stop air coming out.
- Never unscrew the bottle top or pull off a valve or fitting when there is compressed air in the system.

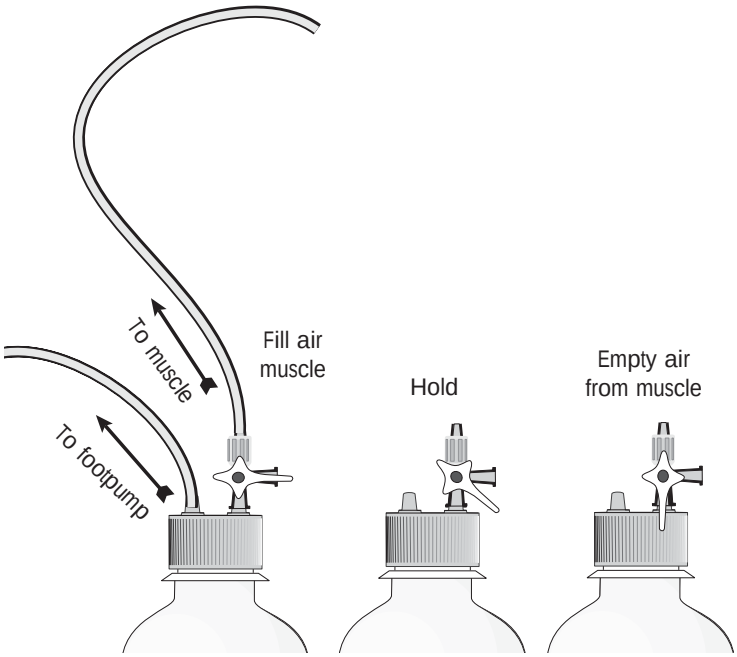
GUIDELINES FOR ATTACHING AIR MUSCLES EFFICIENTLY

1) Make sure the muscle is pulled taut. If the muscle is slack, the rubber tube inside will expand without having any effect. It may be necessary to use a spring or elastic band to pull against the muscle. Do not worry about pulling too hard on the muscle; it is very strong.

2) You should pump up the reservoir until it becomes quite rigid. It will feel hard.

3) The three-way valve can be used to fill the muscle from the reservoir and to empty it to the outside. (See below.)

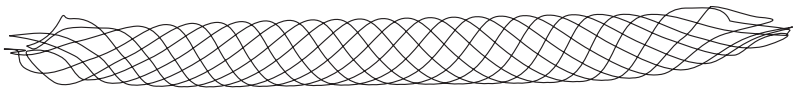
Note: it is quite easy to accidentally vent the reservoir to the outside world, in which case you will have to pump it up again! This happens if you turn the white lever towards the muscle.



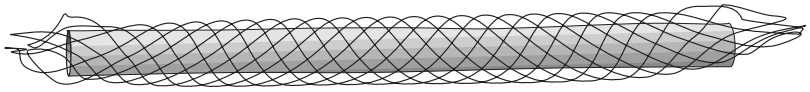
HOW DOES IT WORK?

The SHADOW air muscle consists mainly of a length of soft rubber tube

and some braiding.

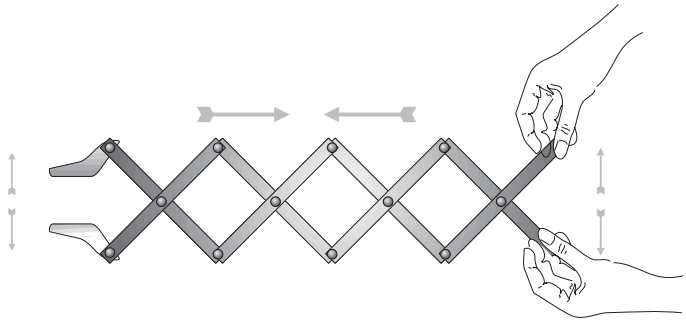


The rubber tube is inside the braiding.



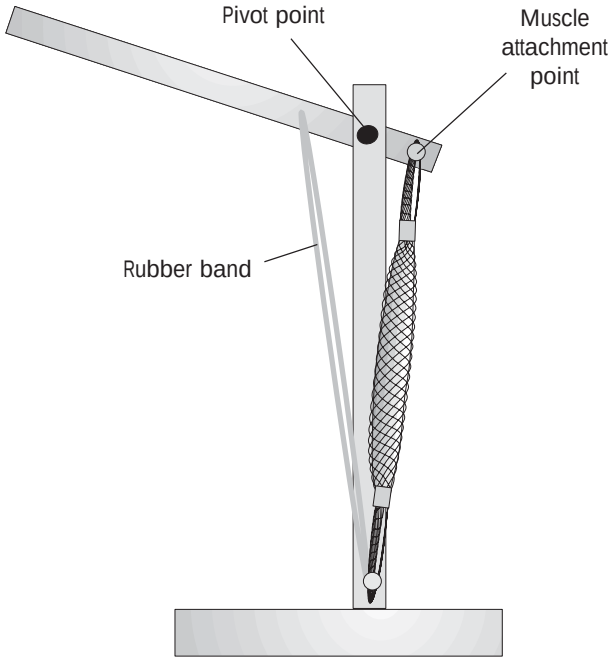
The ends are sealed, the braiding folded back to form loops.

If the soft rubber tube is inflated, it gets fatter. This pushes the braiding, which acts like a pantograph, or lazy tongs. It gets shorter as it gets fatter.

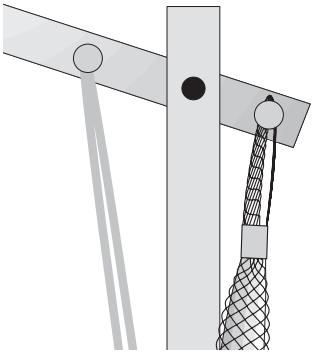


MAKING A BARRIER

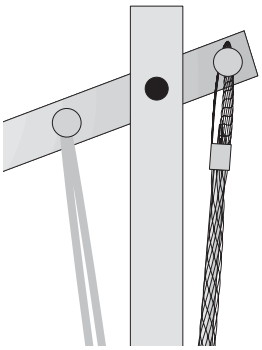
A barrier is needed at an event to let in one person at a time and you are asked to build a working prototype. The basic design is given but you will have to improve it yourselves and report back. (It can be two pieces of wood screwed loosely together, using a nut and bolt, or you might use a construction kit.) The barrier should be wide enough to let only one person through at a time. The operator could work the switch from under a table. Fix the air muscle to one side of the lever and an elastic band or bands to the other.



When the air muscle fills, it shortens, pulling the lever up.



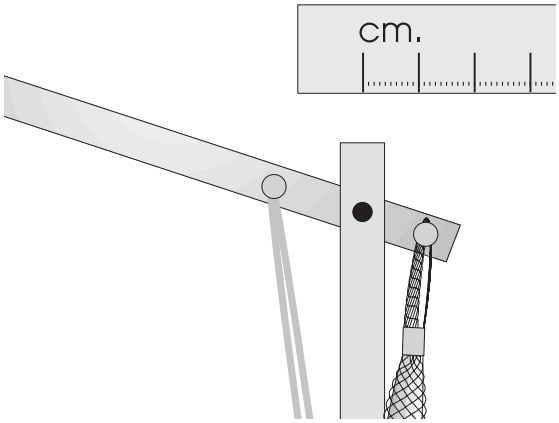
When air is let out, the Muscle lengthens and the elastic bands pull the lever down.



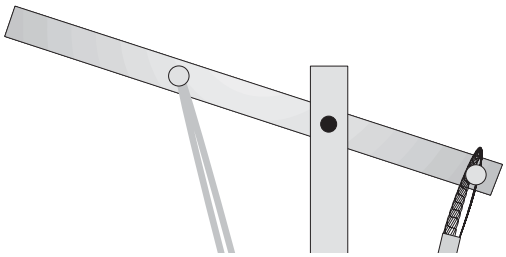
NOTES

1. You need to stretch the empty muscle out so that as it fills with air it can shorten, pulling powerfully.

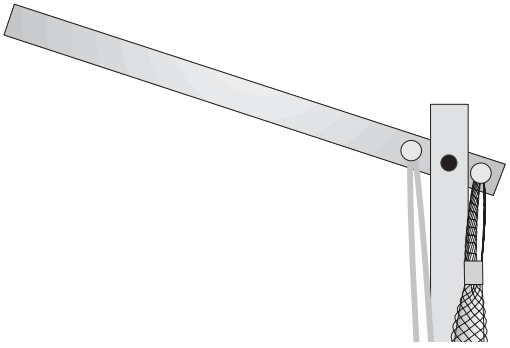
2. Attach the muscle quite close to the pivot point (for example 1 cm). This will give you a good range of movement.



3. For extra power and fine control (but less speed and length of stroke), attach the muscle further away from the pivot point.



4. And of course the opposite is true: attaching the muscle closer to the pivot point gives a longer stroke, faster movement but less power and fine control.



You may decide to modify the barrier design as you build it, such as changing the shape of some components depending on what you have available. Perhaps you think the strength of the barrier could be improved.

You can build a larger and heavier gate if you use some weights to counterbalance the beam. Where would you put the weights for most effect?

SOME THINGS TO CONSIDER...

1) Where do you think the gate could be used?
   How would you modify the design in the light of this?

2) Could you improve the ergonomics? By this we mean how easy it is to use and how comfortable it is. For example, the switch (the three-way air valve) could be made less fiddly.

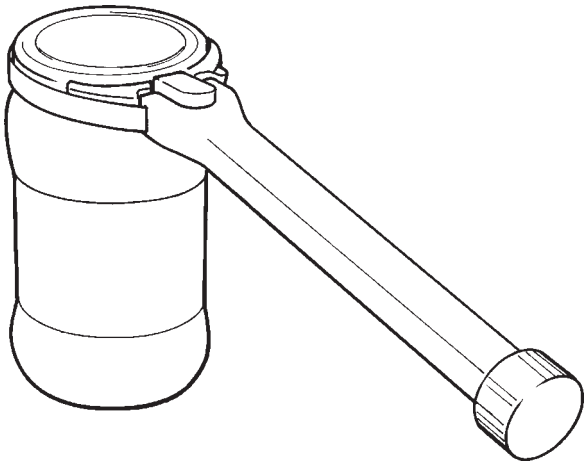
3) What changes would have to be made for cars?

4) Could the barrier be made automatic? If not, why not? What special equipment would be needed, and how would you detect the car or person?

You should answer all of these questions on one side of A4 and submit it to your teacher.

'EASY OPEN' JAR CLAMP

Many chemists sell a device like this to grip the lid of a jar. Old or infirm people can use it to unscrew a lid, if their hands are not strong enough.



But there is a problem...

Dear Sir/Madam

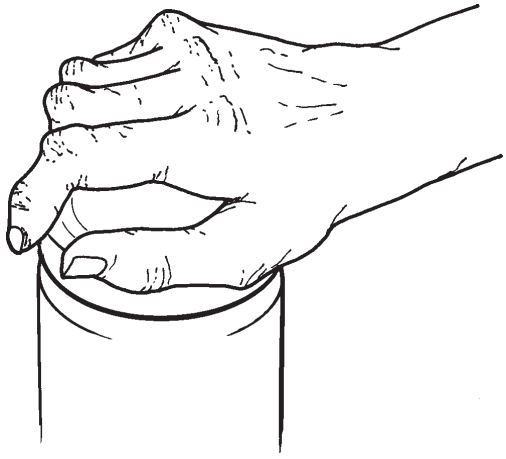
Just yesterday I bought one of your jar openers. You see, I have arthritis and find it very painful to grip things. At the moment I ask a neighbour to loosen all the lids when I buy anything in jars. I hoped that your jar opener would help to make me independent. I have had to return it to you and I was hoping that you would give me back my money (the shop would not take it back as it was not defective). You see, the problem is that I need both hands to grip the opener and so have no way of holding the jar.

Yours sincerely,

Mrs.G.Rashan.

The Managing Director of 'Easy Open' household tools has received the above letter. She has decided to commission some research teams to see if the company can manufacture a cheap clamping device to hold a jar firmly while it is being opened.

Your group is one of those research teams. You have to build a working prototype and then assess your own design for suitability for mass production. Your design brief is as follows...



DESIGN BRIEF

Design an automatic clamp. It has to hold jam jars in place on a table top or kitchen work surface. You are supplied with an example jar opener and do not need to design this.

The following points need to be considered...

(a) The clamp should be as 'hands free' as possible once activated. Both hands should be available to open the jar with the 'Easy open' jar opener.

(b) The device should be able to accept the most common types of jar found in supermarkets.

(c) It should require very little hand strength to set up and attach to the table/worksurface.

(d) It should be easy to use with a simple set of instructions.

(e) It should be cheap.

(f) It should be safe.

DESIGN CONSTRAINTS

(a) As your power source you will be using new air muscle technology. This has been chosen for low cost and safety.

(b) You may use any materials commonly found in the workshop, but bear in mind that the final product will need to be produced cheaply.

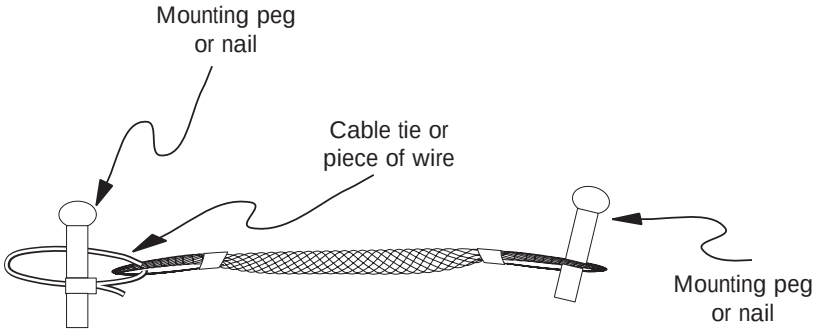
Later you will need to decide which parts to make from metal and which to make from plastic when it is mass produced. It is no good making a large and intricate section from wood if this cannot be made from anything else for mass production.

Other equipment you will need
Besides the air muscle kit and the workshop tools, you will need a jar as an example and a commercial jar opener. In addition, you will need a way of estimating the strength of an old person. One way is to get someone to pull on a forcemeter or spring.

Alternatively, you could get them to press on different sizes of bulldog clip to see which ones they could press. Does anyone in your group know an old person who could help?

WAYS TO CONNECT THE AIR MUSCLE

The air muscle can be connected to any kind of peg or spindle. The peg could simply be a nail or bolt screwed into the surface. Instead of connecting the air muscle directly, it can be attached with a nylon cable tie, (ideally a releaseable one like those supplied with the air muscle), or a length of wire, chain, string, adhesive tape, etc. This allows fine adjustment if the muscle is too slack. The muscle will contract about 25% if it is at full stretch to start with. It needs to be pulled out straight when empty.



Other sources of air (or inert gas) that you can use to operate air muscles include the pump-up type of garden spray (left), and the aerosol cans which are used to power airbrush kits, or blow dust off photographic negatives (on the right). With some pumps, you may need to add a non-return valve. And, of course, any type of compressor can be used.

SOME POINTERS AND TWO POSSIBLE DEVICES

The two key points are how the jar is gripped and how the gripper itself is held or attached to the table.

1) How the gripper is held or attached to the table...

(a) The clamp could have a handle that is held in one hand. An arthritic person would need to use a lot of leverage, so perhaps a long handle may be necessary. You will have to experiment.

(b) The clamp could be attached to the table using a G-cramp or some kind of screw attachment. But if the user is too weak to grip the jar, he or she will probably be too weak to tighten up the G-cramp. One idea is to have a large knob on the G-cramp - in fact the same size as a jar. That way the jar opener can be used to fix the clamp to the table.

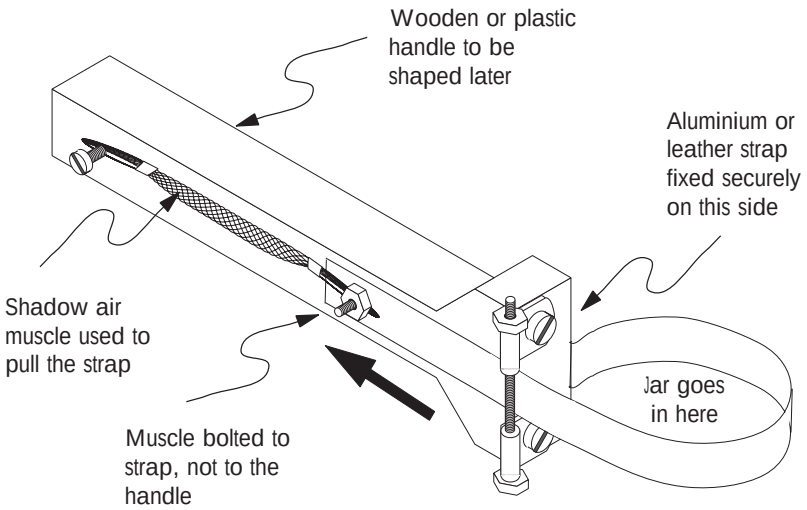
(c) An air muscle could operate a mechanism to grip the table at the same time that the jar-holding muscle is filled. You will need either two muscle kits or a tee piece fitted to the air line so that you can fill both the muscles at once. The forces needed to grip a table are very large, so the muscle will need a great deal of leverage.

(d) The device could simply be screwed down to the table. This might require a neighbour or relative, but would be secure once fitted.

(e) If the device is mounted on a solid board, perhaps the weight of the users arms will be enough to keep it steady?

2) Gripping the jar

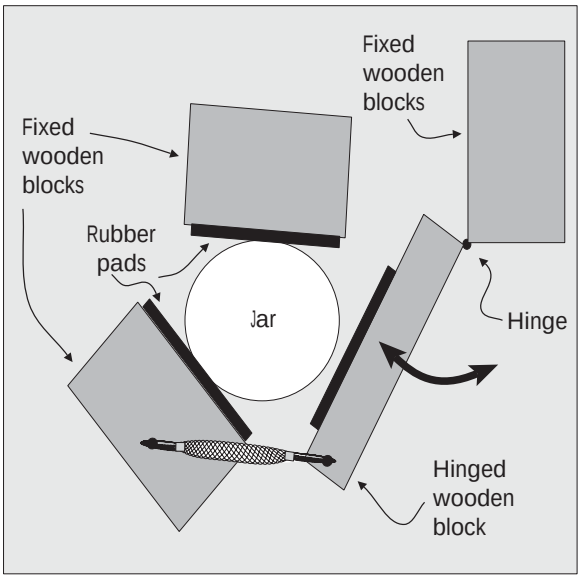
This device is hand held and works by tightening a metal or leather belt around the jar. If this device is to work with different sizes of jar, some kind of adjustment will be needed. For example, several screws could be added for the rear attachment of the muscle. For a different size of jar, the muscle would be unhooked and attached to a different screw.



Note: If a metal strap is used, it should be lined with rubber or similar material for grip

2) Gripping the jar - another suggestion

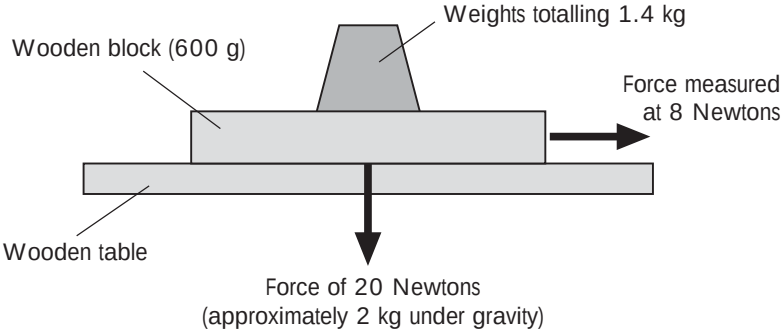
This device is a table mounted clamp that uses the muscle to force the jar into a wedge. The hinge is a simple door hinge and the rest of the pieces are wooden blocks. The blocks have had rubber pads attached for a secure grip. The whole device is screwed down onto a solid baseboard.



NOTES ON FRICTION

Designing your clamp will involve getting the greatest possible force gripping the jar with the highest coefficient of friction. No surface is completely flat. There are small bumps and ridges that will be worn away if two surfaces are rubbed together. As the surfaces pass over each other, these bumps will collide (and break off) and will be felt as a resistance called friction.

That is why your shoes grip, but this is also how they manage to gradually wear down. The friction between two surfaces depends on the strength of the force pushing them together and the properties of the materials. Rubber, for example, is soft enough to squeeze into the crevices and gaps and can easily get stuck in another material and so grips strongly. Stone starts very rough, but will gradually smooth off with wear and so becomes more slippery.



These two pieces of wood were held together by resting a weight on top. One was dragged along and the force was measured... Gravity pulls down a 2kg mass with a force of about 20 Newtons. When we drag the block, we need a force of about 8 Newtons. This is two fifths of the pressing force transmitted as friction. We say that for these two surfaces, the coefficient of friction is 0.4 (two fifths).

EVALUATING THE CLAMP

When your group has finished designing, making and testing your jar clamp, you have to assess it and submit a formal report. You should answer the following questions in your report...

(i) Did the device require any hand strength?

(ii) Was the device easy to set up?

(iii) Was the device secure and strong?

(iv) Would it be easy to manufacture? What redesign would be necessary?

(v) If your clamp did not work very well, what was the main problem? Should the air muscle technology be pursued, or is it inappropriate here?

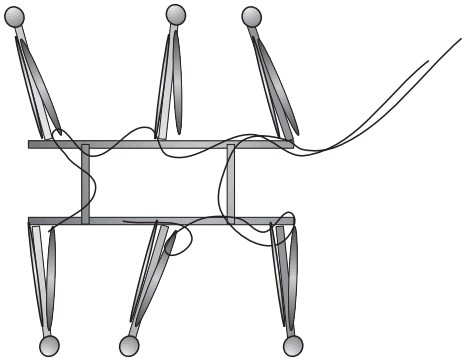
Your report should include a drawing of your device. If possible you should trial the clamp under realistic conditions eg, a kitchen.

Note that the eventual product is unlikely to be powered by a footpump, but is more likely to use a small CO_2 cylinder or an aerosol which can be replaced periodically.

WHY USE SHADOW AIR MUSCLES?

If you have ever wanted to build something that moves on its own, but found it too difficult to connect and control electric motors, servos or cylinders, then the SHADOW air muscle may offer an easier solution. This revolutionary device makes it much easier to obtain controlled movement. It was developed as part of the Shadow Robot Project - a long-term project to build a human-shaped domestic robot. This project, undertaken by a group of about a dozen enthusiasts, has already taken 10 years and will take many, many more. The group has built or is working on a variety of robots, some of which have been shown on television programmes such as the BBC's Tomorrow's World.

Their eventual aim is to build a robot that is able to carry out useful tasks in the home, at a price ordinary people can afford: first very simple tasks then, over the years and decades, more and more complex ones. Laying and clearing the table is one of the easy ones. Doing the ironing is, sadly, one of the most difficult. In the meantime, however, a number of more immediately useful inventions are being generated. One of these is the Shadow air muscle. It is much easier to attach and control than an electric motor, and for robotics its similarity to the human muscle has many advantages. The force the air muscle exerts, the amount it shortens, its speed and fineness of control are almost exactly the same as for a human muscle (but in each case the human muscle just has the edge!)



This six legged walking machine was built by a 15-year old with no previous experience and made to walk using the SHADOW air muscle control kit and drag-and-drop icons software.

This makes it an ideal actuator for the sort of movements that humans and animals make - reciprocal movements. (Electric motors, with their rotary motion, are ideal for buggies and cars, but in nature almost nothing rotates.) They are lightweight, so it is often possible to position them exactly where needed, with no counter-balancing needed. They soft and compliant. If your device crashes into the wall it is much less likely to wreck itself than, for example, one using motors and gears.

So if you want to make something that walks, hops or swims, or does something for us, perhaps open a door or ventilator, or an aid for the disabled, or experiment with Robotics, Animatronics or Virtual Reality, without being a technical genius, an air muscle may be the best kind of actuator to use.

IDEAS FOR OTHER PROJECTS

In Biology
Because air muscles correspond closely to the muscles in their own bodies (as already noted, they have broadly similar capabilities in terms of power, speed, fine control and length of stroke), they provoke students to think about the mechanics of their own bodies.

You might ask them 'How powerful is your little finger?' Then ask them to build a mechanical 'finger' using the air muscle. Ask the same questions as for the human digit, and compare the answers.

Air muscles really come into their own when they are under computer control. The following suggestions for projects are mainly intended for use with the Shadow Control Kit, which allows students to control muscles and make them respond to sensors, using an extremely simple graphical program - you just drag a few icons onto a line.

However, much of the construction work can be done without the computer. Students can install and adjust the muscles, experiment with different attachment points and leverages. They can fill and empty the muscles manually, using the low-tech Sample Pack or Class Pack, perhaps while other students use the computer to develop their control programs.

Dancers!
If you have a sound digitiser, why not make a puppet (or a whole chorus line) which dances in time to the music? Basically, you have the muscles fill when the sound level is high, and empty when it is low. A floppy, dangling puppet, as big as you like, is twitched by a muscle or two. For rapid response, it is better to have the controller board quite close to the puppet(s), and use short lengths of tube.

Of course you could do much the same thing using light levels as the trigger, provided that you have disco-lights flashing in time to the music...

A voice-controlled robot arm...
... is really just a variation of the previous project, and depends on the availability of software to recognise either words or at least noise levels. But if you can solve that problem, building a simple robot arm, with a muscle that fills when you say 'up' and empties when you say 'down', is relatively easy, and might form the core of a system which would be of use to disabled people.

Aids for the disabled
With eight analogue inputs and four air valves, the Shadow air muscle controller board is powerful enough to be used for a variety of aids for the handicapped, which students might devise. Micro-switches, reed switches, light-dependant resistors or a reflective opto sensor (all supplied), can be used to allow users to control the gadget according to their disabilities. Such projects might include a page turner (for a book), door opener, seat adjuster, or even (with great care!) drink delivery system. Of course, safety and caution are paramount here, and fail-safe operation is vital.

Air control can be used, not just for air muscles, but to change the inflation of an inflated rubber cushion, ring or mattress periodically. Or to summon help, by blowing a small airhorn!

Aids for the able-bodied
Production of an earlier version of the Shadow air muscle involved drilling several long, fine holes in perspex. To avoid overheating, the drill bit needed to be pulled out and brushed or blown clean, quite frequently - several dozen times just for one hole. Our solution was to couple a pair of air muscles to the drill press in such a way as to be able to pull the drill into the work. A spring ensured the return movement, and a jet of air (also controlled by the Shadow air muscle system) blew the drill bit clean each time it was pulled out, as well as helping to keep it from overheating.

Automatic rising barrier
As an extension to the project on page 6, build a fully automatic rising barrier.

Set up a light dependant resistor so that someone approaching the bar blocks off light from, say, a window. The computer is set up so that when the signal drops below a certain threshold, the bar is raised.

Other ideas

Nutcracker	*Automatic pliers*	*Scarecrow*
Ball kicker or thrower	*Snooker*	*Door lock*
Force-feedback joystick		

Footpump controlled vice (no reservoir)
Cat dish (to feed cat at pre-set time)
Cat flap (to allow entry to one's own cat only)

Robotics
Take part in the World Robot Games planned to take place in Glasgow in August 1995. For more details contact the Shadow Robot project...