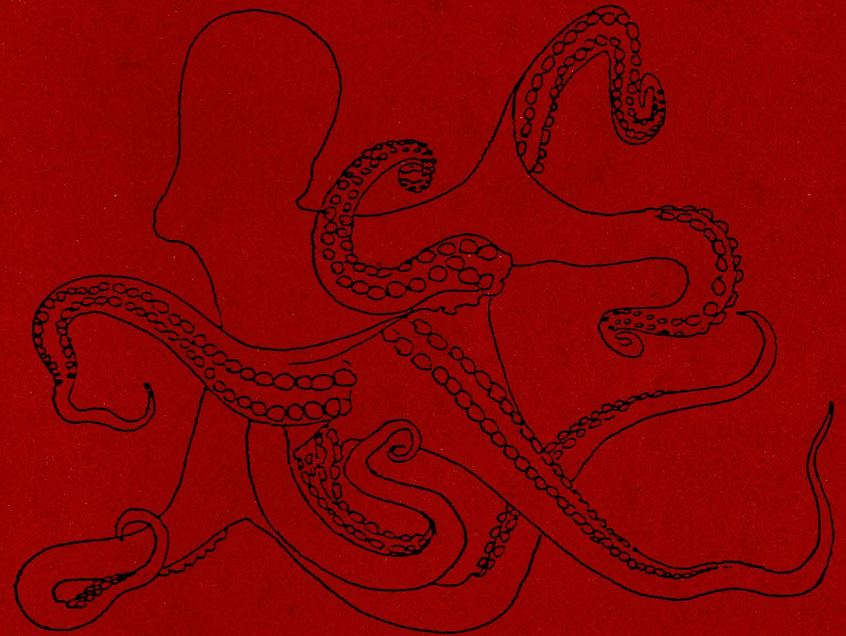


Study and Simulation of Robotic Finger Movements



SPECIAL PROJECT

K.Puhazhendi

Study and Simulation of Robotic Finger Movements

K.Puhazhendi

Submitted in partial fulfilment of the requirements for the
Post-graduate degree in Industrial Design

Guide Prof A.G.Rao

INDUSTRIAL DESIGN CENTRE,
I.I.T.,POWAI,BOMBAY-400 076
APRIL, 1989

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APPROVAL SHEET

This special project entitled "Study and Simulation of Robotic Finger Movements" by K. Puhazhendi is approved in partial fulfillment of the requirements for the Master's degree in Industrial Design.

Signature

Date

GUIDE

K. Puhazhendi

28/4/89.

ACKNOWLEDGEMENT

I express my sincere gratitude to my guide , Prof.A.G.Rao for his invaluable guidance and suggestions which have made this projects possible.

I thank all my friends,colleagues and staff of the IDC for their kind help.

April.7,1989

(K. PULAZHENDI)

IIT Powai,

BOMBAY.

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ROBOTIC GRIPPER

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INTRODUCTION

The Robotic finger is an end effector which is called as Grippers. The gripper is the device mounted at the distal end of a robot arm, enabling it to pick up workpieces and hold, manipulate, transfer, place and release them accurately in a discrete position. Thus the gripper is all important mechanical interface between robot and environment without which, in many circumstances, the robot can not function effectively irrespective of the degree of sophistication it may otherwise possess.

The project consists of two parts namely, a study of existing gripping mechanisms and study of Biological gripping mechanisms. The aim of the work is to provide the designer with a data base of various gripping mechanisms and their related biological mechanisms so as to provide a framework in which the designer can link the two approaches to solve specific gripping problems. This is done by giving a rough classification based on various parameters like type of

mechanism, scope of utility etc. of available gripping mechanisms and certain biological grippers. A study of their functioning is provided to enable the designer to grasp the fundamentals and also to evolve his own classification methodology fitting to his applications.

STUDY AND CLASSIFICATION OF ROBOTIC GRIPPER

The grippers can be classified in many ways but the broad classification can be done by considering its mechanisms and functions and the types of objects in grips.

Based on gripping activity, it is classified in to three categories:

1. Unilateral gripper,
2. Bilateral gripper,
3. Multilateral gripper.

1. UNILATERAL GRIPPER

The gripper of this category has only one surface which comes into contact with the object to be handled.

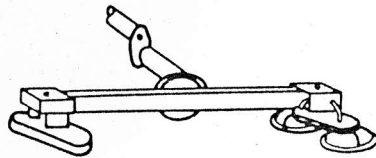
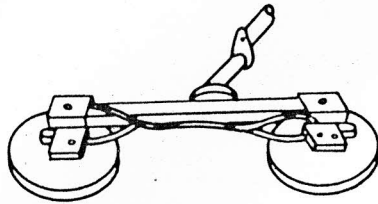
TYPES

1.1 Vacuum clamping/pad gripper

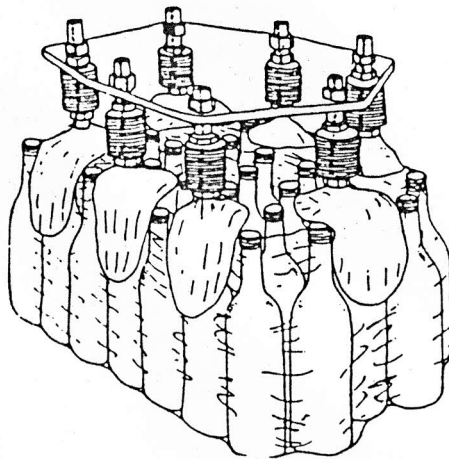
Vacuum clamping is the application of negative pressure to components so they 'adhere' to the gripper.

1.2 Pressure pad gripper

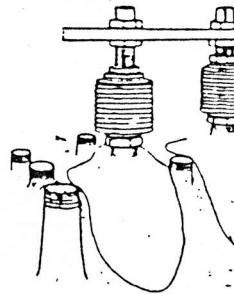
These are used for handling products unsuited to vacuum pads (eg. card board, wood, etc.). Since the depression in

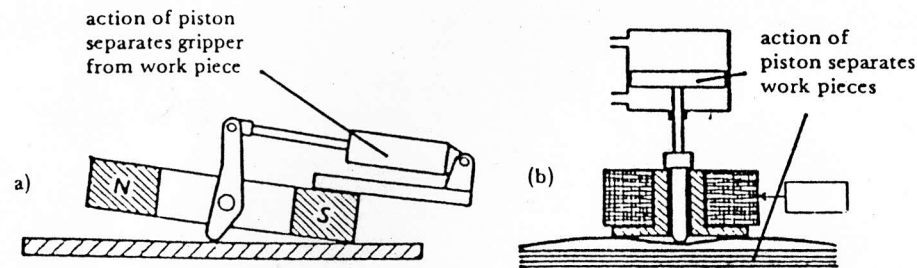


Vacuum pad



Pads used for non-flat objects



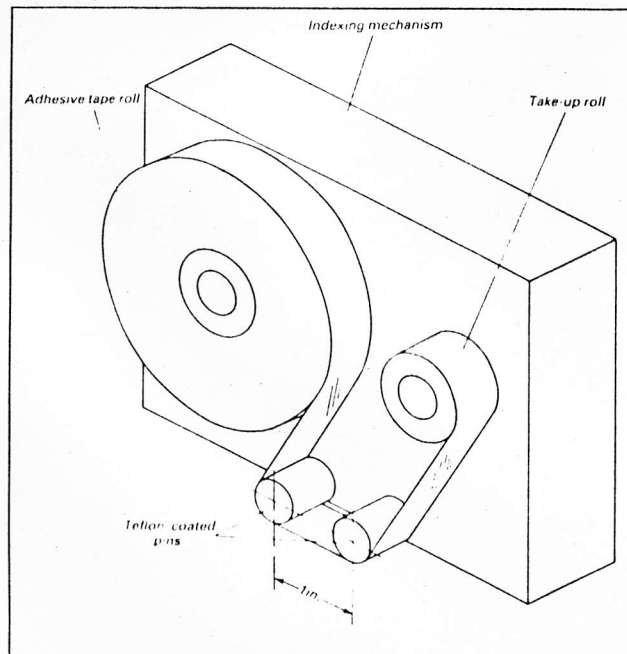


Magnetic pads: (a) permanent magnet gripping device with release system; (b) magnetic gripping device combined with a piston preventing more than one object being lifted at a time (thin sheet) (a similar system can be devised for vacuum pad grippers)

the pad is much less than that obtained when using a vacuum, the area of contact must be larger. The response time is significant when the surface is large.

1.3 Magnetic pad gripper

The magnetic pad gripper uses permanent magnets or electromagnets and this method is only valid for magnetic materials.



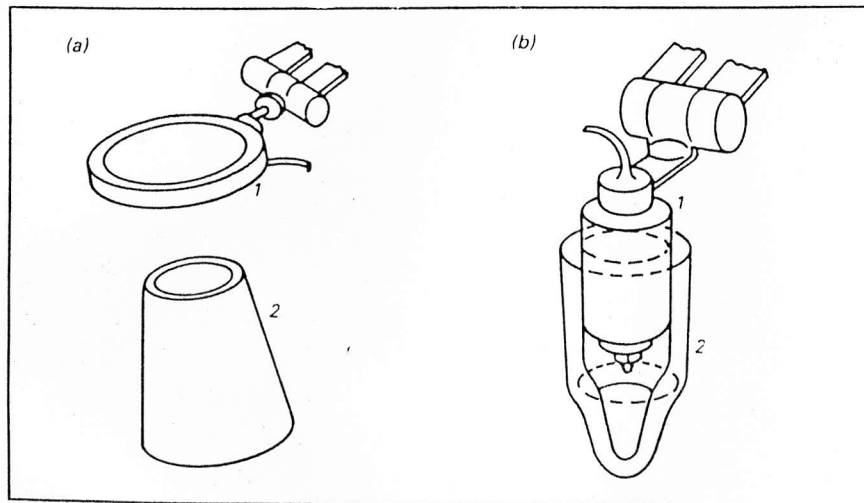
Adhesive gripper

1.4 Adhesive grippers

The grippers make use of sticky tape to pick up and hold the component.

1.5 Expandable ring type gripper

In Fig.a the rubber ring, 1 is expandable so that it will grip the exterior surface of the circular shaped container, 2, tightly. Fig.b shows an expanding elastomer mandrel 1, which fits into the bore of a projectile cone, 2, for a straight vertical lift.



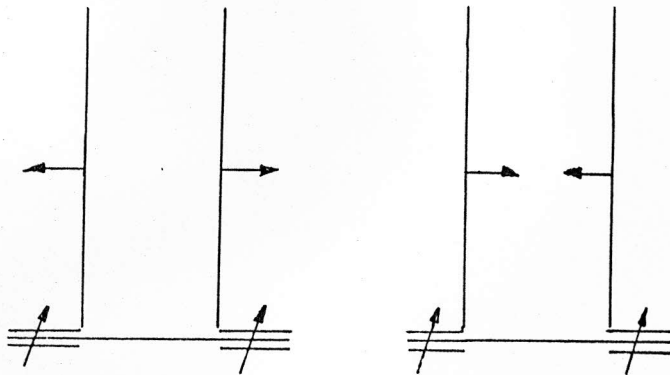
(a) Expandable ring type gripper (b) Expanding mandrel type gripper

2. BILATERAL GRIPPER

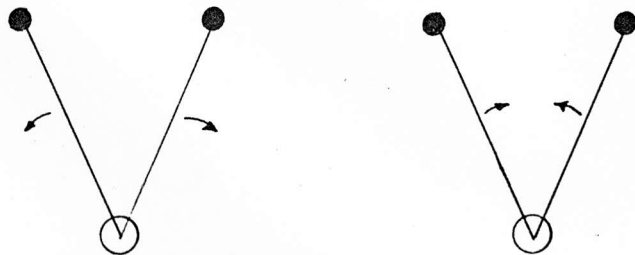
At least two rigid fingers are necessary to grip an object (as opposed to adhering to it). Depending upon the characteristics of the fingers and the object and also on the state of the surfaces (in which dry friction and local deformability is an important factor during operation), contact between the gripper and the object occurs at two points, along two lines or two areas on the surface.

2.1 Symmetrical gripper

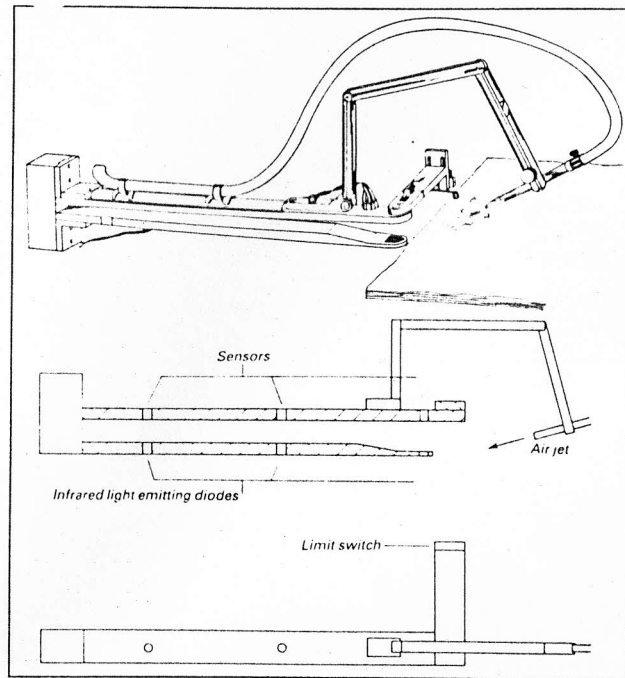
This type of gripper involves symmetrical movement of two fingers (claw, jaw, etc.).



Symmetrical - Transitional

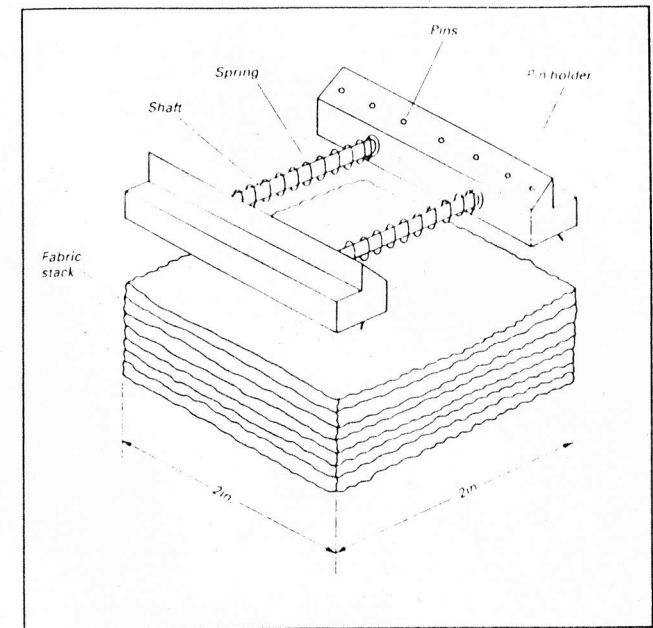


Symmetrical - Rotational



TWO JAW WITH AIR JET

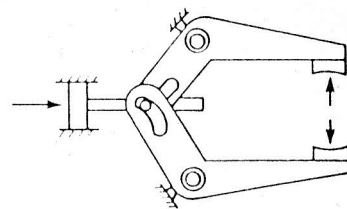
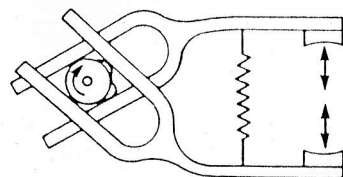
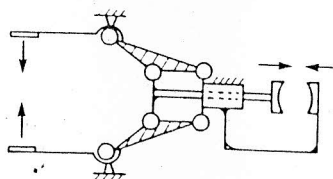
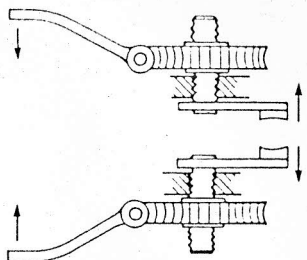
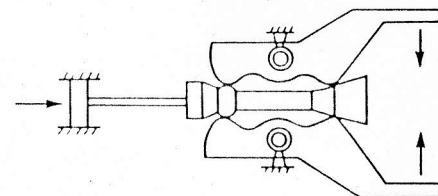
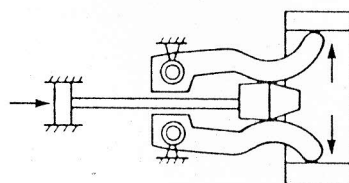
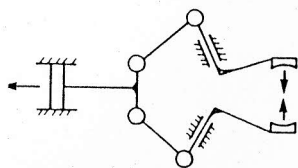
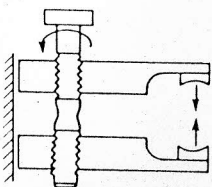
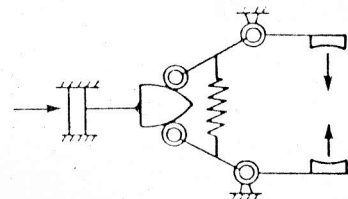
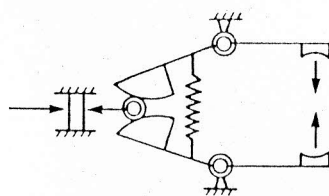
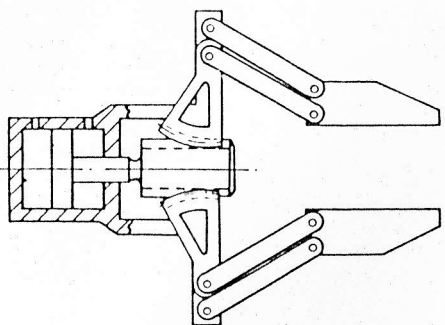
The air jet produces vibrations in the thin top layer fabric material and the tip of the lower jaw of the gripper comes into contact with the vibrating cloth. The robot searches downward so that on continued incremental movement the fabric 'pops' above the lower jaw.

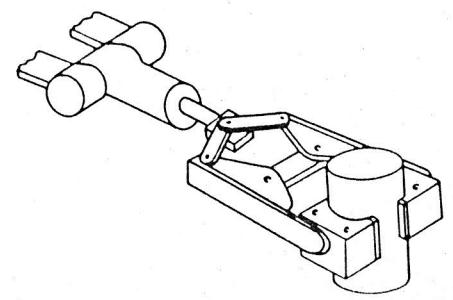
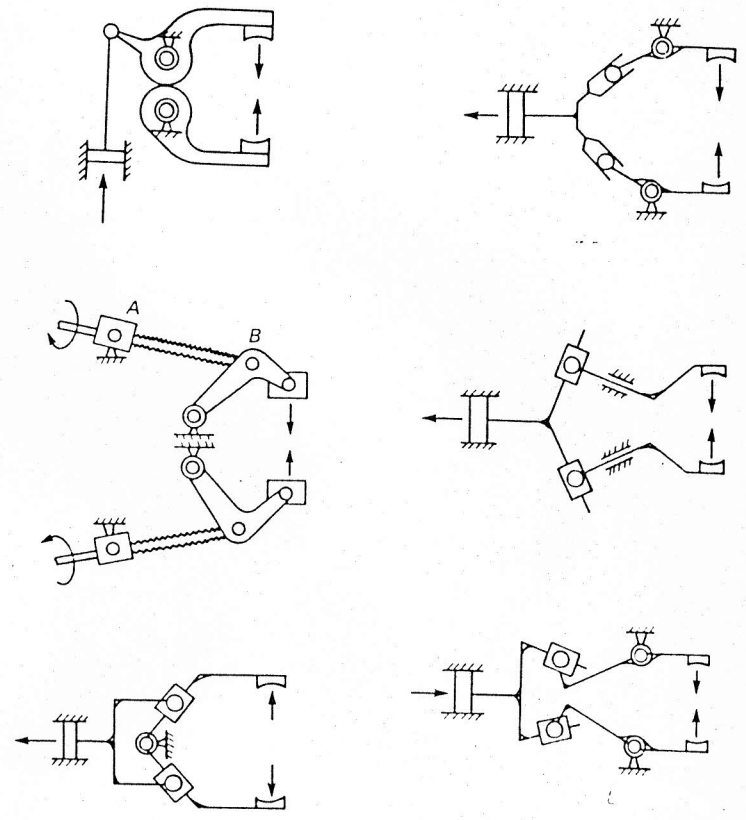
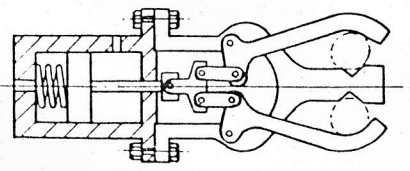
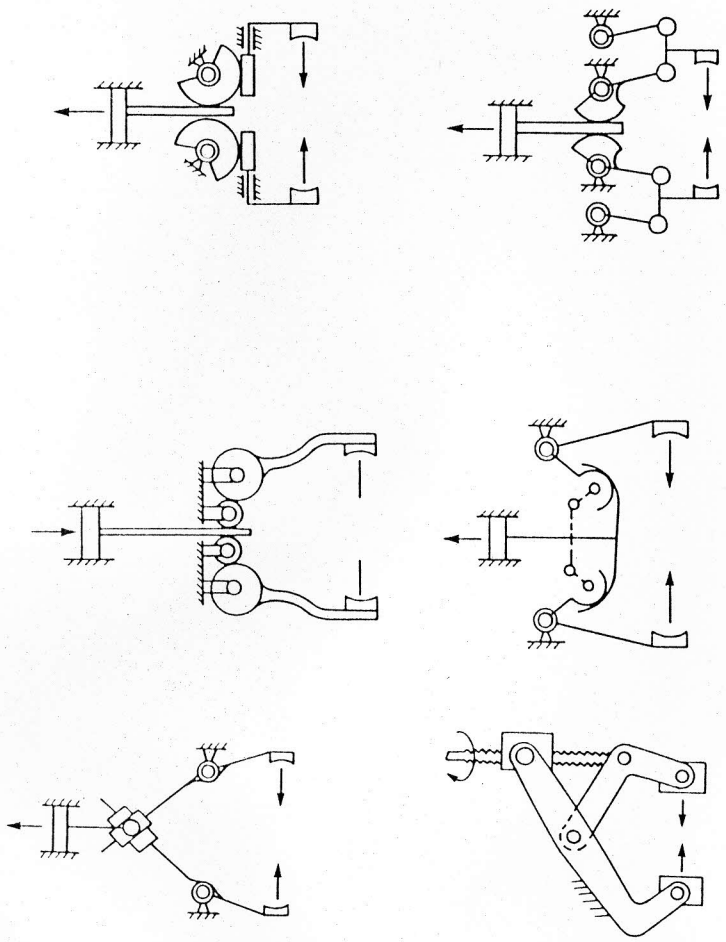


Experimental pin concept device (Note, the shaft was fixed to the left pin holder and was allowed to slide in the right pin holder)

PIN TYPE PARALLEL JAW

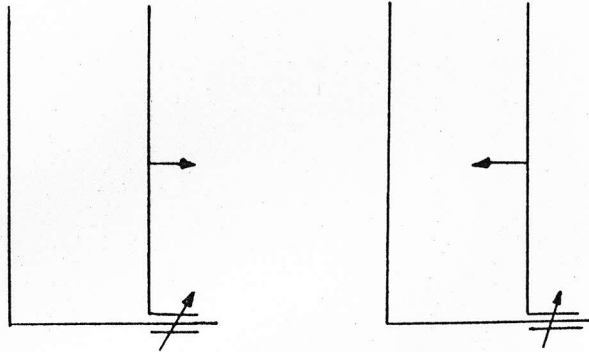
The two pins(jaws) involves inserting the pins through only the top layer of the fabric, then applying tension to the fabric as the pins are allowed to separate the ply.



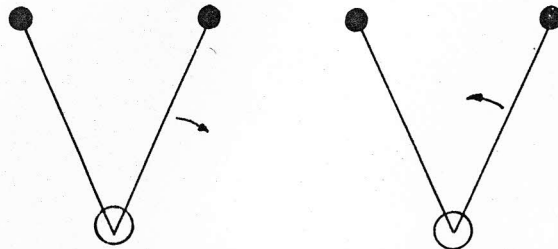


2.2 Asymmetrical gripper

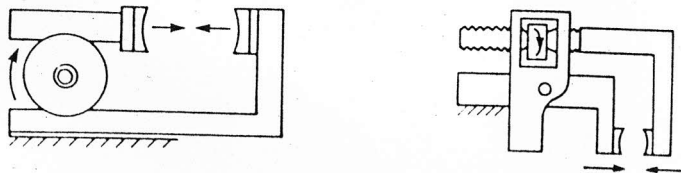
The fingers are having the basic structure as shown in Fig. The shape of the finger depends upon the object: it grasps. These are further classified according to the activating mechanism.

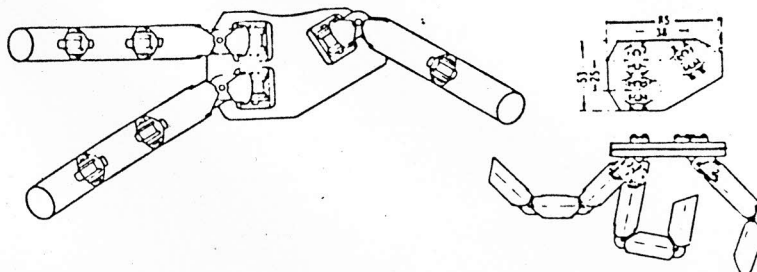
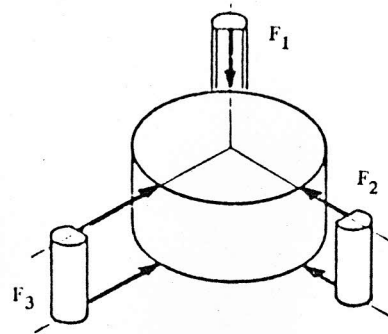
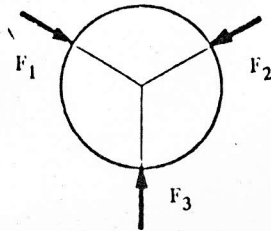
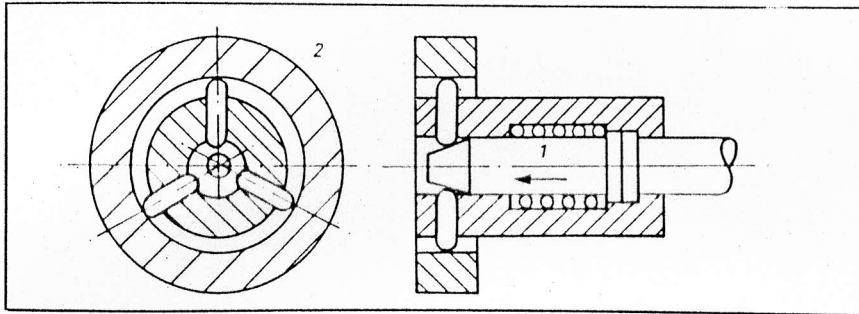


Asymmetrical - Translational



Asymmetrical - Rotational





3 MULTILATERAL GRIPPER

The principle common to all these gripping devices is deformation of the gripper according to the shape of the object so as to increase the areas of contact between the gripper and the object.

3.1 Simple Multilater gripper

3.1.1 Three fingered gripper

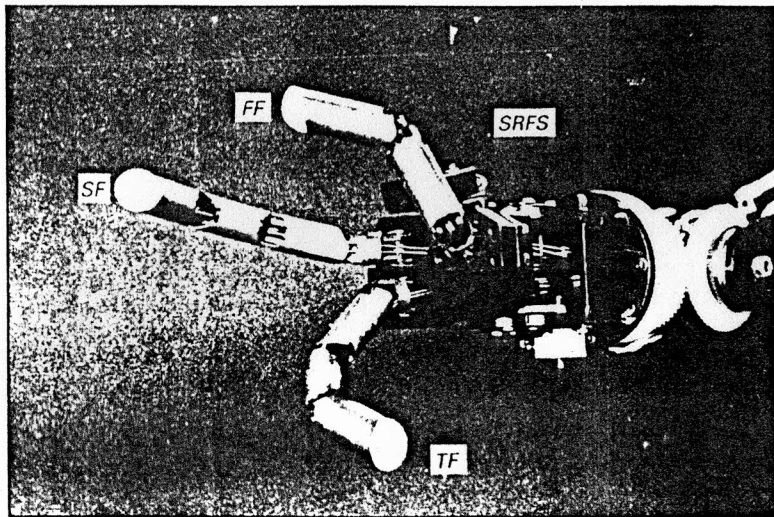
It has three fingers. It holds the object radially inward/outward. The fingers are moving symmetrically/asymmetrically. This is similar type of bilateral gripper with three finger.

3.2 Anthropomorphic Hand Gripper

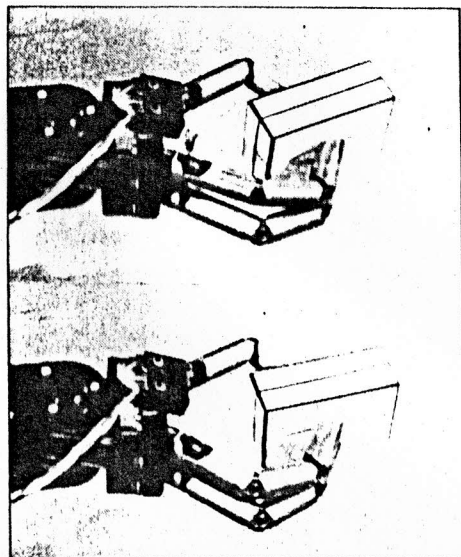
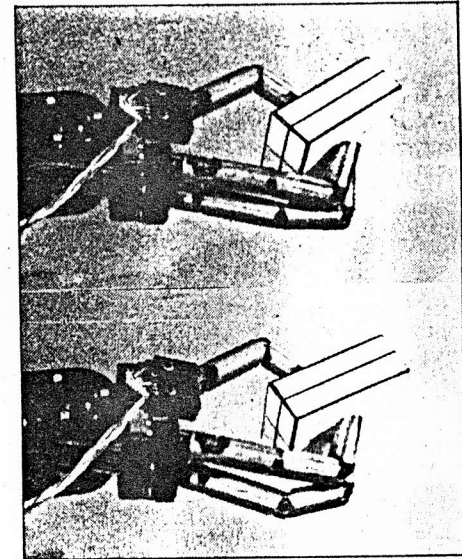
These type of grippers follow the anthropomorphic model as much as possible.

3.2.1 Three fingered gripper

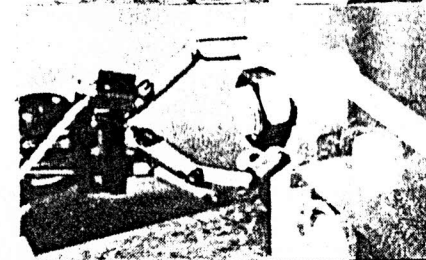
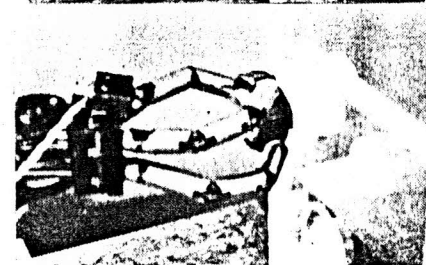
The end effector with three digits (fingers) that is, a thumb and two fingers.



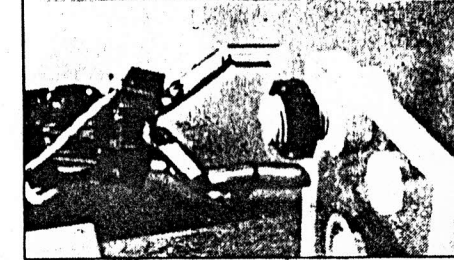
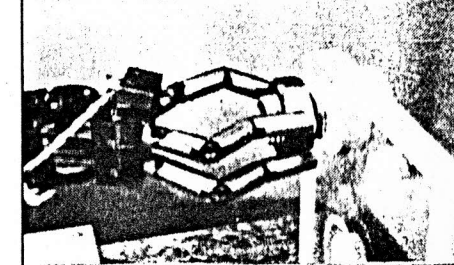
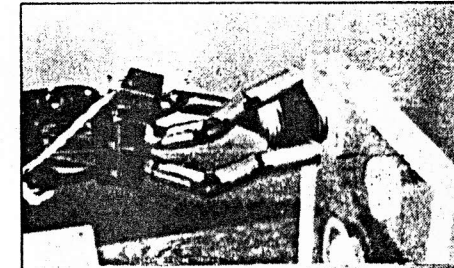
View of finger system

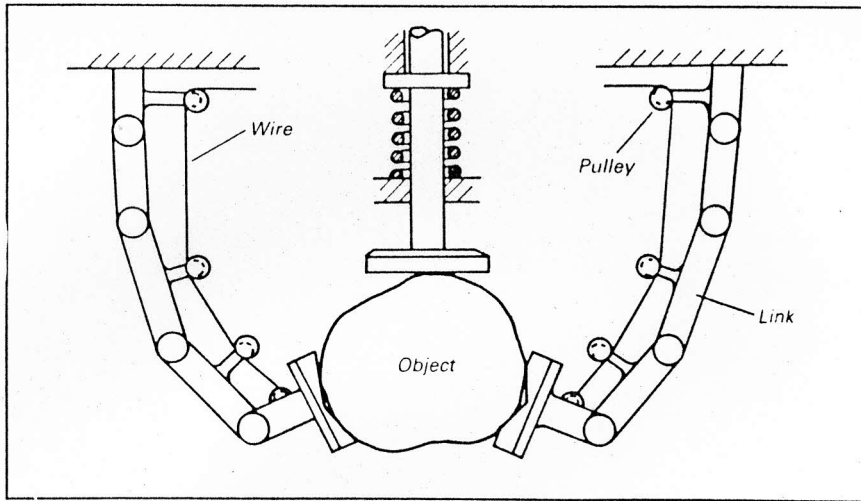


tilting a case to one side



nut-turning



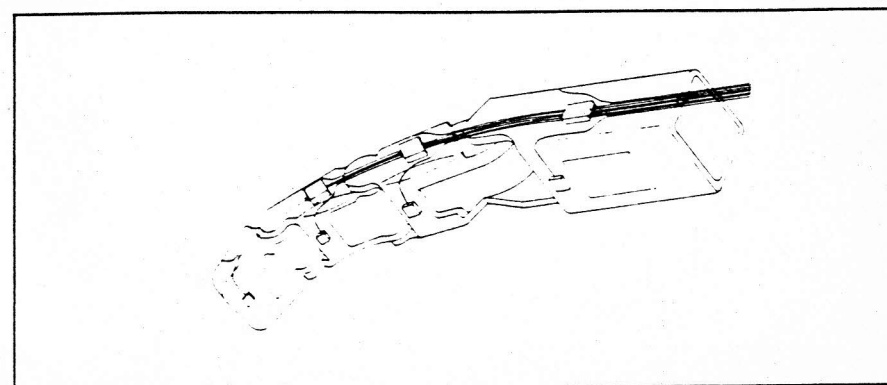
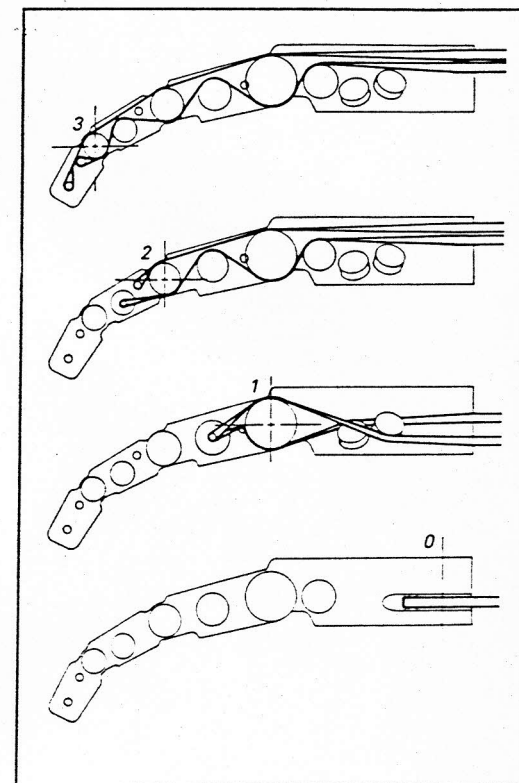
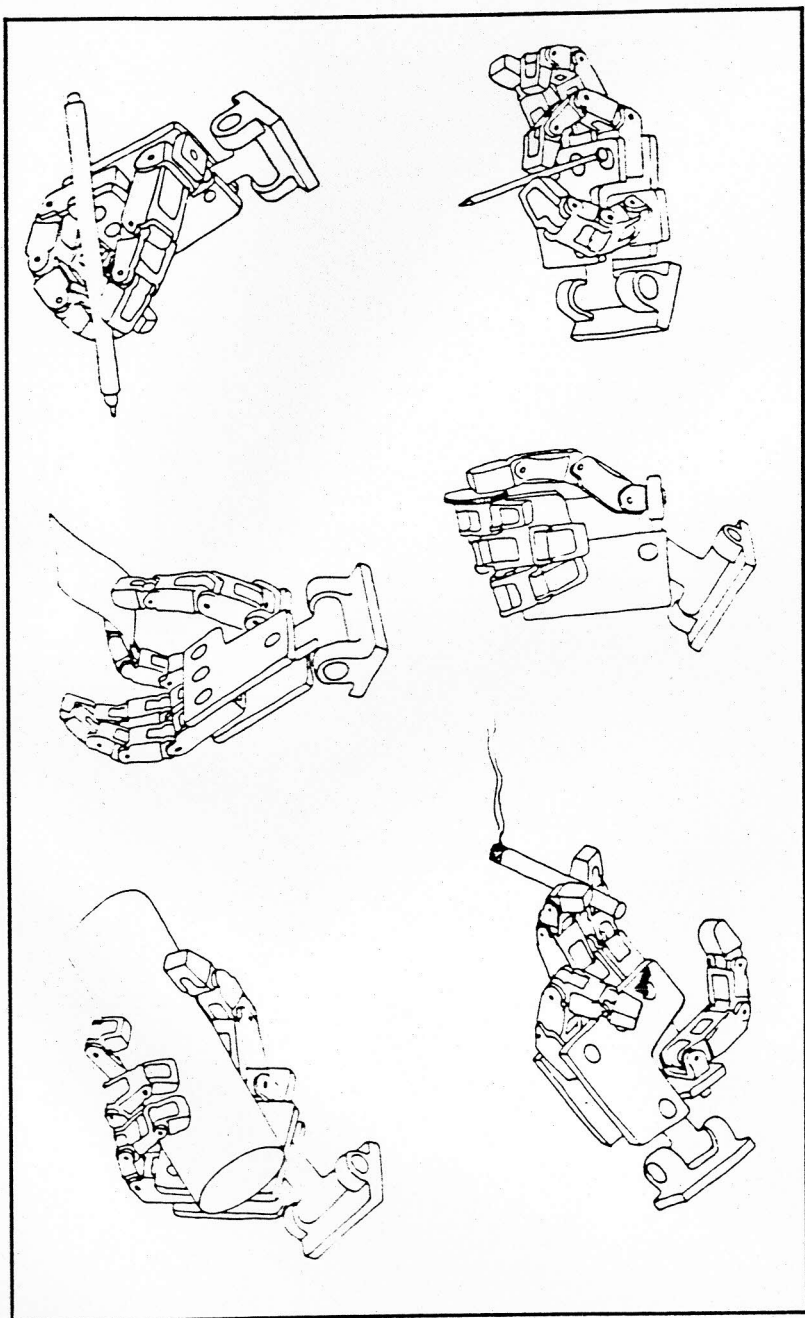


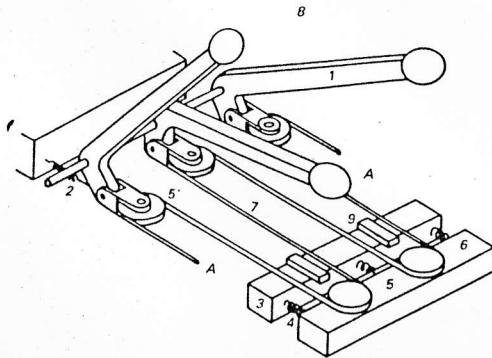
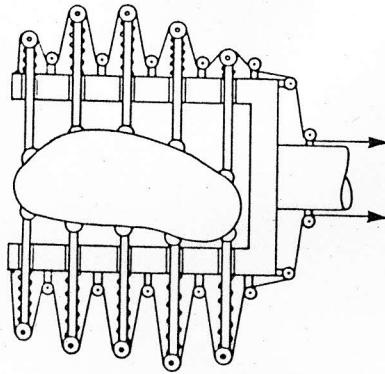
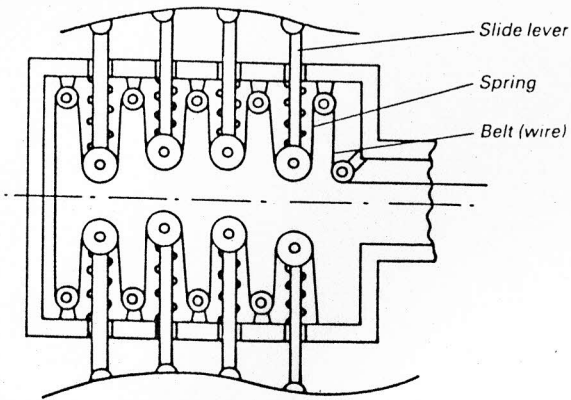
3.2.2 Two finger and a palm type gripper

It has the ability to pick up on object and draw it into a nested grip against the palm.

3.2.3 Four finger gripper

It has four fingers, assembled will be approximately anthropomorphic in geometry.





3.3 CONTOUR ADAPTING GRIPPERS

These type are universal grippers which can hold the object by gripping over the odd shaped profile.

1. Mechanical type gripper

- (i) Solid finger gripper
- (ii) Flexible finger gripper

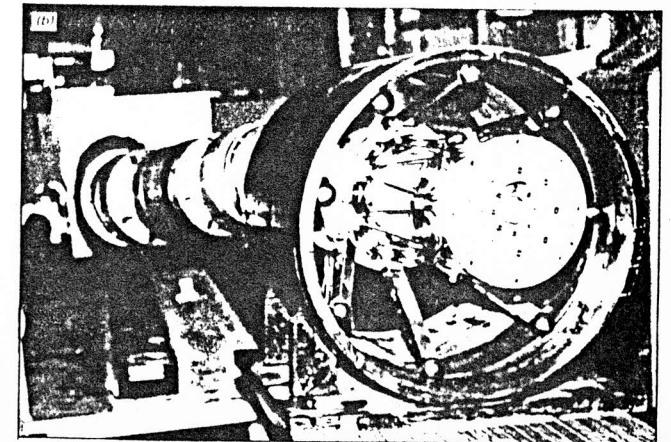
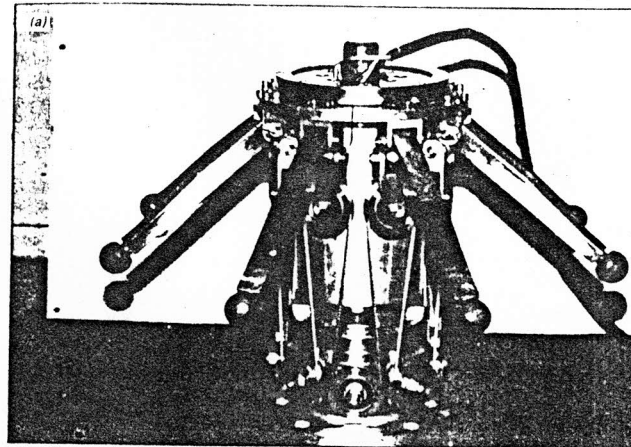
2. Fluid gripper

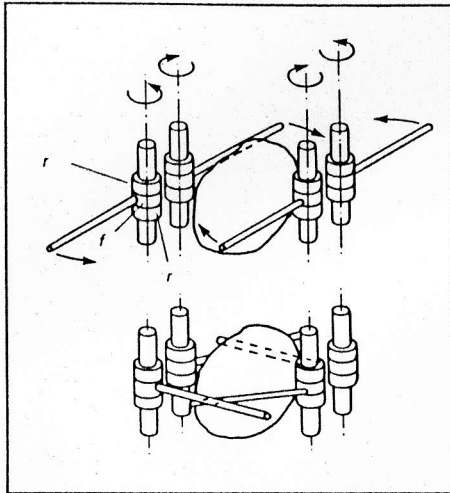
3.3.1 Mechanical type gripper

3.3.1.1 Solid Finger gripper

1. Multiple joint manipulator

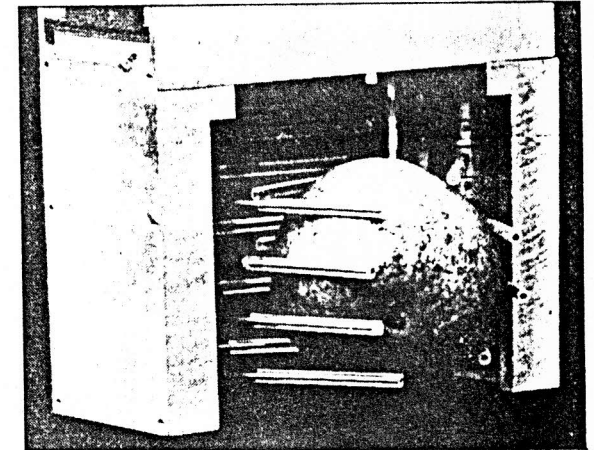
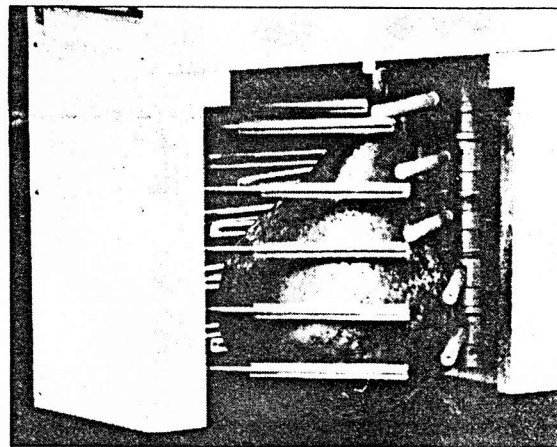
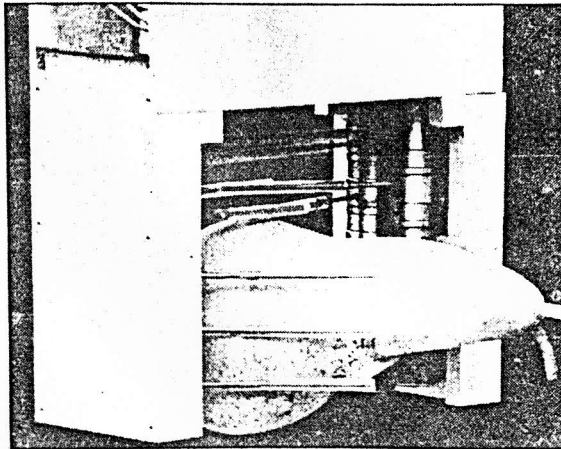
Its principle of motion consists of a mechanism in which levers housed by springs stretch against amorphous runners in uniform tension by hauling a belt.





2. Multifinger gripper

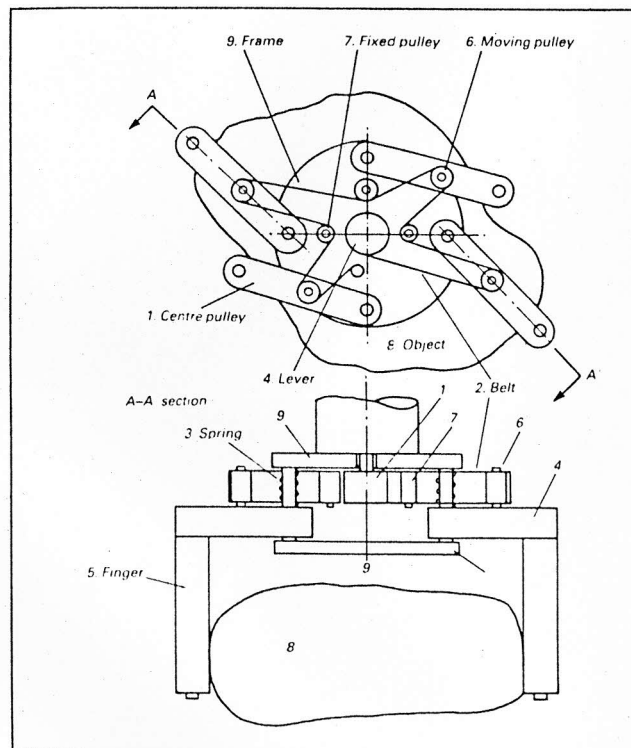
The functioning principle of this gripping system consists in applying redundant number of constraints to the object to be gripped and in the use of constraints that can be adapted to the shape of the object and locked in their final position, enveloping the object as a cage.



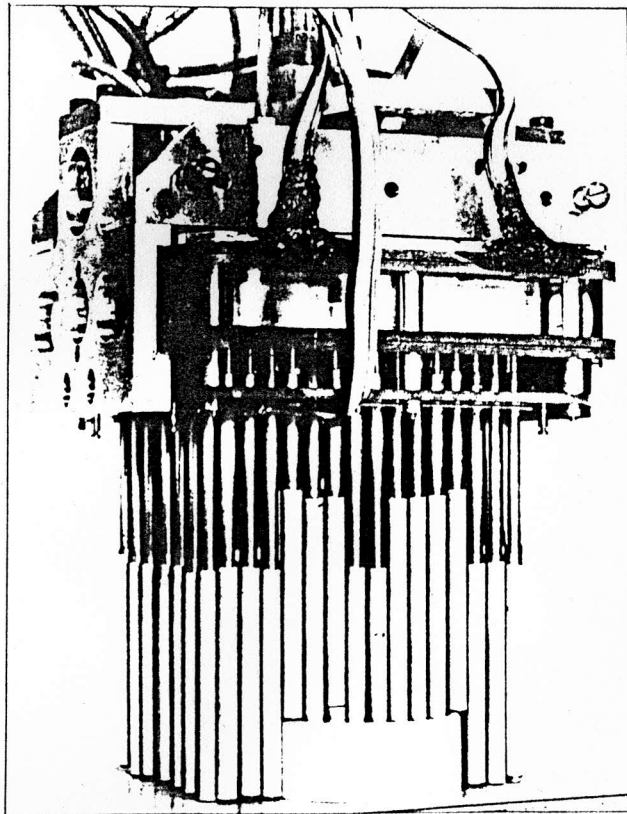
Handling of delicate products

3. Four fingered gripper

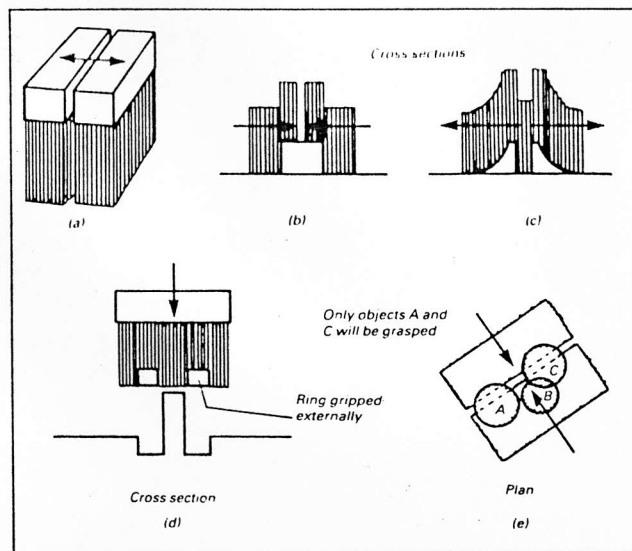
This type of gripper has four fingers to grip the object. The fingers are actuated by rope and pulley method. This fingers make contact on the surface of the object.



Rotary-type four-fingered gripper capable of gripping arbitrary shaped objects with uniform pressure



The Omnigripper



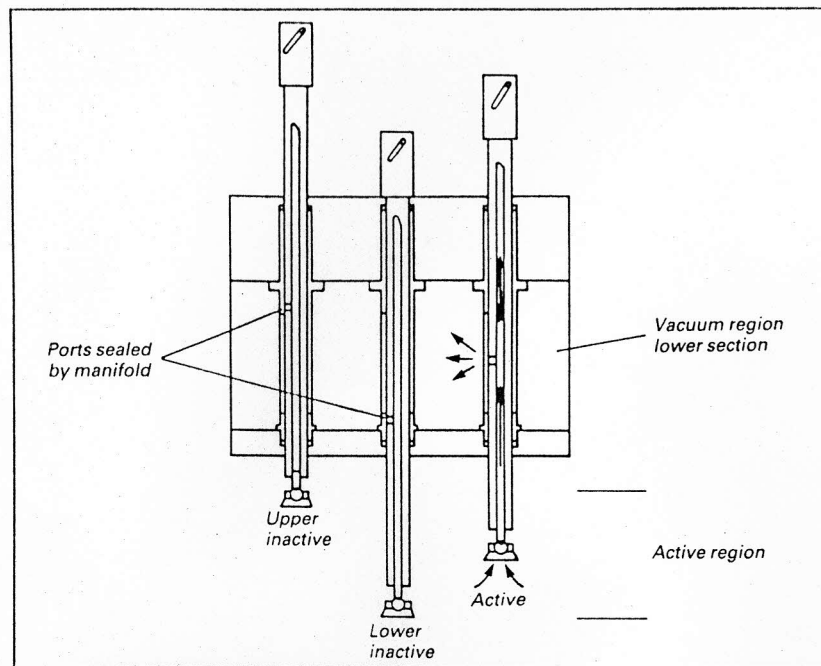
Principle of operation

4. Independent finger with multi joint manipulator

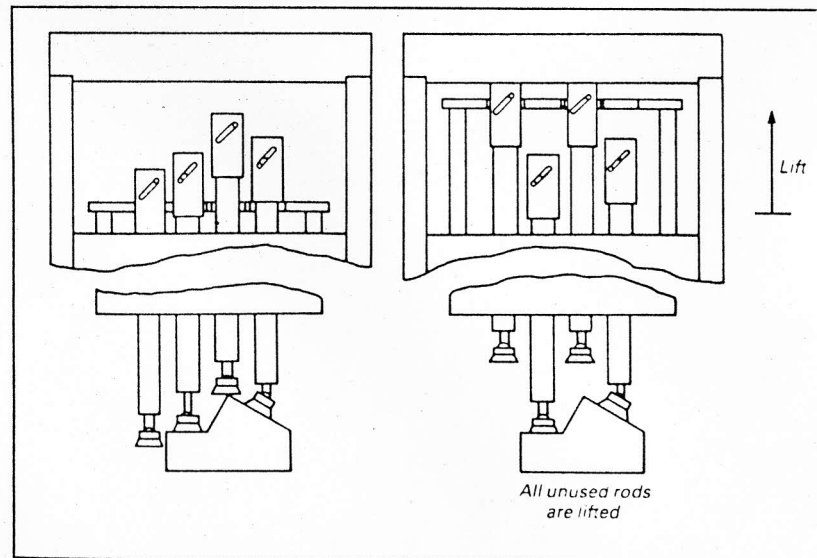
This comprises two parallel slightly separated fingers as in many conventional designs. In this case, however, the fingers each consist of an array of 8x16 closely spaced pins which can ride vertically up and down independently of each other.

A mechanism exists to ensure that all pins can be forced out to the fully extended position. Once all the pins are fully extended, the gripper can be lowered vertically over an object, so pushing some of the pins up out of the way and hence creating 'customised' fingers which fit the upper surfaces of the part.

To grasp objects, the slightly separated ranks of pins can be brought together.



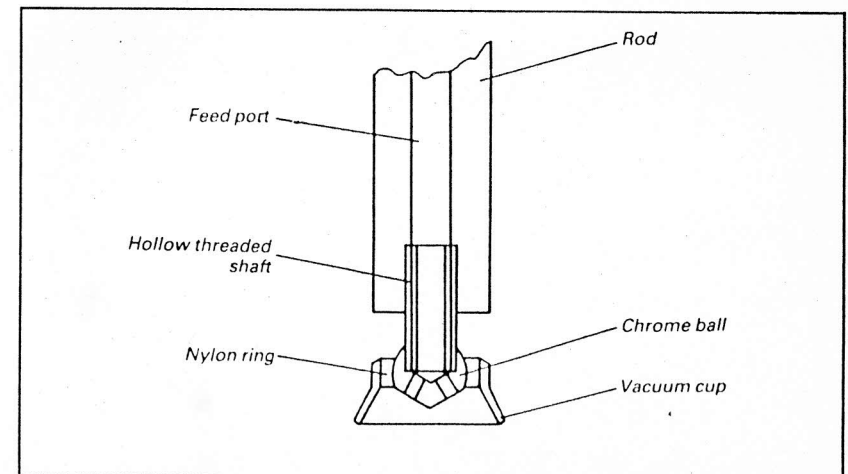
Three states of a rod unit



Rod lifting and grip sensing scheme

5. Surface adapting vacuum cup

To adapt to local variations in surface angle, each unit was equipped with a miniature ball-jointed cup assembly as shown in fig.1. To reduce the effect of shifting which occurred while adapting to a work piece surface, the distance between the joint and cup contact surface was kept to a minimum. The lower portion of the ball which contacts the work piece surface during grasping was machined to a dull point to guarantee a consistent distance between the rod and the contacted work piece surface regardless of work piece surface angle.

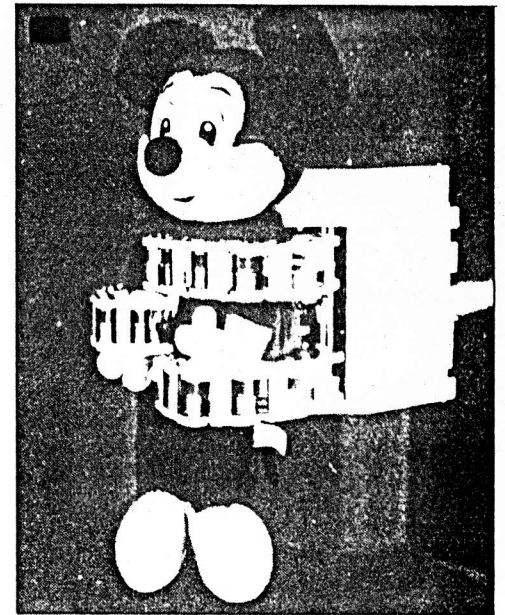
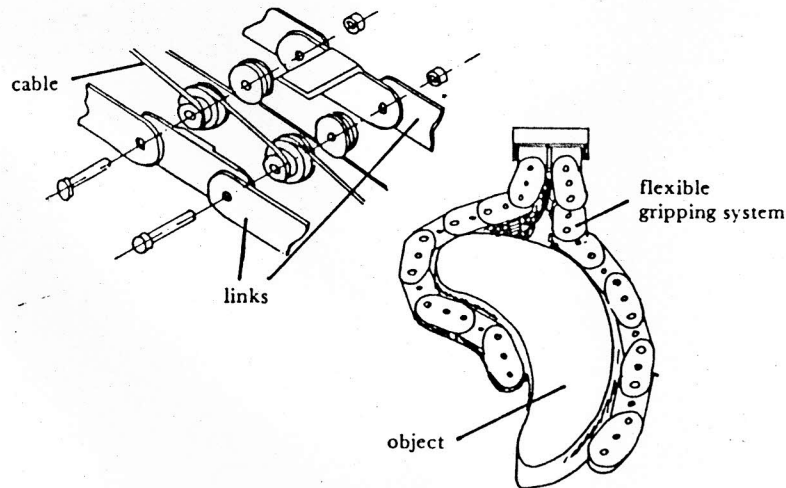
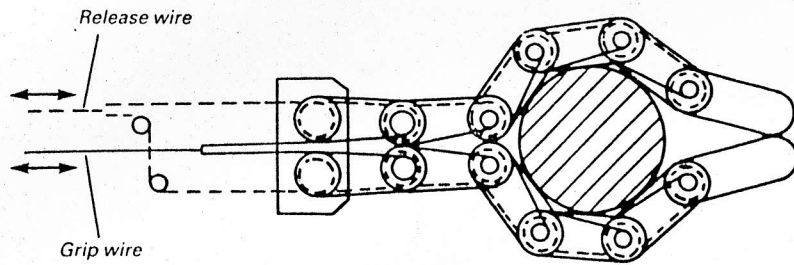


Surface adapting cup assembly

3.3.1.2 Flexible finger gripper

1. Flexible Linkage gripper

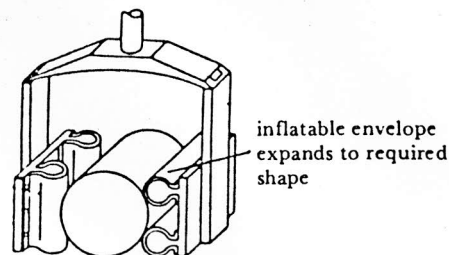
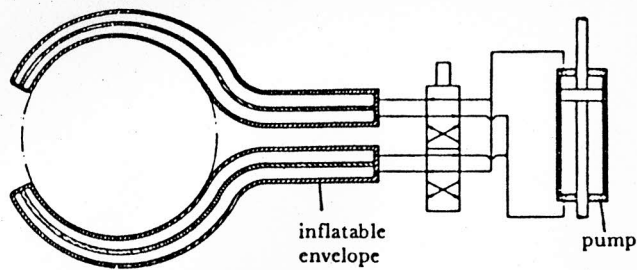
These type multiple linkages which are actuated by rope and pulley arrangement. The basic mechanism of this adapted from snake movement. The links follow the contours of the object and firmly hold it.

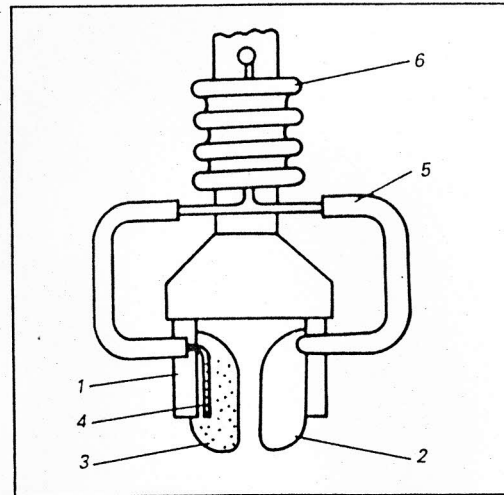


3.3.2 Fluid gripper

1. Inflatable flexible gripper

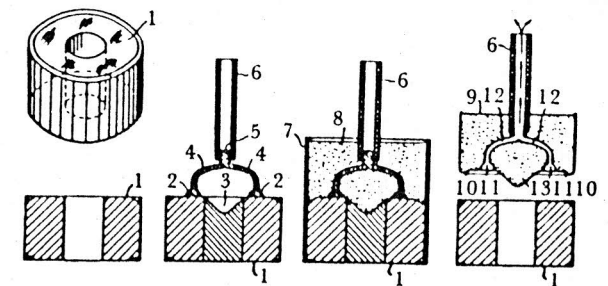
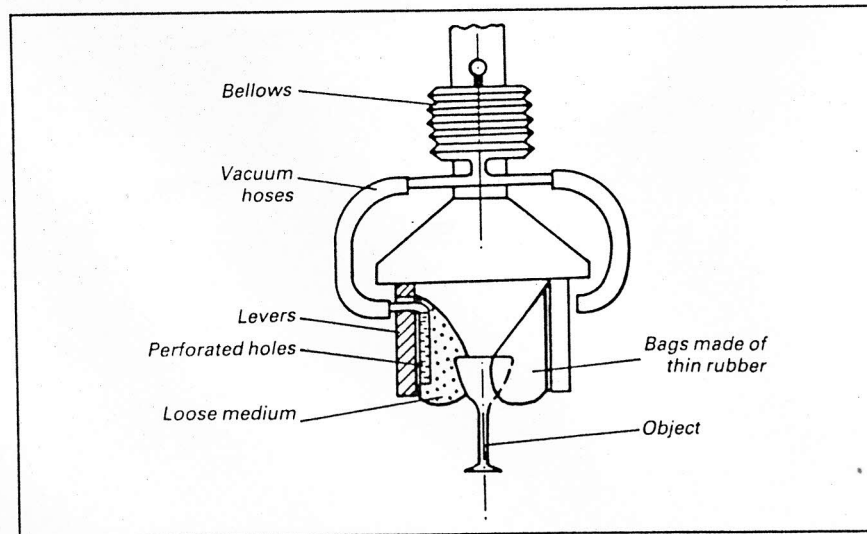
These generally take the form of a flexible but resistant envelope into which fluid is injected under pressure. The flexibility of the envelope means that the object can be grasped due to the elastic deformation of the envelope, which moulds itself to shape. The clamping force proportional to the pressure of the fluid inside the envelope and can be easily controlled according to the fragility of the object.





2. Moulding pad gripper

These type of grippers are having flexible bags contains of free flowing (loose) material that consists of particles of different shapes. These bags will take the shape of the object and the loose materials are tightened by pressure. The tightened particle grips the object.



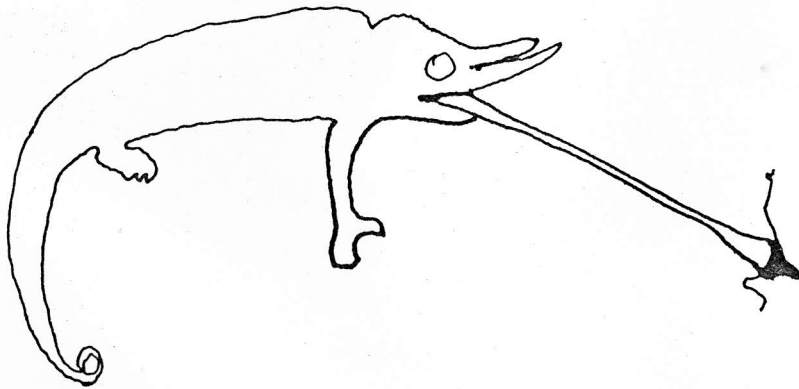
Moulding pads

BIOLOGICAL GRIPPING MECHANISM

1. Unilateral gripper

1.1 Chameleon

A Chameleon's tongue tip is sticky and partly prehensile, giving the insect victim no chance. This is of the adhesive type.

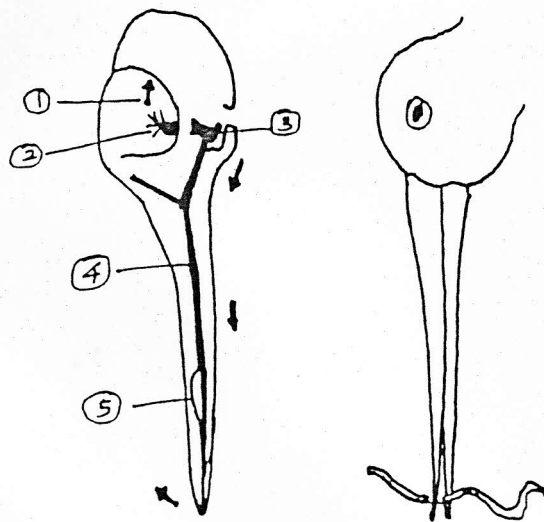


2. Bilateral gripping mechanism

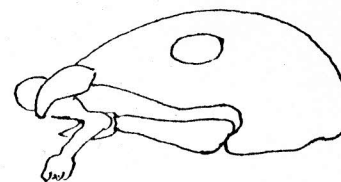
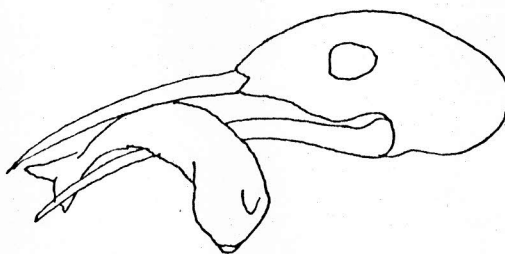
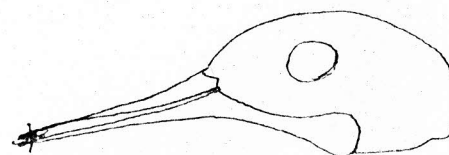
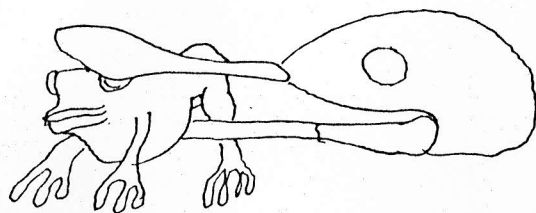
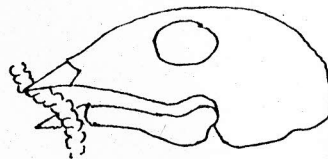
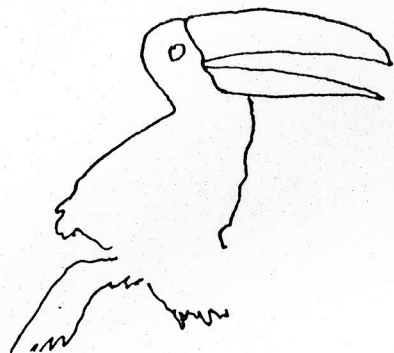
All of the following mechanisms are basically of the Bilateral rotational type with the form of the finger (jaw, claw, beak) dependent upon the object to be gripped.

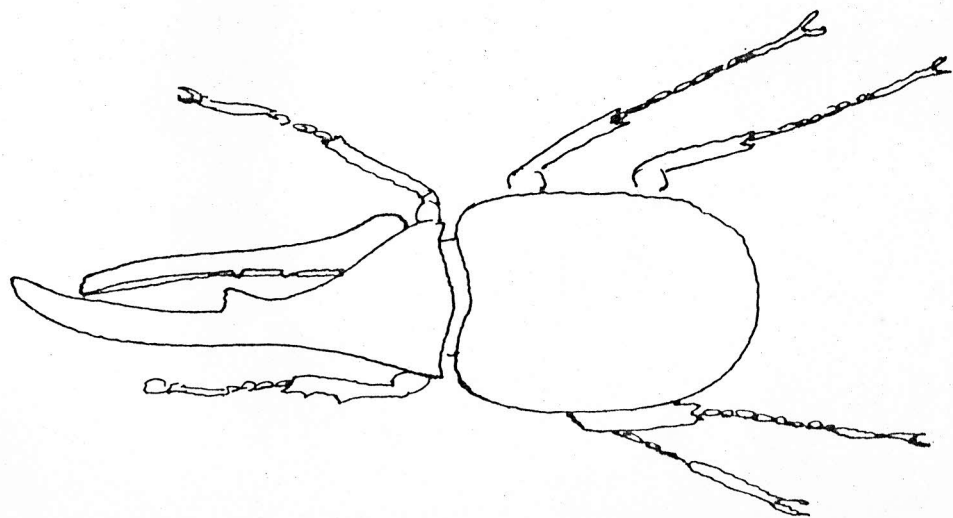
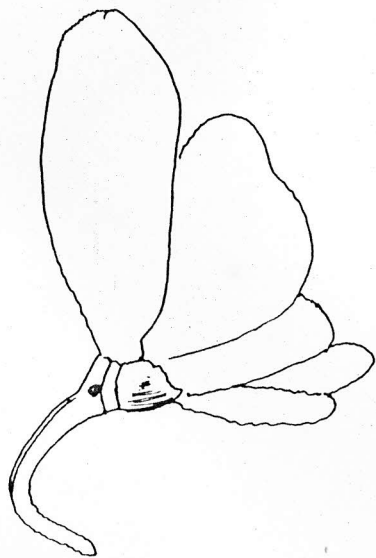
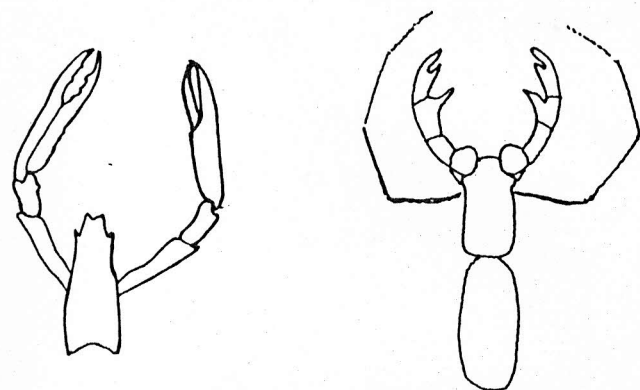
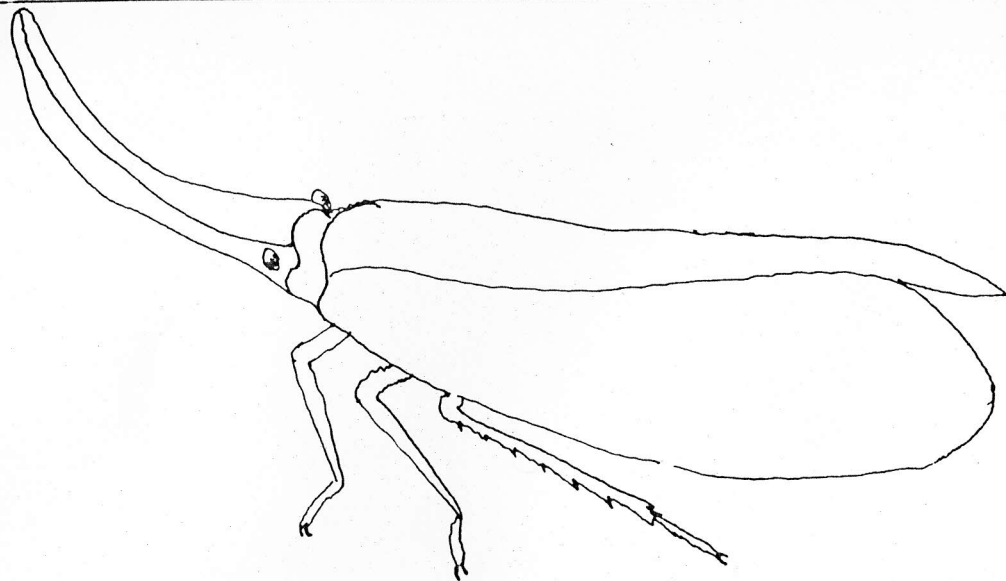
2.1 Wood Cock

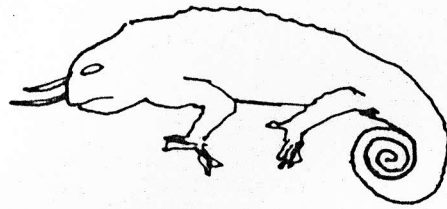
Most manipulations are performed by the bill. The Wood Cock shows how complex such procedures can be when it plunges its bill deep in to mud to take a worm. When it has reached its prey, the bill tip is opened by the quadrate bones (2) rocking forwards in their seating (3) when muscles (1) contract. This pushes forwards on the jugal bones (4), these in turn push the tip of the upper beak open beyond a thin, hinge like area (5).



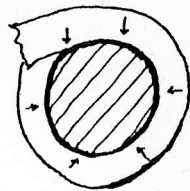
Wood cock



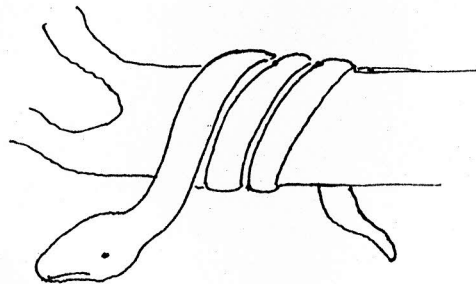




CHAMELEON



Gripping Force



3. Multilateral grippers in Nature

1. Chameleon

The tail of the Chameleon is not basically used for gripping. But the mechanism can be adapted for grippers. It rolls its tail like a spiral. This mechanism can be utilised for a gripper which should follow the contour for surface gripping.

2. Snake

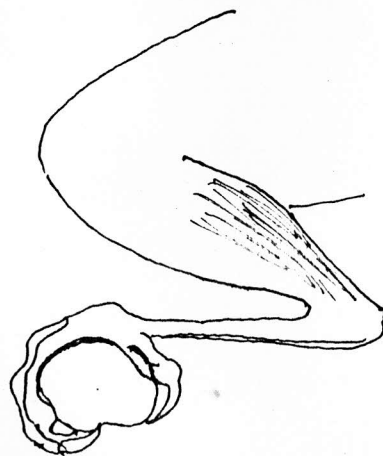
The snakes generally wrap arround the object with a helical meeting with the object surface. It generates the gripping force radially inward.

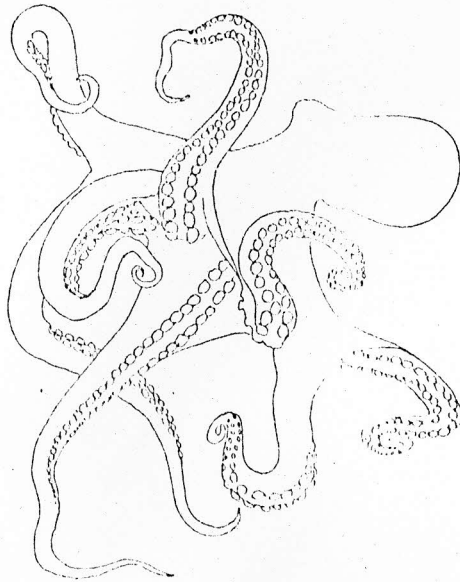
Snakes and Chameleon are of contour adapting flexible type.



3. Birds Leg

This is of the multifingered flexible type gripper with a hook at the end.

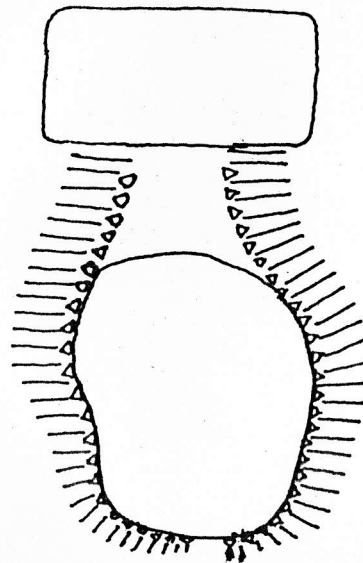




4. Octopus

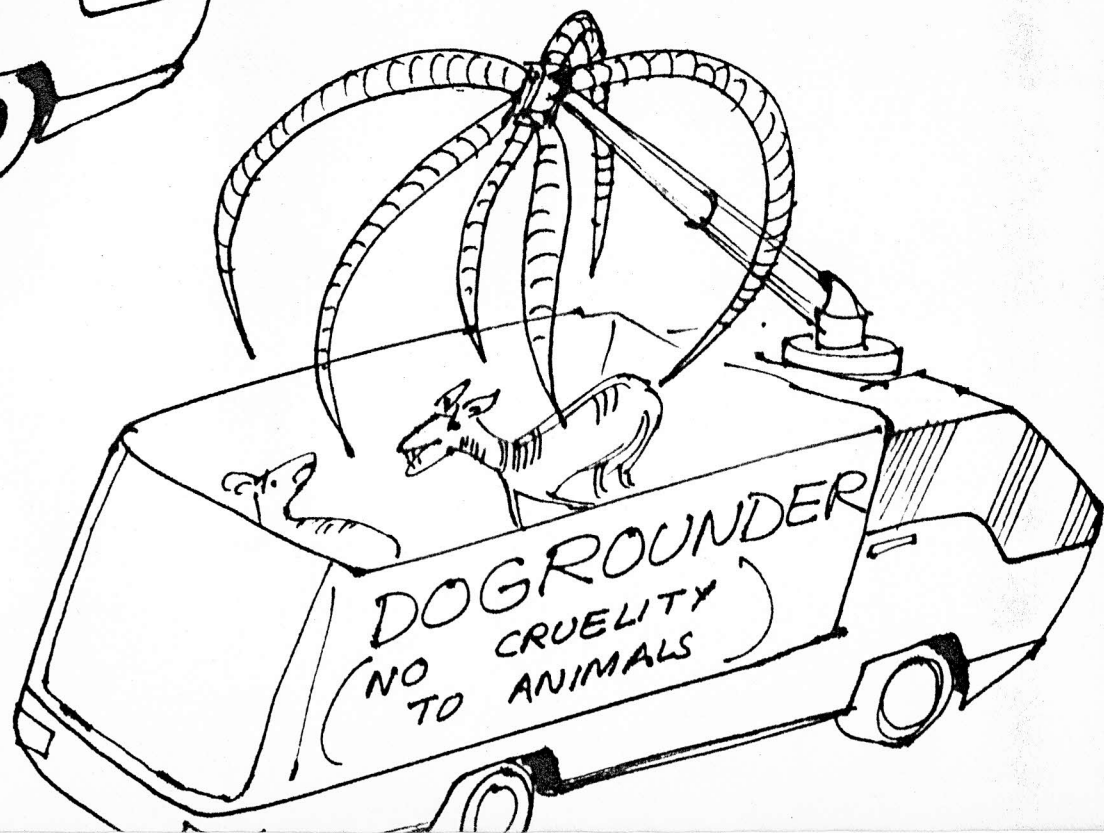
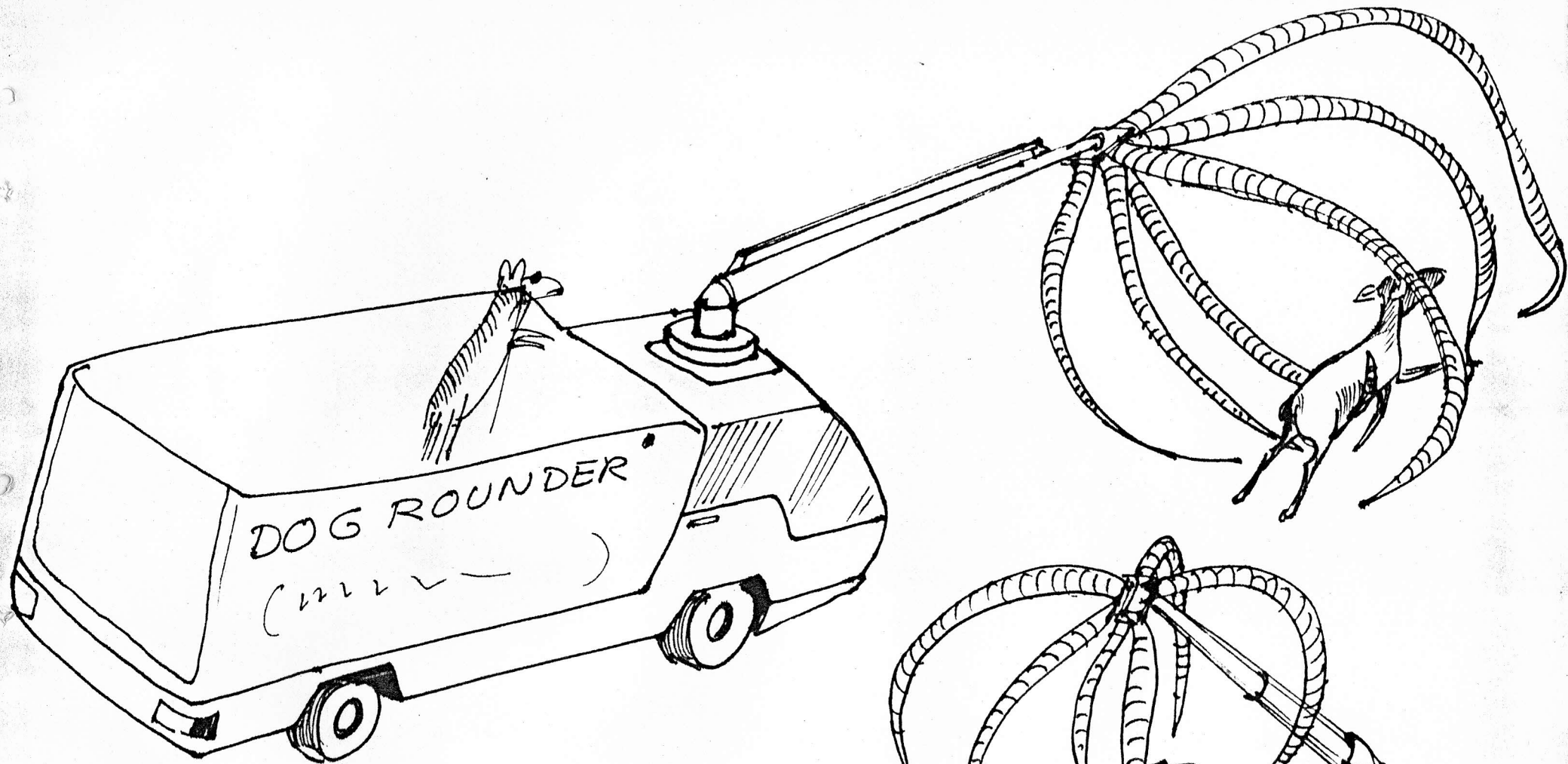
This is of the multifinger flexible type.

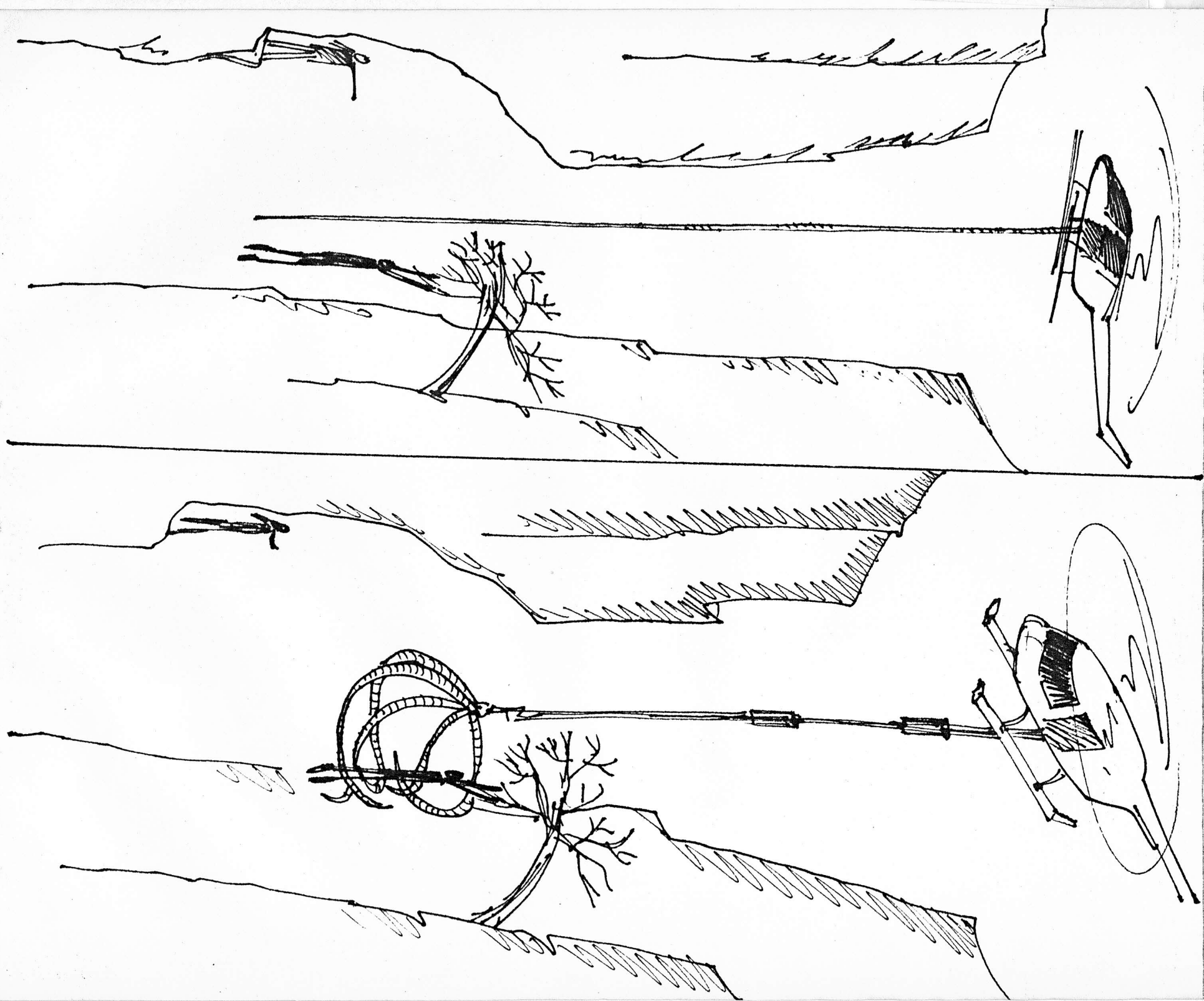
The tentacles that surround the mouth, armed with suckers on muscular stalks, help to seize the victim and thrust it between the horny jaws.

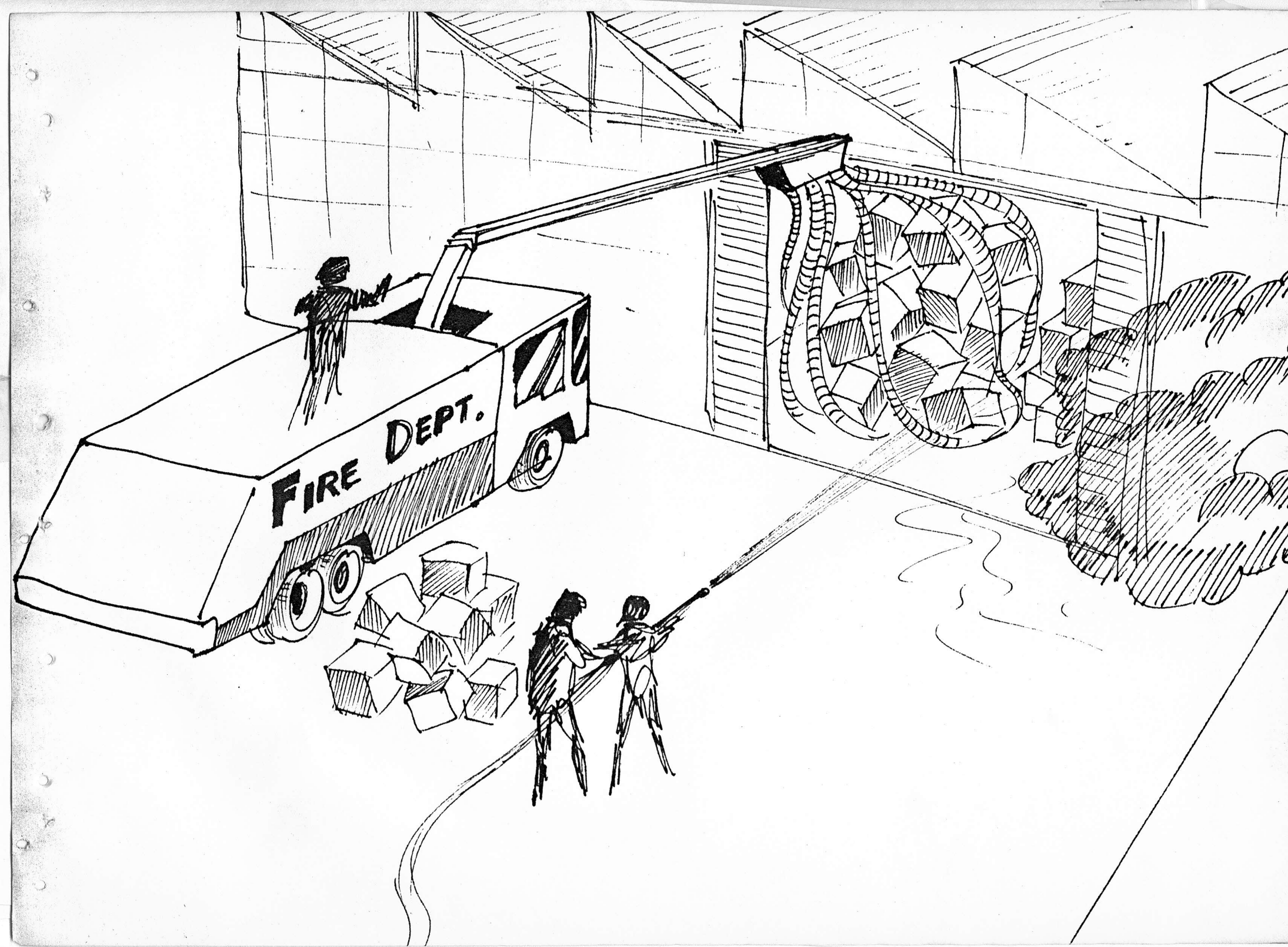


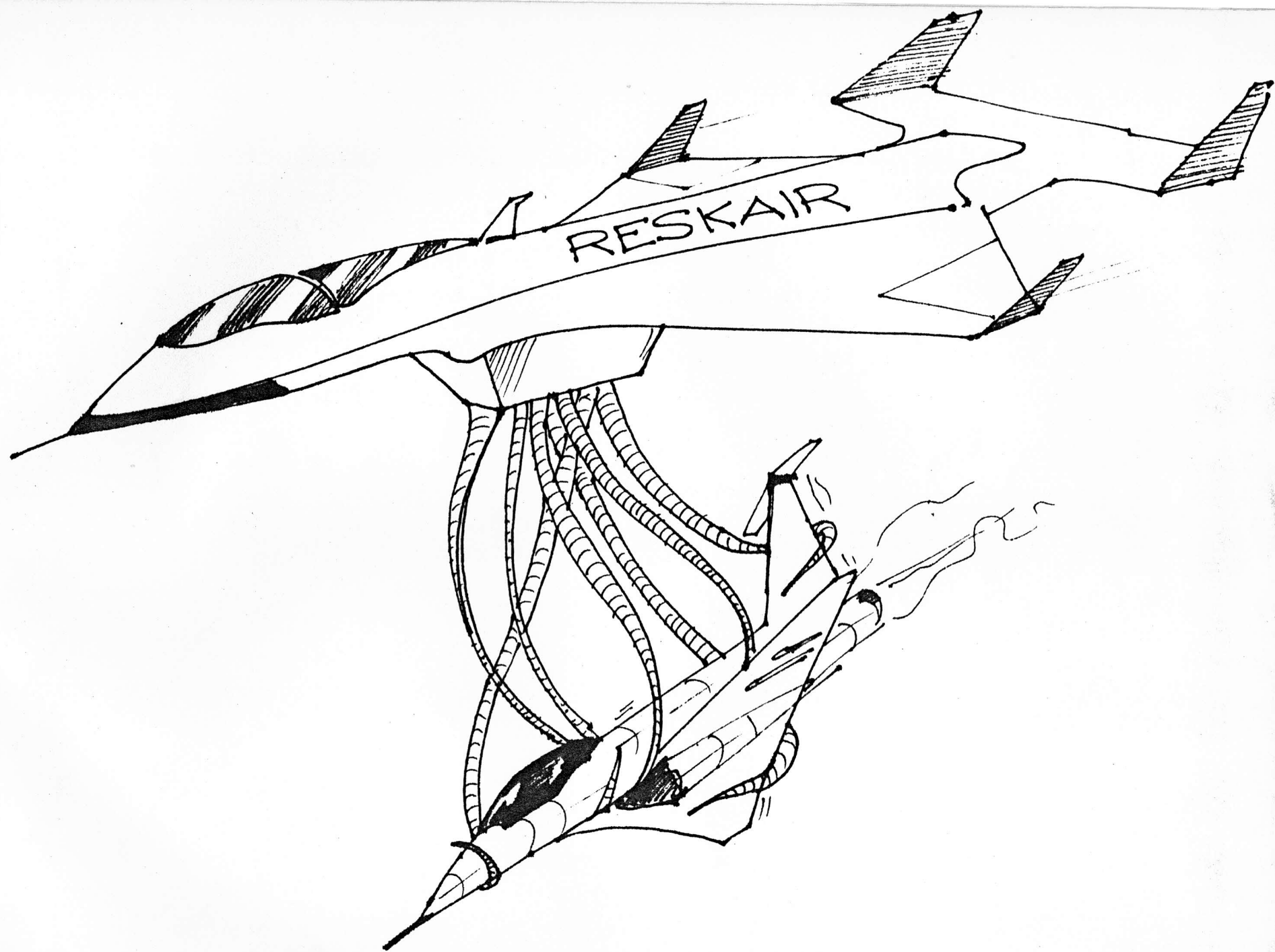
○ Vacuum pad ≡ Flexible tentacle

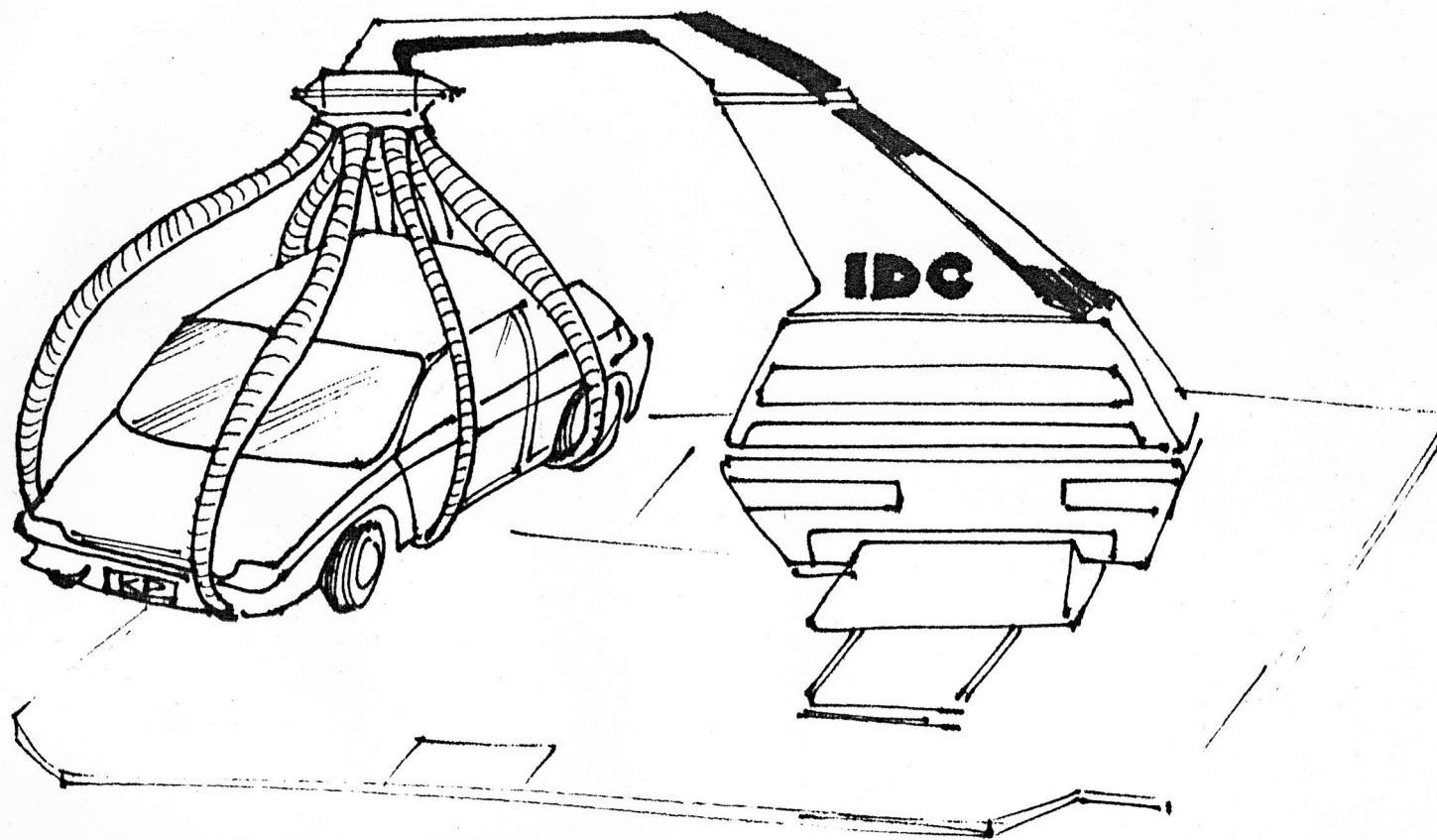


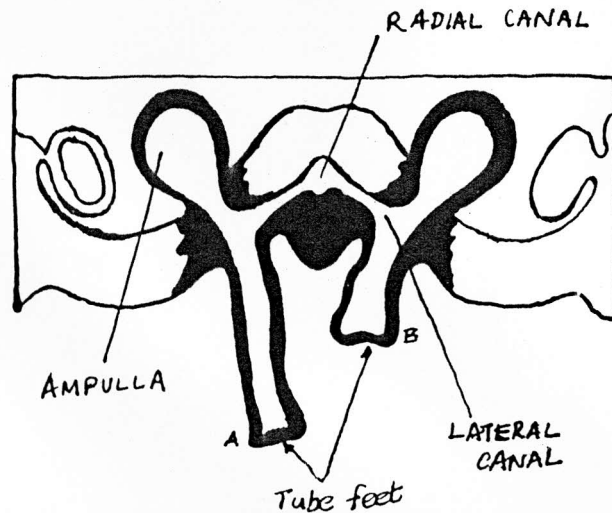
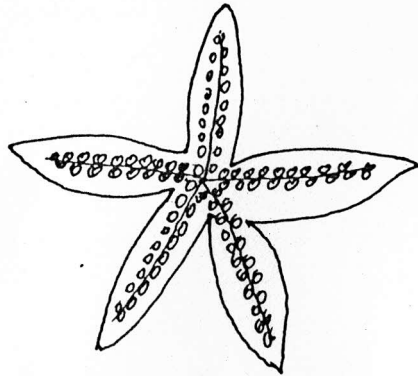








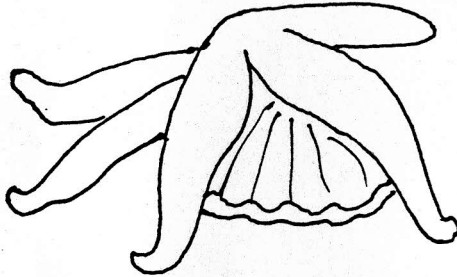




5. Star Fish

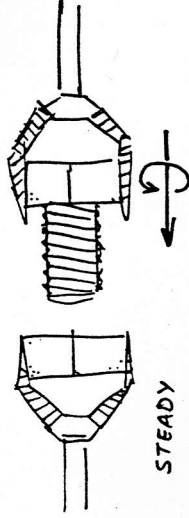
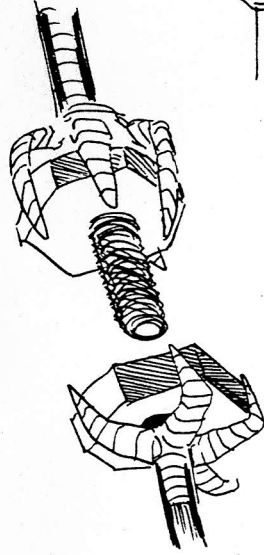
This is also of the multifinger flexible type.

Water powers the movement of the star fish's tube feet. It is drawn through a series of tubes into a radial canal supplying each arm. The radial canal divides into two lateral canals, each with a valve and ending in a bulb-like ampulla and a foot. During movement the ampulla contracts, the lateral canal value closes and water is forced into the foot which elongates (A), swings forwards and adheres to the substrate. Longitudinal muscles then contract, shortening the foot (B) and forcing fluid back into the ampulla. Each foot is controlled by an intricate system of nerve fibres and works independently, but during forward movement all the feet in leading arm or arms move in the same direction.



To prise open a shellfish,
the starfish makes use
of the adhesive force
of its tube-feet, firmly
attached to the two shell
valves. By applying a
strong steady pressure
the starfish opens the
two shells far.

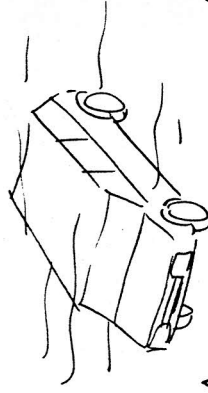
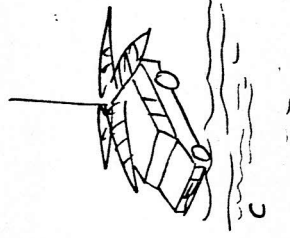
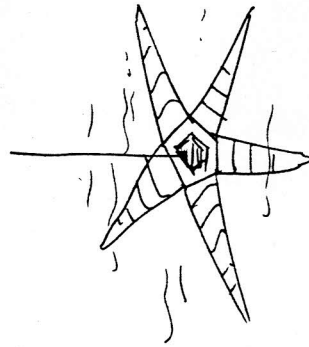
STAR-FISH FASTNERS



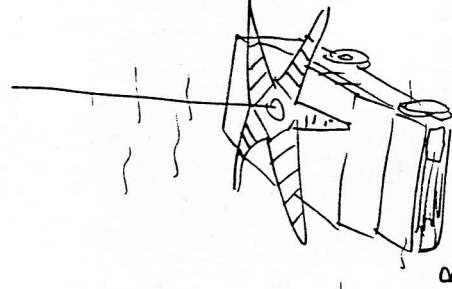
STEADY

RETRIEVER

SUBMERGED



A



B

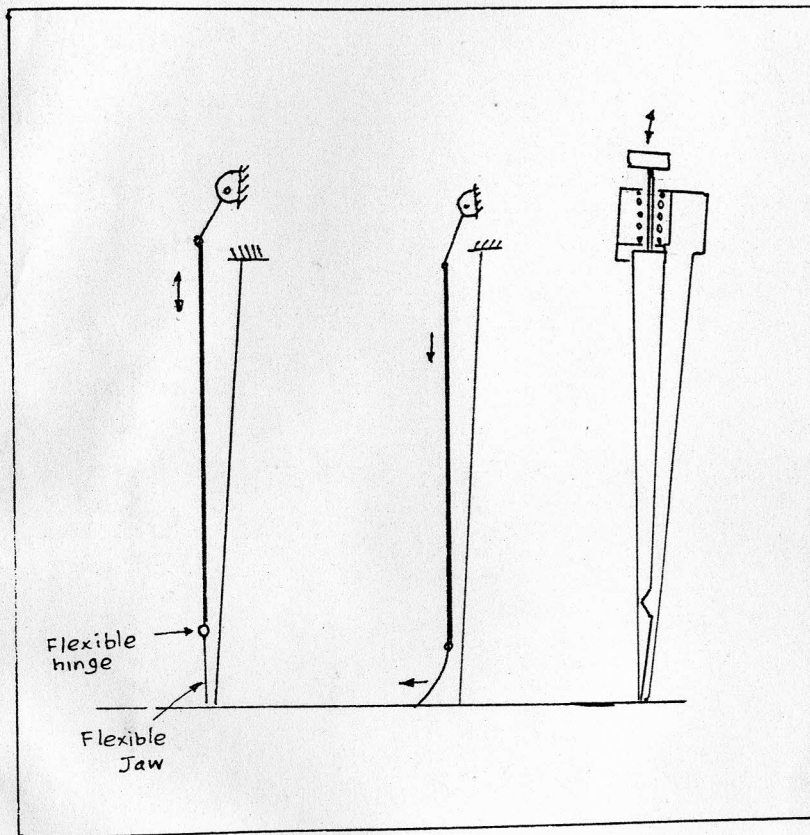
SIMULATION

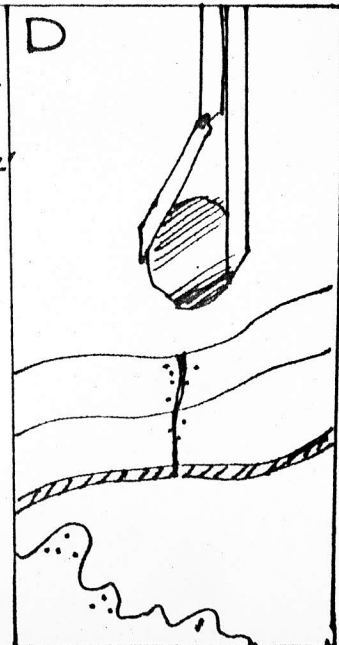
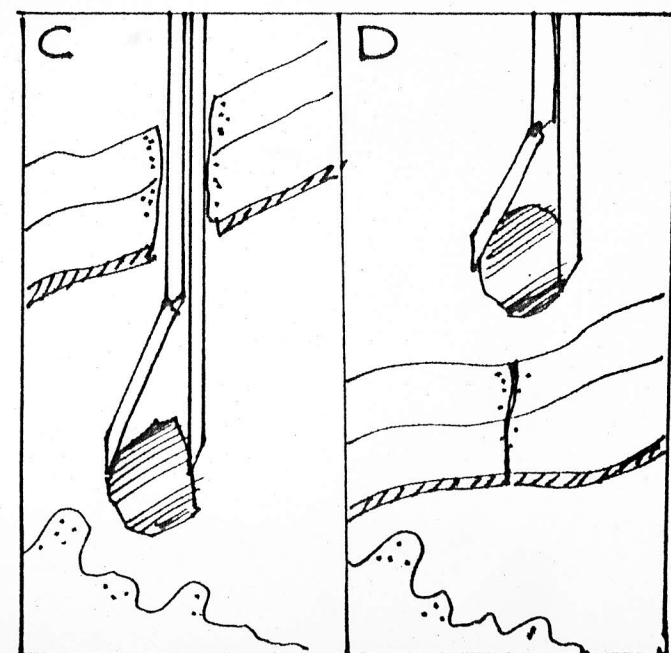
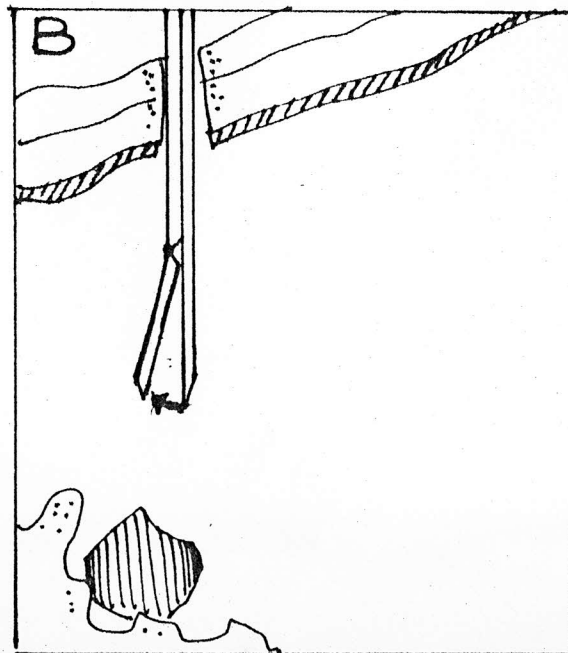
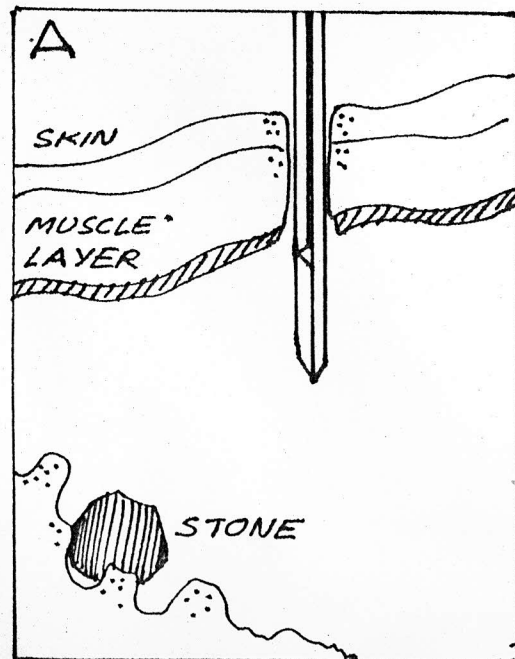
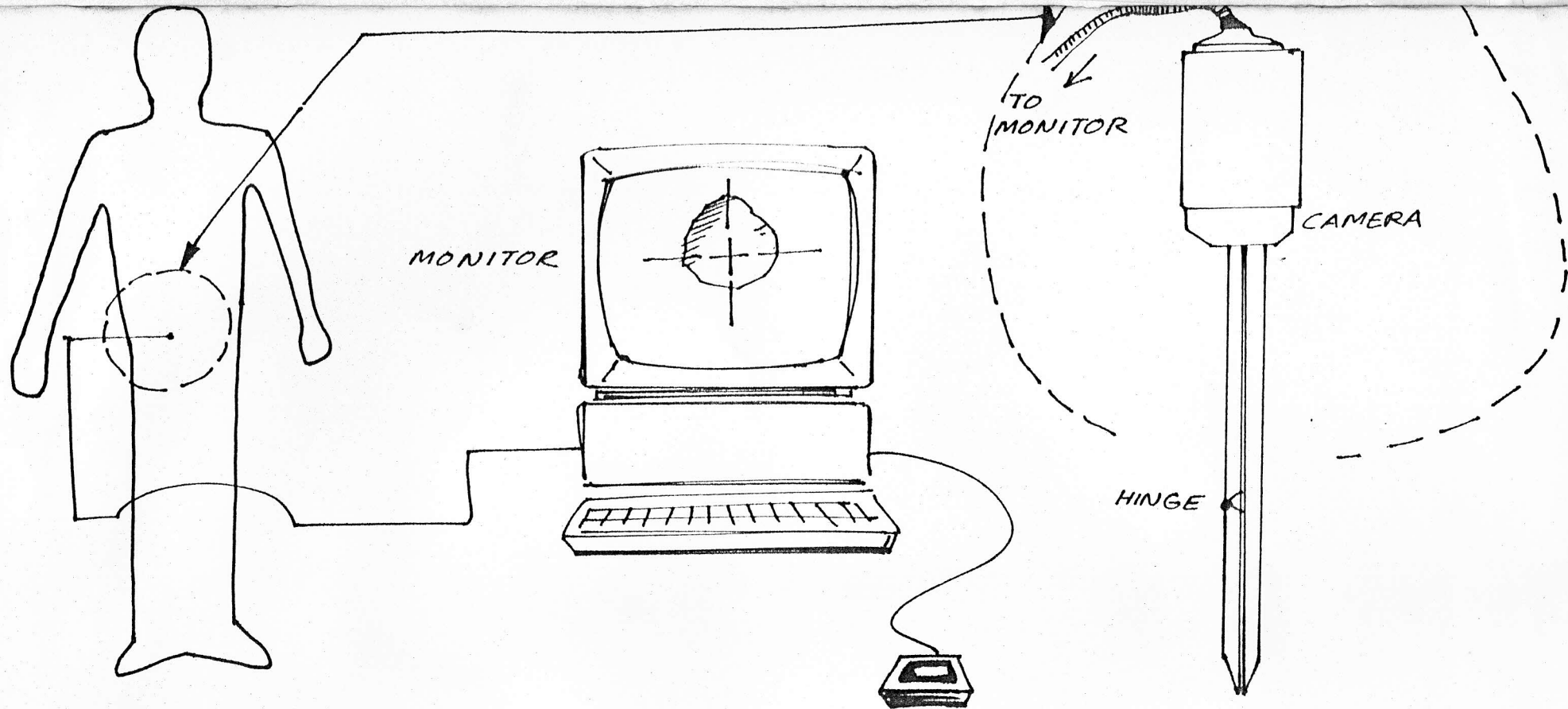
The simulation of the 'Robotic finger movements' has been done in 3D model. The 'wood cock' beak gripping mechanism was adopted. The function and the biological mechanism was explained in the 'Biological gripping mechanism' section, under Bilateral gripping mechanism.

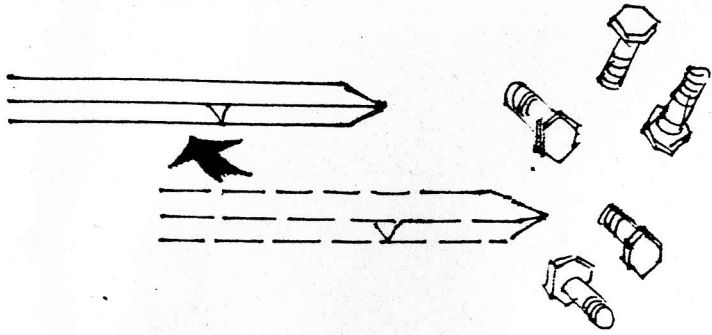
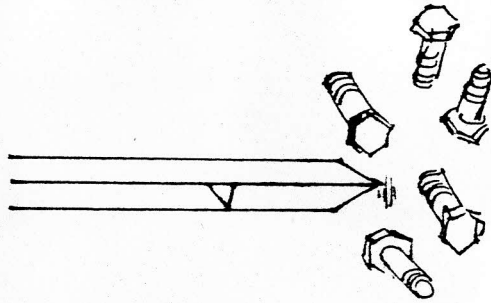
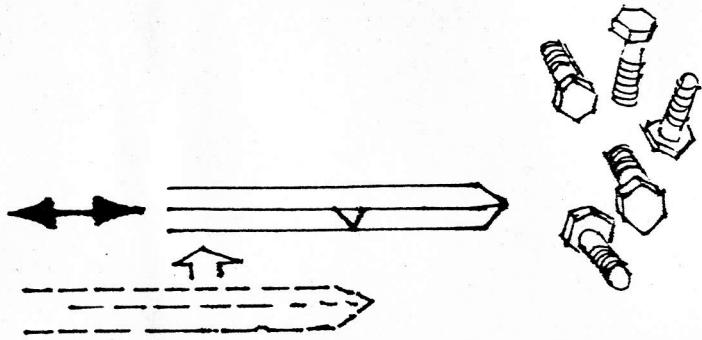
The basic mechanical structure of the beak movement was developed.

The form and the actuating mechanism can be modified to suit the specific need.

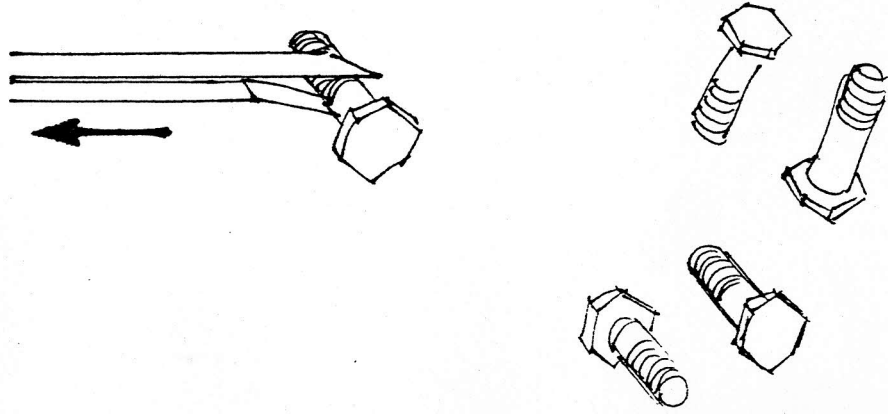
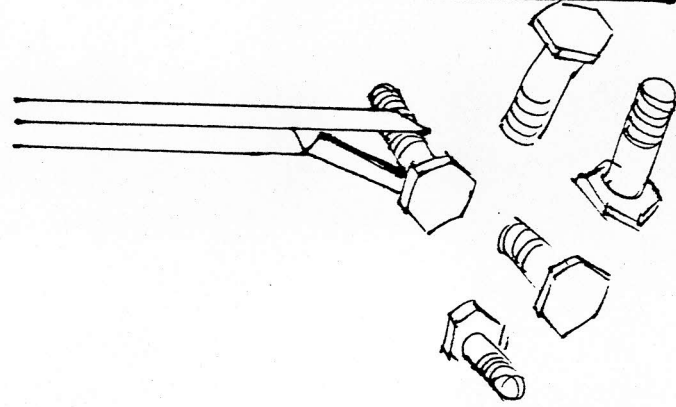
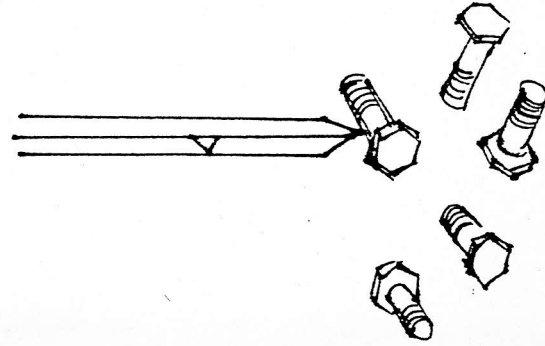
This gripper has a good potential in medical application and random picking of objects.







Random picking
of objects



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1. "Robot Grippers", edited by D.T. Pham and W.B. Heginbotham, IFS (Publications) Ltd, UK, 1986.
2. "Robot Technology" (vol.4) by Francois L'Hote, Jean-Marie Kauffmann, Pierre Andre', and Jean-Pierre Taillard, Prentice-Hall, Inc., 1983.
3. "Robot Hands and the Mechanics of Manipulation" by Mathew T. Mason and J. Kenneth Salisbury, Jr., MIT press, Cambridge, London, 1985.
4. "The Natural World" by Gwynne Vevvers Mitchellbeazley, 1977.
5. "Life on Earth" by G. Pretto, A. Minelli and M.U. Tanara, Newsweek Books, New York 1977.
6. "Robotica e strutture naturali" by Centro Ricerche Strutture Naturali, Istituto Europeo Di Design, 1983.

CLASSIFICATION CHART

		Type of contact			Force between gripper and object			Shape of object						
		Point	Line	Surface	Friction	Dead stop	others specify	Two dimensional	prismatic	regular curve	Cylindrical	Irregular	Cable	micro solid
	○ Good gripping qualities TYPES OF GRIPPER							□	▢	○	⦿	⚡	⦿	⦿
UNILATERAL	Vacuum pad		○	○			Vacuum	○	○	○				
	Pressure pad			○	○			○	○	○	○			
	Magnetic pad			○			Magnetic attraction	○	○					○
	Adhesive			○			Adhesive	○						
	Expandable ring type			○	○					○	○			
BILATERAL	Pincer with two finger	○	○	○	○	○		○	○	○	○			
	Pin	○			○			○						
	Two finger and a palm	○	○		○					○	○		○	
	Two finger and a palm	○	○	Palm only	○	○			○	○	○	○		

Physical state			Consistency			Surface			Weight		Temperature			Others	Type of finger
Solid	Viscous	Liquid	Fragile	Deformable	Resistant	Rough	Smooth	Viscid	Heavy	Light	High	Normal	Low		
															
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐		Vacuum cup/suction cup
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐		pressure pad
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Ferrous object	Magnetic bar
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Fabric material	Adhesive tape
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐		Flexible ring (Inflatable)
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐		Jaw, claw,
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Fabric material	pins
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐		
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐		Segmented finger rigid palm

Finger characteristics				Finger movements						
Number of finger	Degree of freedom	Rigidity	Surface	symmetrical	Asymmetrical	Rotational	Translational	Internal	External	Remarks
		Flexible	Smooth/ even						☐	There may be multiple vacuum cups to increase gripping force and the capacity to carry weight
		Flexible	rough						☐	Multiple pads can be used
		Solid	even						☐	Multiple pads can be used
		Flexible	even						☐	
		Flexible	rough/ smooth						☐	Flexible rings used for external gripping and expanding mandrels used for internal gripping
2	1	Solid	depends upon object	☐	☐	☐	☐	☐	☐	The two fingers can also be made flexible depending upon the actual application
2	1	Solid		☐			☐	☐		
3	1	Solid		☐			☐	☐	☐	
3	3	Solid	rough		☐	☐	☐		☐	Fingers move rotational rotationally

3	8	Solid	rough/ Smooth		○	○			○	
4	16	Solid	rough/ Smooth		○	○			○	
varies with design		Solid	rough		○	○	○	○	○	Rotational movement is achieved by radial lever type finger for internal gripping only.
varies with design		Solid	rough		○	○			○	
4	1	Solid	rough		○				○	
varies with design	1	Solid	rough	○			○	○	○	
varies with design	equal to number of finger	Flexible	Smooth		○		○		○	
varies with design	equal to number of finger	Solid	rough/ Smooth	○	○	○			○	
		Flexible	rough/ Smooth					○	○	
		Flexible	rough/ Smooth					○	○	
		Flexible	rough/ Smooth					○		This can be classified in both unilateral and Multilateral gripper
2	1	Solid/ Flexible	rough/ Smooth	○	○	○			○	
4		Flexible	rough/ Smooth		○	○			○	

MULTILATERAL

Three finger with palm	☐	☐	palm only	☐	☐		☐	☐	☐	☐		
Four Finger	☐	☐	☐	☐	☐		☐	☐	☐	☐	☐	
Multiple joint manipulator	☐			☐			☐	☐	☐	☐		
Multi finger Gripper	☐	☐		☐	☐		☐	☐	☐	☐		
Four finger (contour adapting)	☐	☐		☐			☐	☐	☐	☐		
Omini Gripper	☐	☐		☐			☐	☐	☐	☐		
Surface adapting vacuum cup			☐	☐			☐	☐				
Flexible Linkage gripper			☐	☐			☐	☐	☐	☐		

chameleon tongue

Adhesive

crustacens, Beak arthropods

Birds leg

Snake /chameleon tail

octopus

suction

Star fish

suction

	Segmented anthropomorphic
	Segmented anthropomorphic
	opposite pushrod Solid finger
	Independent solid fingers
	Solid finger
	Several independent fingers
	Independent rigid finger with freely rotating vacuum cup
	Segmented linkage finger
	Flexible finger with adhesive coating
	claw, jaw, pincer
	Segmented finger with hook at the tip
	Flexible linkage
	Flexible tentacle with vacuum pad
	Flexible tentacle with vacuum pad

