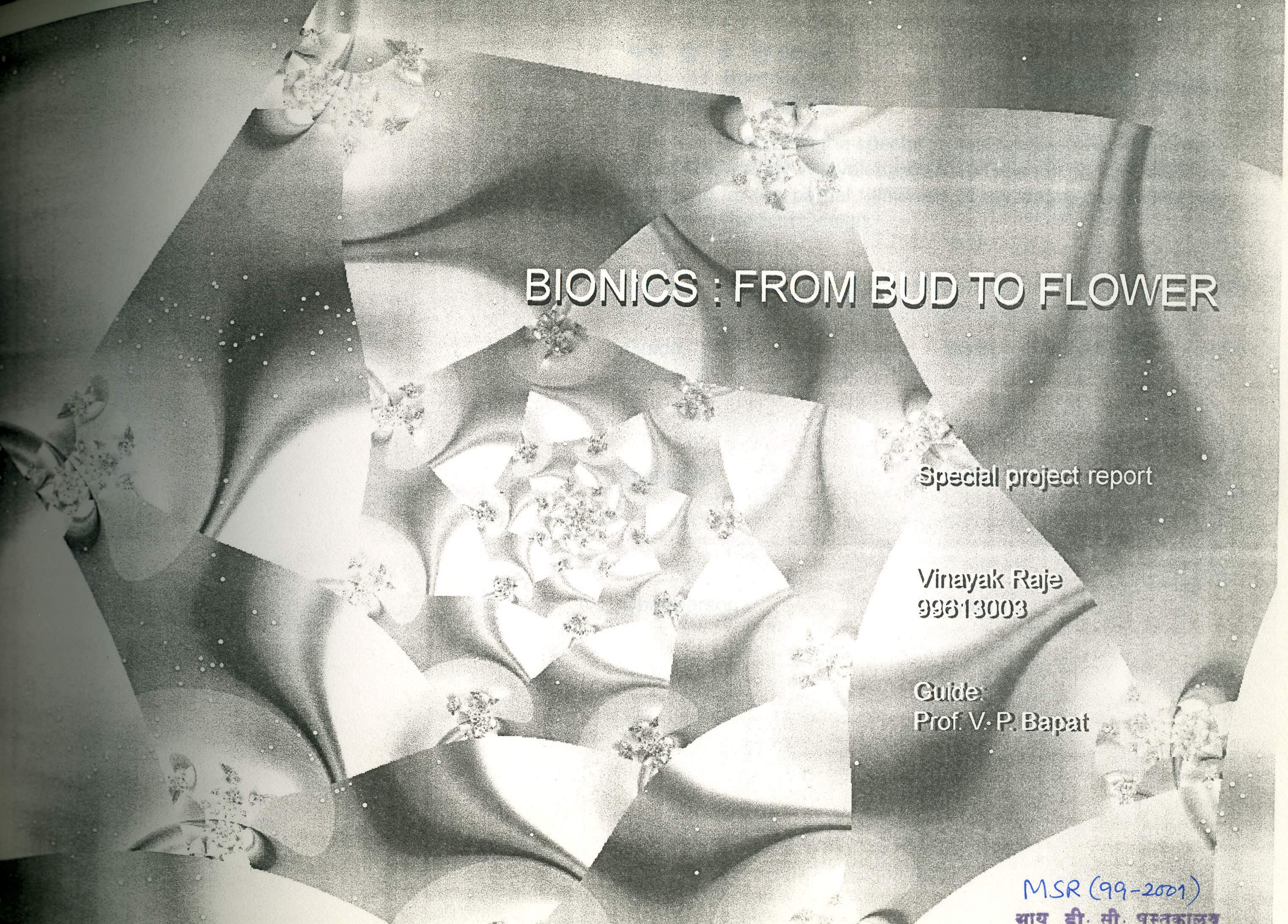

BIONICS : FROM BUD TO FLOWER

Special project report

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Guide:
Prof. V. P. Bapat

Approval sheet

This is to certify that the special project entitled " Bionics: From Bud to Flower" by Vinayak Keshaorao Raje roll no 99613003 is approved for the partial fulfillment of the degree of Master of Design in Product Design.

Guide Bapat VF Date 10/7/01

Examiner Date

Chairperson Date

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I am also thankful to Mr. Roger P. Hangarter who has given his own collection of flower blossoming movies for study.

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Vinayak

Contents:

Introduction

The term Bionics is science of constructing artificial systems that have some of the characteristics of living systems. Bionics is not a specialized science but an interscience discipline; it may be compared with cybernetics (The science of communication and control in animal and machine.) Bionics and cybernetics have been called the two sides of the same coin. Both use models of living systems, bionics in order to find new ideas for useful artificial machines and systems, cybernetics to seek the explanation of living beings' behavior.

The project Bionics: From bud to flower is an attempt to relate the beautiful natural phenomenon of flower blossoming with some application in design. The process of bionic science has been understood with case studies. The process of flower blossoming has been analysed in design terms and then analogous system has been developed with possible combinations.

Bionics

Nature is a place with infinite resources. Mimicry of nature is an old idea. Many inventors have modeled machines after animals throughout the centuries. Copying from nature has distinct advantages. Most living creatures now on the Earth are the product of two billion years of evolution, and the construction of machines to work in an environment resembling that of living creatures can profit from this enormous experience. Although the easiest way may be thought to be direct imitation of nature, this is often difficult if not impossible, among other reasons because of the difference in scale. Bionics researchers have found that it is more advantageous to understand the principles of why things work in nature than to slavishly copy details.

The process of finding inspiration from nature does not limit to one inspiration for one application. One can even extend two three inspirations for achieving one result. The nature has been designed with 100 percent efficient systems, which is hardly a case in man made design. The new designs can be developed so that there will be bare minimum consumption of resources while getting desired results. There are two broad classes of bionic systems

Analogic synthetic bionic systems

These are technical systems based on biological principles. The classic example is developing radar from the study of bat echo location principles. This is what many designers think of as bionics. Examples range from "cold light" devices based on bioluminescent marine animals, to tensile structures based on spider webs, to solar arrays that track the sun like sunflowers, to irridescent art forms based on the keratin structure in bird feathers that refracts light. There are, of course, many many other examples.

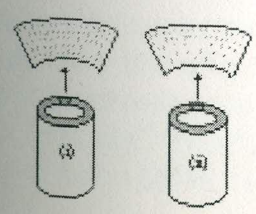
Composition synthetic bionic systems

These are systems that contain both technical and biological components. This can serve as a design paradigm for analyzing relationships between the artificial and natural as whole systems. A person driving a car or wearing glasses, human-computer interaction (HCI), the city and its surrounding ecosystem, crocodiles that swallow rocks as ballast, and the cyborgs of science fiction are all bionic systems of this sort.

Case study 1:
New Materials from Nature

Almost all natural biomaterials are composite materials, such as bamboo, wood, bone, muscle and shell. The role of biomimetics is to mimic the best features of these composites while avciding some of their disadvantages, for example some natural materials such as wool shrink at relatively low temperatures while others are not waterproof and have a tendency to rot if kept slightly damp.

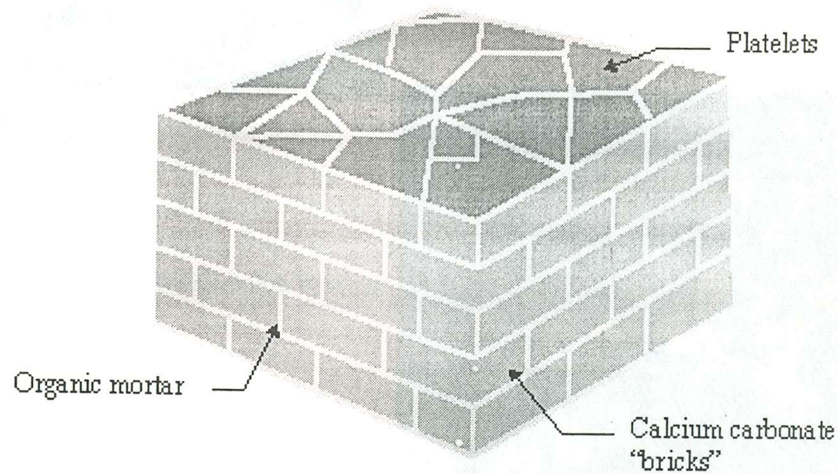
One of the greatest drivers of current research in biomaterials stems from the growing pressure to be more environmentally friendly. Regulations, such as ISO 9000, are calling for all industries to become less wasteful and look to sustainable development. Biomaterials are extremely refined as a result of millions of years of natural selection. In addition they are often made under harmless conditions, at ambient temperatures and from water based solutions, while their synthetic counterparts, such as ceramics or polymers, often need scorching heat or poisonous solvents.



A good example of an optimised natural structure is bamboo. This is a typical composite reinforced by long fibres. Vascular bundles are considered as the reinforcement (the fibre) and the thin-walled cells regarded as the matrix of a composite. The difference in the distribution and structure of vascular bundles and the thin-walled cells results in different properties at different parts. The volume fraction of the fibres increases in a gradient from the inner surface to the outer surface of the cross section of the bamboo, which causes an associated increase in strength. Figure 1 shows how optimised composites can be designed through comparison with bamboo. The fine structure of the individual bamboo fibres also shows non-uniform degrees of lignification in their cross section. The reason for this non-homogeneity was discovered by Li et al, 1994 who showed that by thickening the outer layer in a composite fibre a relatively small decrease in normal stiffness will be accompanied by a large increase in shear stiffness and toughness. This has resulted in improvements in synthetic fibres.

Bill Clegg at Cambridge University is developing materials for super-tough jet engine blades by mimicking the structure of nacre, - mother of pearl. The nacre on the inner layer of many mollusc shells is 95% chalk, yet up to 3000 times tougher than bulk chalk. Nacre's toughness is a result of its composite structure, most of which is aragonite. This is a dense and crystalline form of calcium carbonate which is arranged in layers of microscopic "platelets" about 8 micrometers across and 0.5 micrometers thick. Joining the platelets is a tenuous "matrix" of sticky silk-like protein. This combination provides toughness in two ways. First, when a heavy weight is placed on nacre, cracks go through the platelets but are deflected as they try to cross the protein layers. This dissipates the force, and can stop a crack in its tracks. A second strengthening factor is that as a crack forms the protein matrix stretches out in strands across the fracture. This process absorbs the energy that is essential for the crack to continue.

The main disadvantage of nacre is that at 600C the silk-like matrix starts to break down. Clegg has overcome this problem by combining nacre with heat-resistant materials. He rolled out layers of ceramic paste 150 micrometers thick and piled them on top of each other. He separated the layers with a dusting of graphite and baked the ceramic. This produced a material that can withstand temperatures of around 15000C yet has vastly improved toughness. Clegg hopes to use this material for turbine blades which may eliminate the need for cumbersome cooling systems .



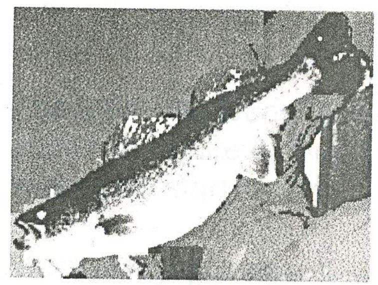
Case study 2:

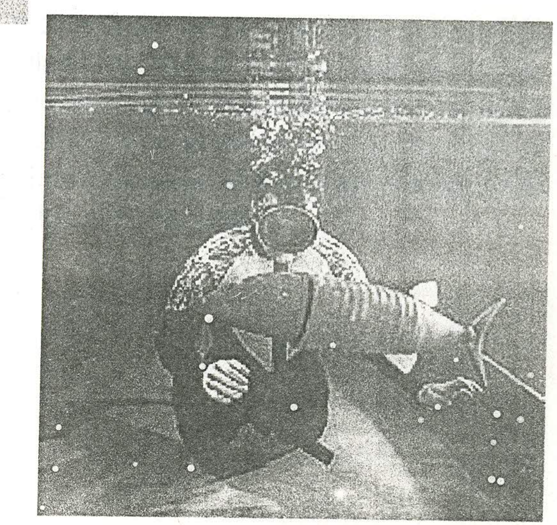
The use of bionics in machine design

It is often not practical to mimic nature when designing machines due to the fundamental differences that exist between man-made and naturally occuring systems. For example metal and rotational machinery are ubiquitous in man's technology whereas nature tends to use only non-metals and reciprocating, flexing or twisting mechanisms. However, one area where nature can provide much inspiration is in the design of machines for hostile conditions, for example some types of fish are far more efficient than any submarines made to date.

There is currently an increased interest in the use of long range Autonomous Undersea Vehicles (A.U.V.'s) for oceanographic observation, military surveillance and commercial search missions. Existing A.U.V.'s are relatively small vehicles for three reasons; low cost (fully autonomous vehicles have a significant probability of being lost), ease of deployment (to allow operations from conventional ships), and safety (to minimise the danger to manned ships and installations). They are powered by small rotary propellers driven by electric motors. The propellers typically operate at fairly low efficiencies and suffer from serious lag times in transient response. The space required for the batteries often approaches 70% of the hull volume. These problems lead to short mission times, restricted payloads, and control problems.

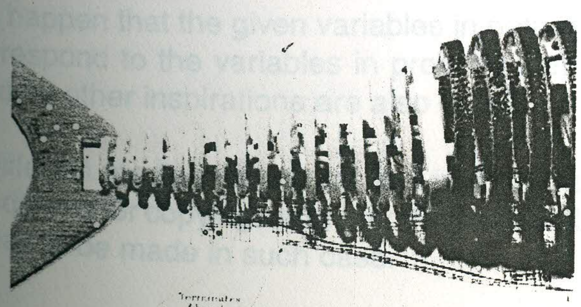
Engineers at the Massachusetts Institute of Technology (MIT) have been trying to resolve these problems by designing a robot that mimics the way fish swim. "Nobody really knew why fish could swim so fast given their muscle power" says Professor Michael Triantafyllou, head of MIT's Ocean Engineering Laboratory.



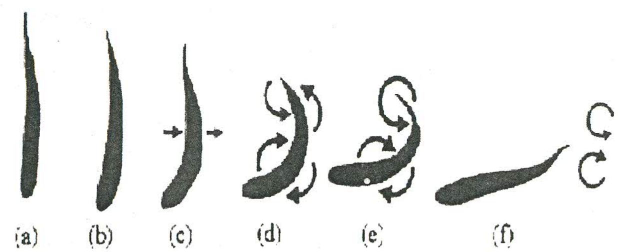


The team at MIT believe they have finally solved the mystery by using lasers to study the flows around fish. When a rigid body like a ship moves forward through water it sheds vortices, small rotating parcels of fluid, which when they emerge at the rear of the ship, tend to cause drag in its wake, dissipating energy and reducing its propulsive power. Segmented bodies can reduce this drag. Through natural adaptation fish have learnt to pass these vortices along their bodies as they undulate. When the vortices reach the fish's tail it flicks them from one side of its body to the other so translating the energy into propulsive power.

MIT's first robot fish, RoboTuna, shown in Figure, demonstrated how this vorticity control could be translated into a mechanical system. The team are now investigating quick turning and fast acceleration by mimicking a Chain Pickerel type pike, such as that shown in Figure. The Robot Pike is 80cm long and has a fibreglass nose which contains motors to propel it forward. These pull on tungsten wires attached to the helical spring that forms the fish's exoskeleton, see Figure 5, and cause three separate sections to flex.



Pictures of a fish turning:
(Courtesy of Jamie Anderson, Phd)



The team has found that when fish assume a C or S shape, as shown in Figure 6, they can control vortices extremely quickly when they start moving.

The skin of the Pike is made from lycra and has a stainless steel mesh. Power is provided by Nickel Metal Hydride batteries. The team chose to flood the hull of fish rather than design a flexible waterproof cover since this eliminates the number of seals required. The main disadvantage of this was that the individual components had to be waterproofed.

Discussion:

The examples studied shows that the process of developing the bionic models consists of a specific method of analogy.

First the challenge is understood in terms of its environment, goals, restrictions and detailed necessities.

Then the corresponding environment where the similar environment exists is searched and natural reaction to such problem is observed.

The natural activity is analysed thoroughly to get the variables that are involved and their behavior in different scenarios.

The analogy is developed in some of the variables of understood goal and corresponding ones in natural activity.

This analogy is used for developing ideas and then designing details.

It sometimes happen that the given variables in natural activity does not correspond to the variables in problem identified. In such case, some other inspirations are also used.

The use of different medium in natural and in man made systems make it difficult for copying natural activities directly. Some adjustment has to be made in such case.

It has been found that the analysis of the natural system is carried out and mathematical models are developed. These mathematical models act as direct influencers in any concept development.

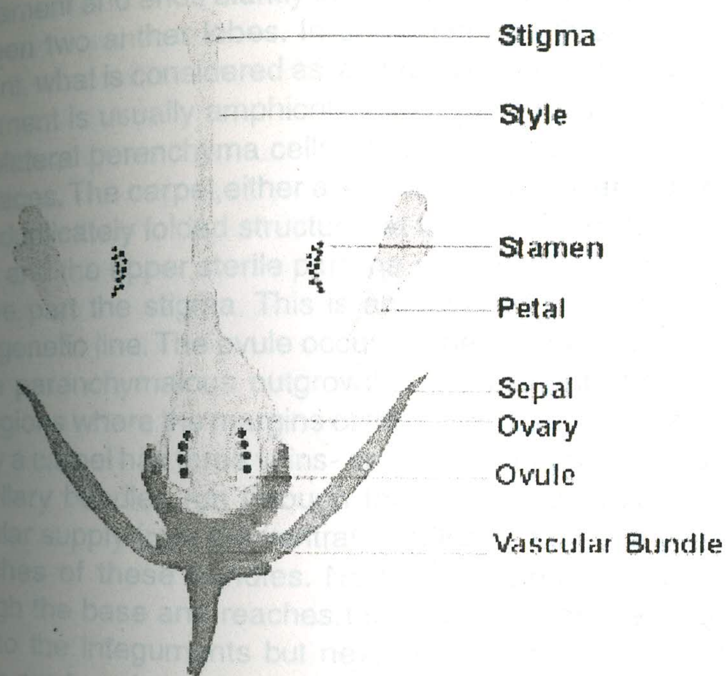


Fig (1) V. S. of flower

Flower structure:

Structurally and developementally the floral apex resembles the shoot apex in almost all fundamental features, slight differences that exist are due to the fact that the flower is a determinate stem with closely crowded appendages and very much suppressed internodes. It is at any rate assumed that the shoot apex is organized into the floral apex and the two are merely growth forms of the same meristem.

The vascular organization of flower may in a general way be compared to that of a vegetative shoot. the axis exhibits three zones epidermis, ground tissues and vascular system. The later is really a complex of traces which runs onto the floral parts- often branch and again combine with each other in the axis in an irregular manner.

The accessory parts sepals and petals resemble the leaves in internal structure. The ground tissue hardly show any differentiation in palliade and spongy cells. The epidermis is normally made up of pappilose cells, often with intercellular spaces covered by cuticles. Trichomes and stomata may occasionally occur. Special cells containing volatile oils may be present in the epidermis of petals imparting fragrance to the flowers. Inspite of some variations it may be said that a sepal has may traces of the leaf of that plant and it resembles a bract anatomically. A petal of dicotyledon normally has one trace, whereas perianth member (tepal) of a monocotyledon has one to many traces. Like those of foliage leaves the vascular bundles from complex systems in the sepals and the veinlets are usually dichotomously branched.

The stamen is simple structure with the filament surmounted by the anther. A single vascular bundle runs through the filament and ends bluntly in the connective which is located between two anther lobes. In some families three traces are present, what is considered as a primitive condition. The bundle of filament is usually amphicribral and remains surrounded by vacuolateral perenchyma cells without conspicuous intracellular spaces. The carpel,either a simple or an apocarpous one is a conduplicately folded structure, at the besal part forming the ovary and the upper sterile part the style,which ends in the receptive part the stigma. This is an advanced condition in the phylogenetic line. The ovule occur on the ovarion wall attached to the parenchymalous outgrowths, the placenta normally at the regions where the margins of the folded carpels meet. Commonly a carpel has three veins- one dorsal and two ventral. The carpellary bundles run through the style. The ovules get the vascular supply from the ventral bundles or from the placental branches of these bundles. Normally a single trace enters through the base and reaches the chalaza; branches may extend to the integuments but never to the nuclear region. the ovules are largely made up of parenchymatous tissue with primary vascular system which may be functioning during the maturation of the seed. The ovary and the style are the simple structures from the histological point of view being composed of cuticulrised epidermis, parenchymatous ground tissues and vascular bundles.

Flower development:

After establishment of roots stems and leaves, flowers and then seeds form, perpetuating the species and completing the life cycle. Most angiosperm species produce bisexual (perfect) flowers containing functional female and male parts, while others such as spinach cottonwoods, willos, maples, and date palms are dioecious, containing imperfect staminate(male) and pistillate(female) flowers on different individual plants. Monoecious species such as maize, cocklebur, pumpkins and many hardwood trees form staminate and pistillate flowers at different positions along a single stem. The reproductive structures of conifers develop in unisexual (strobili).

Anthesis, the opening of flowers with parts available for pollination, is sometimes a spectacular phenomenon, usually associated with scent and color development. While many flowers remain open from anthesis until abscission (falling off), others such as tulips open and close at certain time of the day for several days. Opening is usually caused by faster growth of inner compared to the outer parts of the petals, but continued closing and opening is a response to temporary changes in turgor pressure across two sides. Opening and closing are influenced by temperature and atmospheric vapor pressure, but the major factor is often an internal clock set by daily dawn and dusk signals.

After anthesis and pollination, the petals eventually wither die and abscise. In some species withering follows antheisis rapidly. Such withering is commonly associated with extensive transport of solute from flowers to other plant parts, often to the ovary with rapid water loss. There is an accelerated breakdown of protein and RNA from petals and sepals during withering and hydrolactic enzymes such as proteases and riboneucleases are apparently activated by harmonal changes to cause such breakdown. Nitrogenous products such as amino acids and amides are then transported to seeds and other tissues where growing is occurring, so nutrients are conserved. Although withering and color fading are common, certain rose and dahila species loose petals that are still turgid and that contain most of their original protein.

Flower blossoming

The blossoming flower has following development variables:

1. The growth:

The growth of any flower happens because of phenomenon of cell division. This cell division along with turgur pressure brings about the increase in volume. The phenomenon of the growth which is possible in flowers is not possible in non living environment. The cell division process is multiplying and end products resemble in shape and size to the original parent. But the change in volume can be used as a parameter to simulate. The bud in small shape takes huge volume at the end of blossoming. Even the increase in height of the petals with respect to the stem of flower can be simulated.

2. The Change in shape:

This is a wonderful visual phenomenon where the overall shape of the flower changes to the blossomed one in some time span. As the time span is more i.e. varying from ten minutes to half an hour, at an instance its difficult to see the process. But people have tried making fast processes by shooting and fast forward techniques. This process can be used in making something open in a rhythm which is similar to the flower opening.

3. The shape of the petal:

The shape of the petal which is curled in spirals at the beginning of the blossoming process changes to expanded and reversed curled. The flexible yet tight petal surface is an inspiration of self standing structure that changes its shape for its requirements. Like when in bud form it has to be in the bud and small, it curles and overlaps the other petals and acquires minimum area. Later at the time when it has to attract bees, it needs to expand to the maximum area and hence acquires reverse curl structure. Even when the flower dies, the vein structure of the flower collapses to add weight to itself causing it to fall.

4.The colour

The colour of the bud is dominated by the green calyx which engulfs whole flower. Later as the petals start coming out from the bud they become attractive and catch the attention. This is because there is a kind of colour contrast that exists. And slowly as the petals grow the flower becomes dynamic, the colour varies on the petal itself. The beautiful change in colour is like a indication of some pleasant activity happening to all other animals around.

5. The death of the petal

As the flower dies, it collapses, fades and fells down. The flowers of fruiting tress tall in size often fell before dying whereas for small bushes, the flowers remain on their parent tree till death. The death.. the process of winding up itself for a flower acts as an indication of its end and is visually suggestive. The colour, the texture, the composition i.e. shape and size are all making that effect.

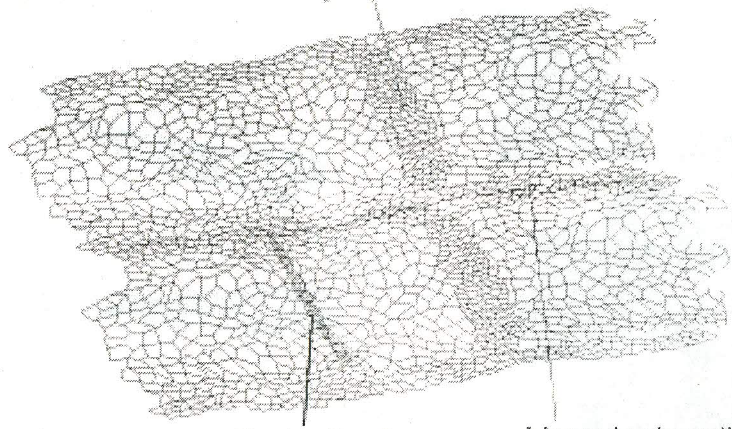
The Abcission

The plants commonly lose various parts periodically. Lower vascular plants usually do not shed their parts, which remain attached to the plants and ultimately get decayed. But in the higher vascular plants the fall of the parts particularly of the leaves, floral members and fruits- is mainly caused by the formation of a distinct zone where usually parts get detached from the mother plant. The process is referred as abscission and the zone as the absciss zone.

Periodic defoliation is a notable feature of gymnosperms and most of woody dicotyledons. The deciduous plants shed their leaves at the approach of winter. The evergreen plants have no fixed season for fall of leaves; but they may shed their leaves in any season. Some structural modifications actually take place at the base of the flowers and leaves, and finally they are abscissed. The formation of the absceiss zone is usually initiated before the leaf fall. In fact the leaves now become mature, turn yellowish in colour due to disintegration of chlorophyll and preponderance of carotinoid pigments. Moreover the waste products are transferred to the leaves, so that the plant may get rid of them with the leaf fall.

The absciss zone is usually formed at the base of the petiole in case of simple leaves. In compound leaves it is formed at the base of the rachis and also at the base of the individual leaflets. It is narrow zone composed of few layers of cells. Before the fall of leaf a distinct separation layer is formed in the absciss zone which may be considered as the immediate structural reason for the fall of leaf. Besides this, there developes a protective layer in the absciss zone which protects the exposed surface after leaf fall from loss of water and attacks of micro organisms. Periderm is formed later and provides affective protection.

The absciss zone is the weakest spot on the petiole of the leaf. In some cases it becomes slightly constricted and thus rendered externally visible. The vascular bundle becomes reduced here and the strengthening tissues are minimum. Collenchyma cells are absent and sclerenchyma, if present, are weakly developed. the separation layer consists of at least two rows of cells which are different form those occurring above and below the absciss zone in cell size and cell contents. The cells of this layer are smaller in size have denser protoplasm, and abundant starch grains. The vessels usually becomes clogged by gums and tyloses below the zone. Distinct changes take place in all the parenchyma cells of separation layer. The middle lamella and the outer walls of the cells swell, become gelatinous and eventually break down. Calcium pectate of middle lamella is converted into pectic acid and that into water soluble pectin. Thus the cells now become separate from one another either along the lamella or the walls actually break down. Now that separation layer is thus formed, the leaf remains attached to the stem only by vascular elements. It breaks in time either by mechanical weight of the leaf or by slight swaying due to wind. During rains, the leaf gains in weight and gelatinization of the cell wall is hastened, resulting in quicker abscission.



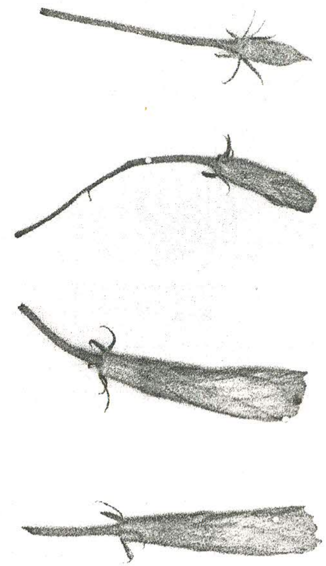
Hibiscus

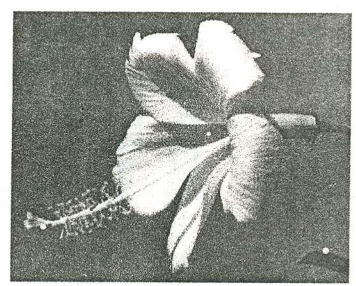
There are no words to express the beauty of a Hibiscus flower which is extremely popular in all tropical countries. There are nine main types of Hibiscus blossoms with many more varieties of colours coming from these types.

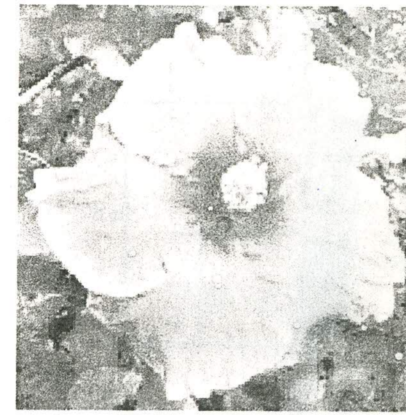
The word Hibiscus comes from the Greek word hibiskus used by Dioscorides to name the mallow. They are flowering, deciduous shrubs, perennials(periodic) and annuals. They hail from all continents, but particularly the countries around the Indian ocean -Eastern Africa, Madagascar and Malaysia- as well as the Pacific islands, India, Australia and China.

Besides having that pompous look, these exotic creations have other values too. The flowers of the red variety yield a red food coloring, a tea and a shoe black. They are also used in cough syrups and hair oils. Chinese women used the petal juice to blacken their eyebrows. In South east Asia the bark, root, leaf and flowers have medicinal uses.

In India Hibiscus flowers are widely used in the worship of the deity. It is said that these flowers are dedicated to the goddess Durga. As mentioned in Devi Bhagavat, when the goddess took the form of Kali to destroy evil, the red color of the flower was donated to her to depict anger through her eyes. In return Jaswandi (hibiscus) was granted a wish that anyone who offered its flowers to her would be blessed.



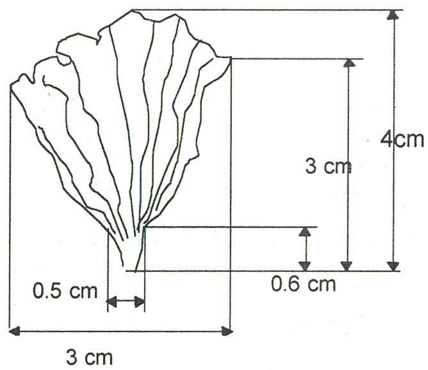




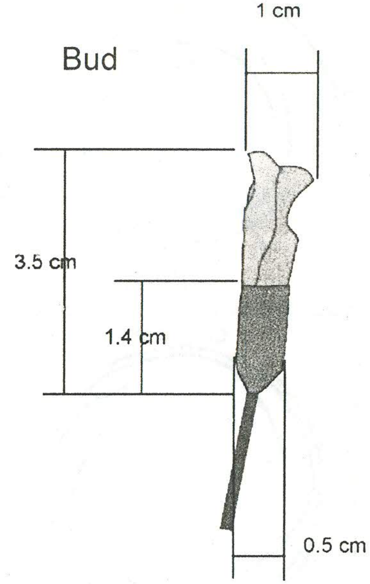
Structure:

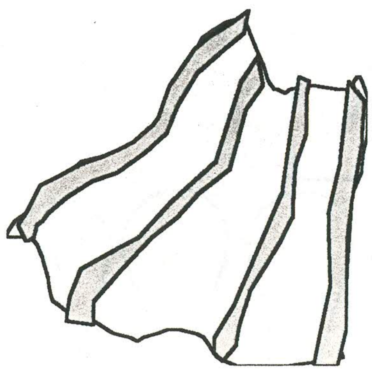
Hibiscus flower has structure similar to the other flowers in general. It belongs to the dicotyledons family. It has five petals and are seen over green sepals forming bowl shape. The style which emerges from the bottom of the sepals is the tallest part and supports andrecium and gynaecium. The bottom of the style is overy. The colour of flower found in India is red. This colour attracts insects and butterflies and thus promotes pollination.

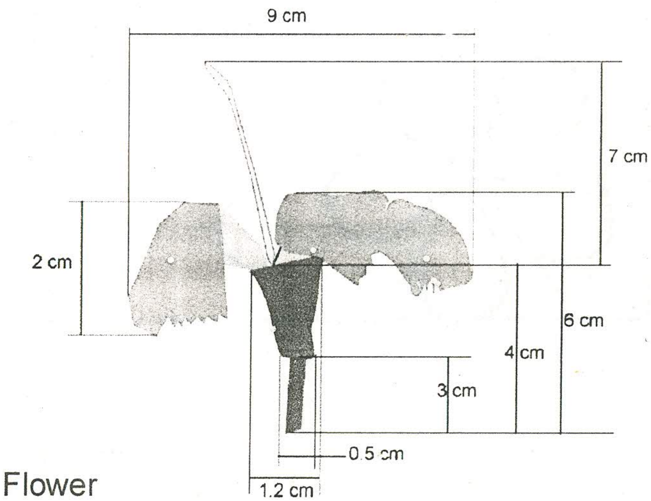
The veins of the hibiscus petal form the structure to support the petal. It also carries food and nurishment for the cells in petal. The arrangement of the veins is such tht it is denser at the bottom of the petal. There the petal is strong while at the open end it needs to be flexible and hence veins are less denser. The thickness hence varies from maximum at bottom of the petal to minimum at the open end.



Bud





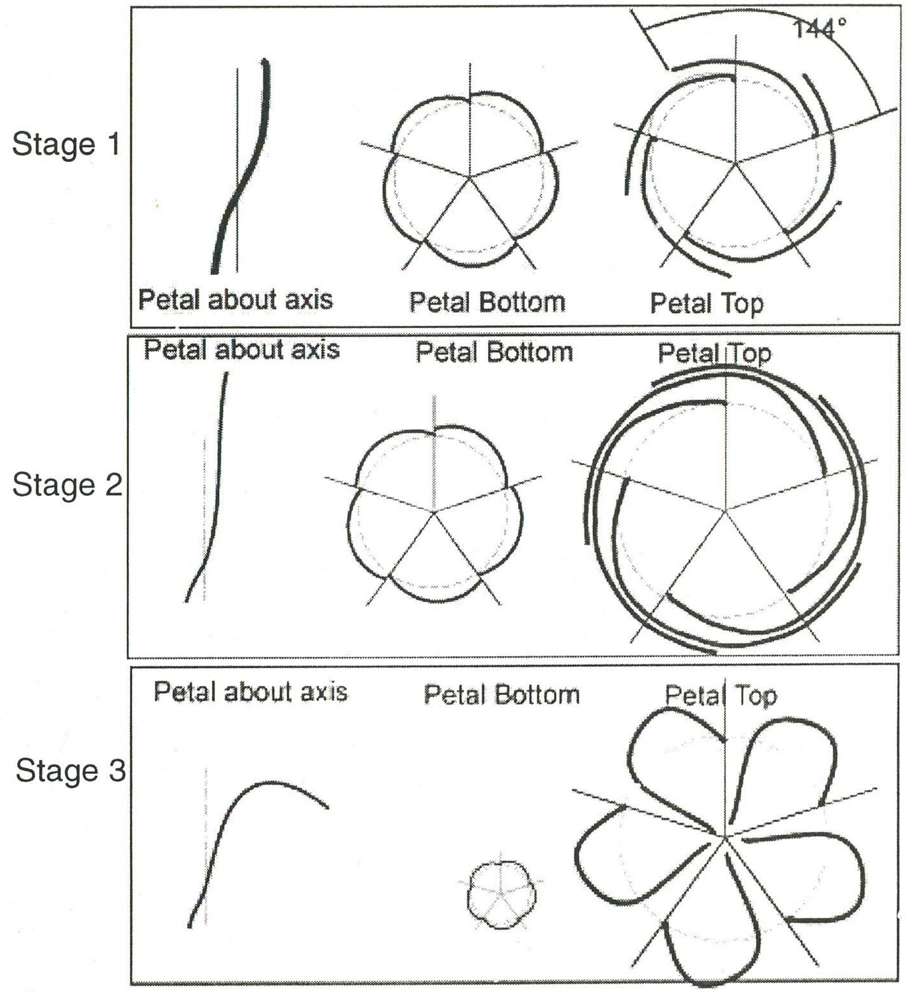


Flower

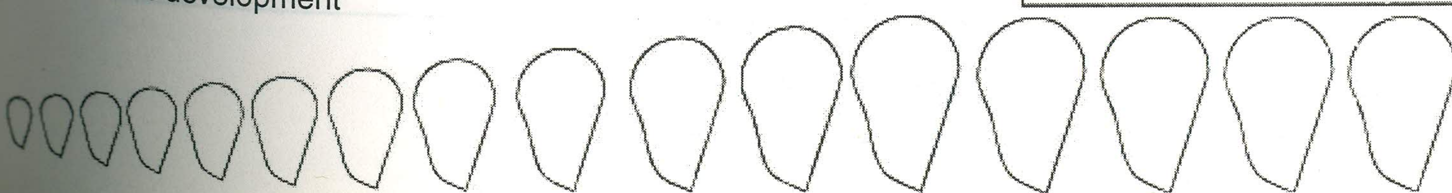
Blossoming of Hibiscus:

The petals at the bud stage are entirely inside the sepals. Those are smll in size. The sepal growth stops at one stage, while petals still keep growing. The sepals seperate allowing the petals to come out. At the begining, they are curved and enveloped with each other. But at the later stages of the growth, the area of the petal at the apex increases and the flower petals start opening. At one stage when sufficient lighting and temperature conditions are reached, the turgur pressure increases causing veins to strech and opening the flower. The increased water content in petals brings the freshness and beautiful look to the flower.

The following are the observations and measurements taken of hibiscus flower at verious stages of its blossoming. These measurements are taken by selecting flower with the most resembling developmental stage to the reference one. Three stages are shown in figure for understanding overall configur ation.

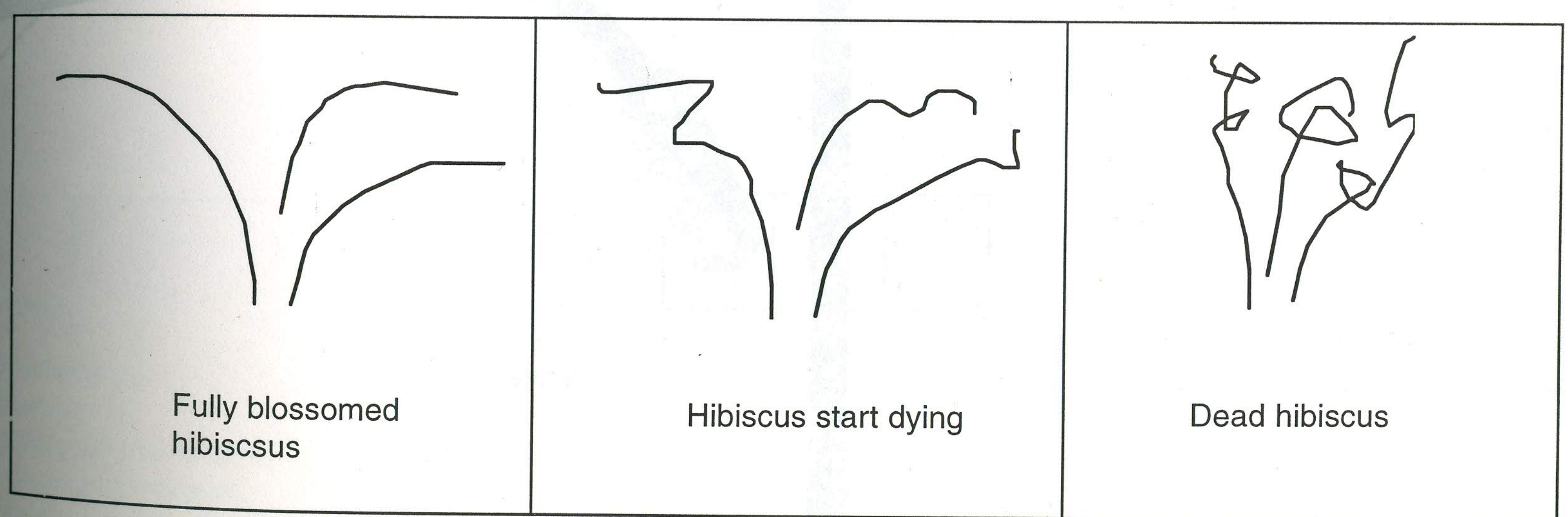


Typicai Petal development



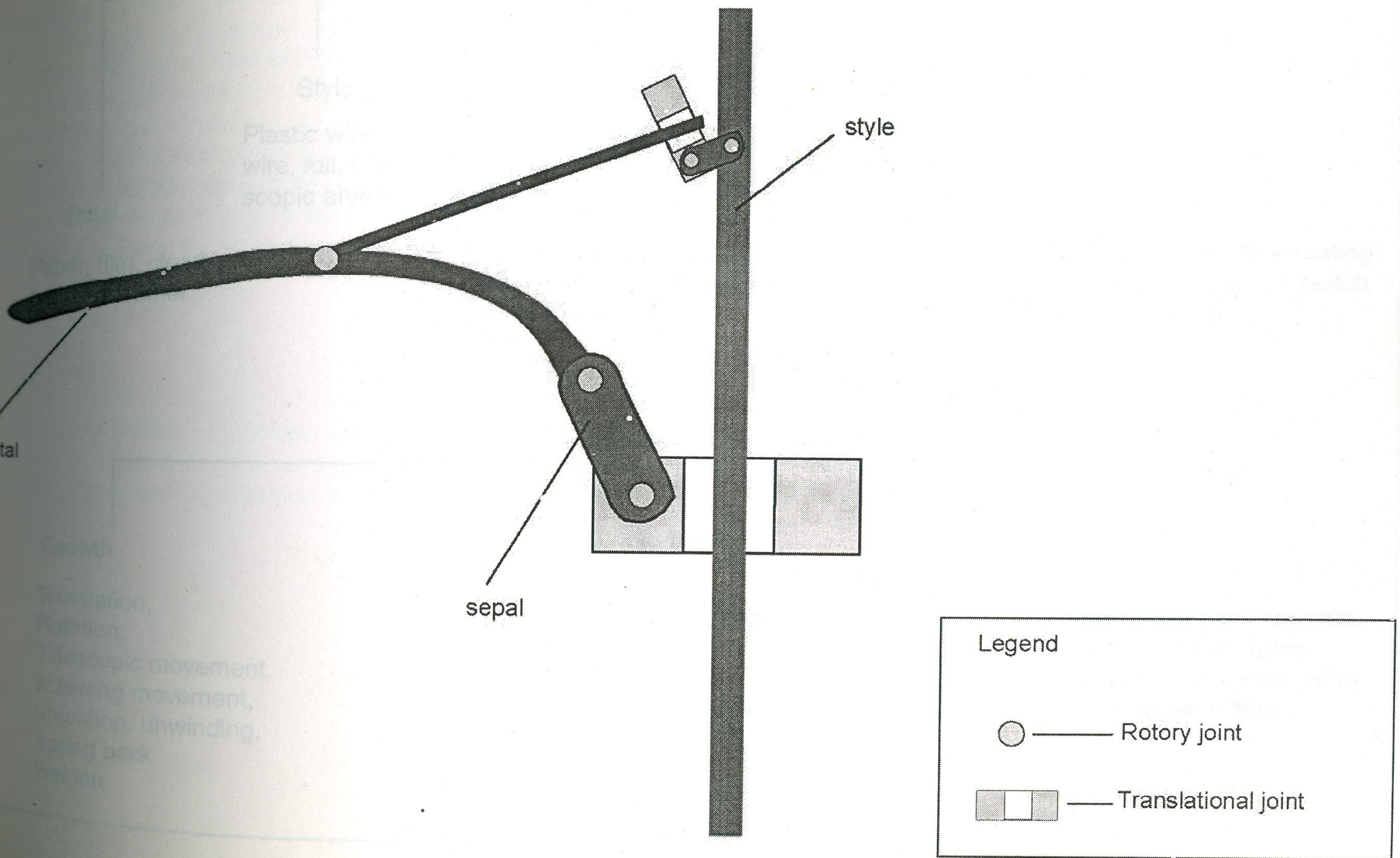
Death of Hibiscus

Hibiscus belongs to shrubs category. When the flower dies, it remains on the plant till death. After most of the cells die, the flower falls down by self weight or wind. The veins of the petal and sepal die out. They turn and twist, and hence the petal gets twisted. The phenomenon is as if flower doesn't want to die and twists its body trying to bear the event. The colour of the flower becomes dark red brown. The beauty is almost gone. It later falls and disintegrates.



Petal Twisting

Simplified mechanical model of Hibiscus



Analogy development

Flower Parts

Petal

Paper, film, cloath, net, thin leather

Style

Plastic wire, Steel wire, foil, tele-scopic antena,

Vein

Aluminium wire structure, plastic wires, metal foil net, sewing of cloath, bamboo view

Sepals

cap of plastic, cloath, wireframe structure,

Stem

Place from where actuating signal comes.. lever, switch, screwing knob,

Activities

Growth

Translation,
Rotation,
Telescopic movement,
screwing movement,
unfolding, unwinding,
spring back
Baloon

Petal deformation

Turning motion, bending, folding,

Colour

New colour after opening, lighting (acrylic type), spraying new colour while opening each time

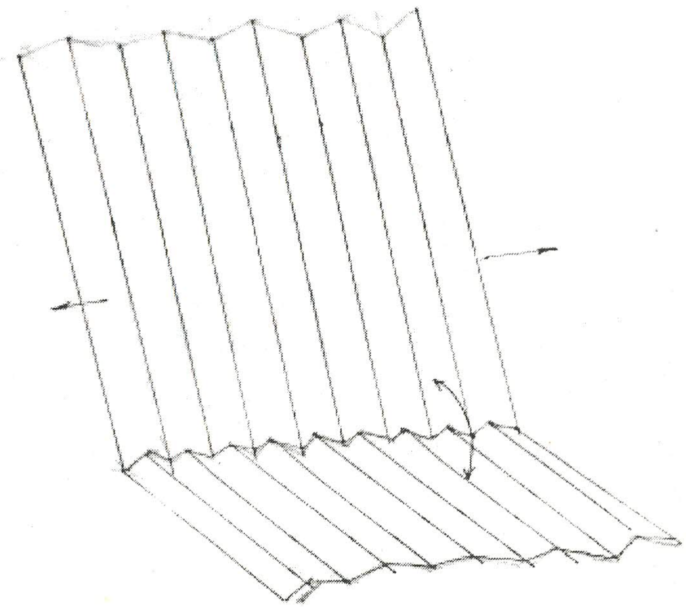
Concepts and Applications

Inspiration from the growth:

The petal of the flower of hibiscus opens and grows simultaneously. The petal curls as well as spreads at the same time. This action can be simulated using a paper folded structure. As soon as the paper is unfolded, due to the typical structure of the folds, the paper spreads in the lateral direction. The folds of the paper act as the strengthening elements for the structure to acquire that particular shape. They are analogous to the veins. The advantage of this method is that it has high ratio of surface area after expansion to the surface area before expansion.

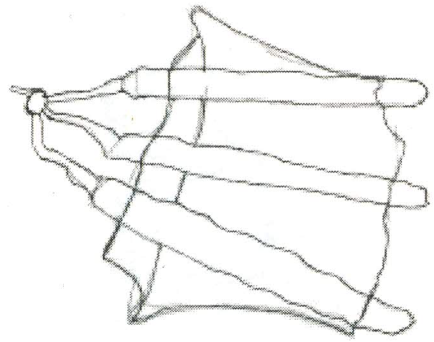
Applications:

The system can be used in folded structures for exhibition panels, in the low space requirement applications like space station solar panels and even temporary false ceilings for tents.



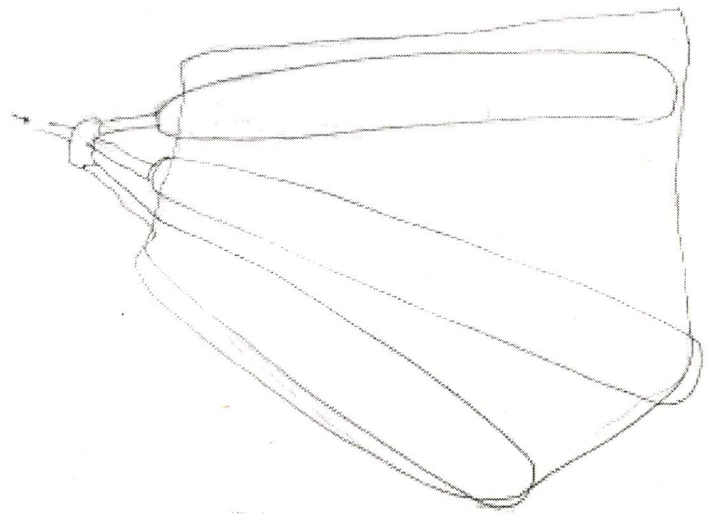
Inspiration from the vein functioning

The veins of the flower petal open up because of hydraulic action inside them. There are two activities happening at the same time, one being the growth of veins and the other being the expansion of the surface. Balloon functions in similar way where initially before applying the pressure, it has minimum volume, whereas when the pressure is applied, it takes large space and particular shape. This property can be made use of by tying a large folded piece of cloth or paper to the flat baloon. When balloon is blown, it will take certain shape.



Applications

This concept can be made use of in building temporary tents and display systems. The balloons if are filled with hydrogen, can fly in air.

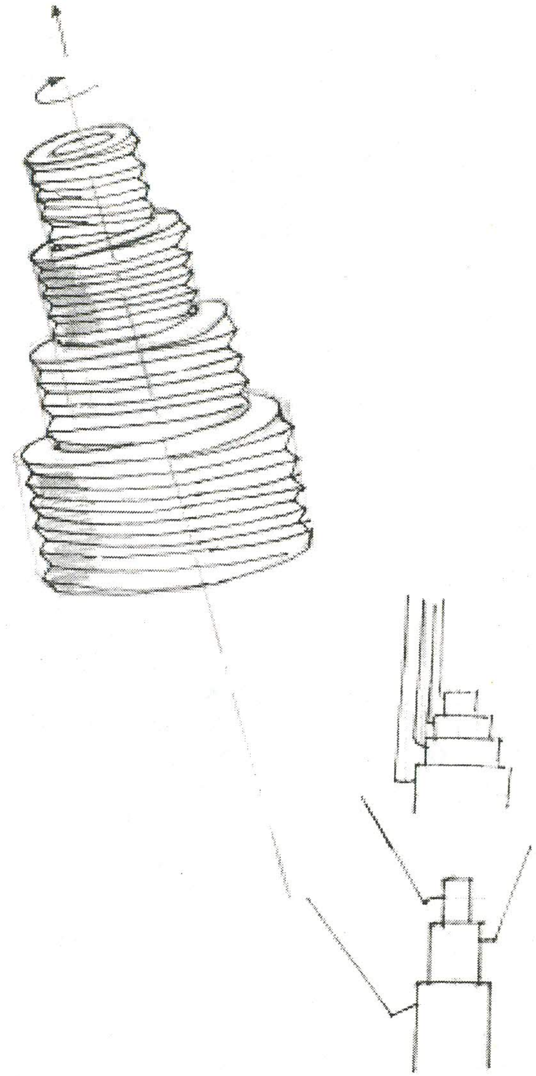


Inspiration from radial spread and growth

The flower petals in bud form are curled and are overlapping. When the flower opens, they start coming out of sepals, grow, turn and spread. When screws of same pitch are put one inside other, they open up in such a way that they rotate and progress axially. If some flappers are attached to the individual screws, in most closed condition they overlap, whereas in the open condition, they move axially as well as radially, forming a 3D structure.

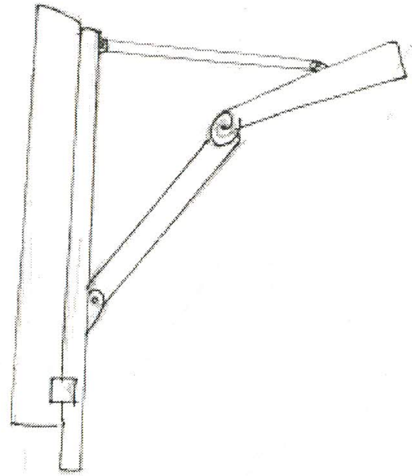
Applications:

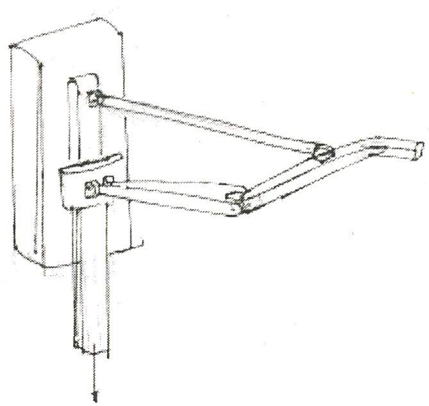
The radial structure can be used as display systems in fashion shops, even as furniture in a different environment. This system can be used in many machine related applications.



Direct analogous system of flower.

This is an application using the simplified model of the flower. This system can be used as a bracket on the wall, for umbrella etc.



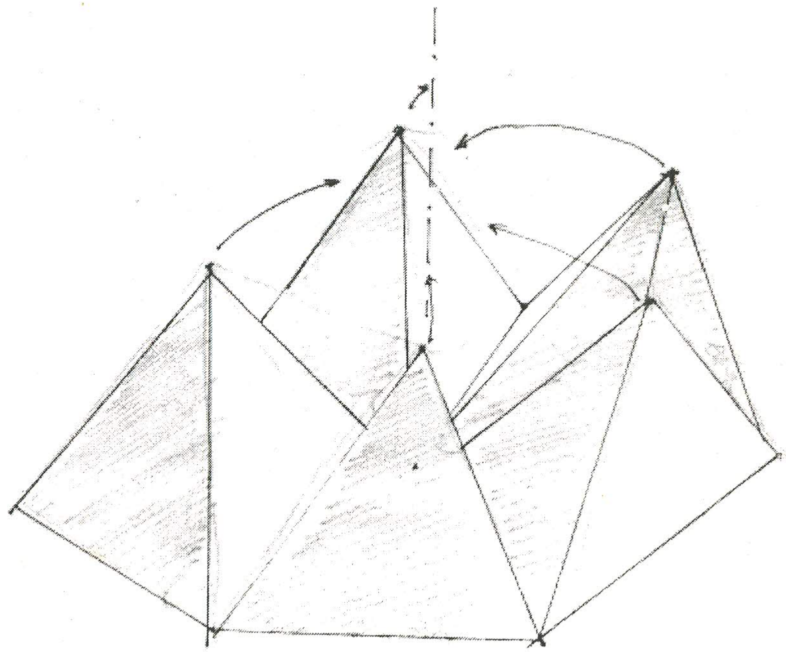


Inspiration from petal opening

The petals of the hibiscus open radially and spread. If paper is folded as shown in the adjacent figure, the system can open and close with respect to each other and take different forms. If the elements are used in large numbers, they will take more space.

Applications:

The idea can be used in areas like advertising system, display, furniture accessory (as stand), or even lighting systems.

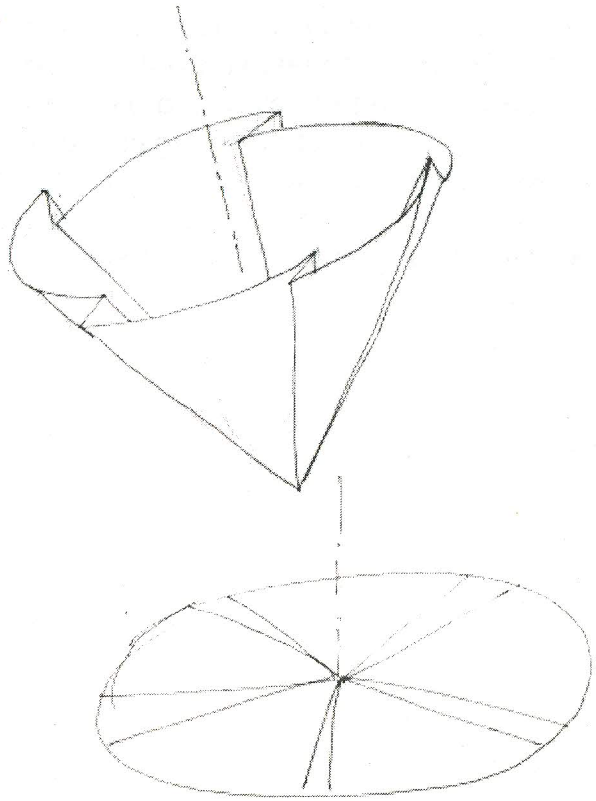


Inspiration from petal overlap:

The petals of the flower of hibiscus overlap and are hence compact. As soon as they spread, they separate and take large space. If a flat sheet of paper be folded in such a way that it folds and overlaps itself, the form of the paper becomes cone.

Applications:

The cone and flat form transition can be used in areas like a bowl and a dish (multipurpose), and light spreader.



Conclusion

The flower is a wonderful creation of nature. It has many facets. The more one understands its beauty, more is the knowledge that he finds is still to know. Flower has been found responding to the light condition, to the atmospheric vapor contents, to the biological clocks and particular atmospheric temperature. Some flowers are found in all seasons while some flowers open once in thirty two years. They have different colours, different scents, different forms and different ways of opening. They have medicinal, cultural and religious importance.

Each of these areas can be opportunities to exploit. Their behaviour in particular environment can give inspiration for making something which could solve our system problems.

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