Fruit Bionics or Bio-mimicry for Designers

a g rao

Back ground : In Late 60's I came across the fascinating book **'Synectics'** by W.J.J Gordon, which used many analogies from Nature to solve problems in man-made world. In 70's I got interested in 'Bionics' which manifested into 'Bio-mimicry' later. There are two varied meanings of 'Bionics', one used as an engineering translation from Nature and other engineering imitation to match biological replacements in Medical field like an artificial limb. However, the German equivalent of Bionics, i.e *'Bionik' always refers to broader meaning of developing engineering solutions from biological models.*
The word 'Bio-mimicry' which arrived later looks more appropriate for our task at hand.

In 1980, I was interested to study Bionics as a part of my UNESCO fellowship. Very little work on the subject could be seen in Design Schools in USA or Europe! A lot of work seems to have been done in 'Bionic studies' by U.S Army. But the information was not easily accessible. Much later I came across 'Work done at Milan in a polytechnic' which was inspiring.

My interest in the subject manifested into one-month project for Master of Design students in 1990. . Bionic discoveries like 'Bats' making use of 'Radar principle', were fascinating and caught everybody's imagination. Though we knew for long that bats could fly in darkness without hitting objects in their way, we had no idea of how they did it. We could understand the 'science behind' only after the invention of 'Radar' principle. There were hardly any new inventions claimed in man-made world which came out of specific study of 'Nature' as such. Most of the design innovations were based on ideas gained by linking metaphorically , 'Research' (Study and Analysis) done by scientists in their own specializations like Biology, Etholgy, etc,.

Even where claims were made that the new innovations came out of 'study of nature", there has been no *documentation of the methodology of the process*!

So it was a challenge to take up Bionic study to culminate into a 'new design' in the limited time frame of one month! Never the less I was keen and set a problem for the students.

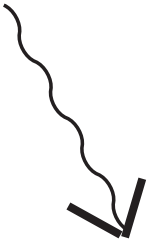
Problem posed

Design a Confectionery Package based on Bionic study of any fruit/nut. The package, to be made industrially, should reveal the unique ***'Geometry and Mechanism of protection'*** *in the fruit/nut. Children(user) should be able to retain the 'plastic fruit container' after eating the chocolate/confectionery as a collection!*

When we started the task we were lucky to get an energetic young, guest faculty from Brazil, **Dr.Luiz Vidal Gomes**. He had just completed his Phd in visual design in London! To my surprise I discovered that Luiz*(we became good friends in no time)* had attended 'one month workshop' at the Milan Polytechnic on Bionics. He introduced to our students a technique to make a visual presentations in an inexpensive butter tracing paper to show the analysis of the geometric structure of the fruit.

The first phase was to comprehend the 3D geometry of the fruit and document it

Twelve fruits were taken. Each student started looking at the 3D geometry of the fruit which was not obvious. Some fruits like 'Pineapple had an interesting structure. Soon the student discovered a 3D geometrical unit(akin to a pyramid) inside which manifested as a 2D tessellated unit, on outside.



Then the next question I put was:

"Can you find the unique property and feel of the skin/cover/ shell of the fruit?
How is it 'peeled, broken or opened?'

A Zen-experiencing of the fruit was required here!

Some students got on to it.

Mandal discovered how walnut is broken if you hit it on the centre line. He could see the beautiful organic binding of the nut-shell with the inside content.

So the next step:

Can we simulate the natural material and the mechanism with man-made materials and processes?
Abstraction rather than the direct imitation was the key for a good solution.

Essentially the task was to see the principles of good design in a fruit as a package for preserving and protecting its contents and
Abstract the geometric structure out of its organic construction which is not visible at first sight.

Careful observation was required. One also has to observe the 'Human(or animal/bird) practice' of interaction with the fruit/ nut..

How do we break open it to eat the contents?

Almond Eating Experience

I generally introduce an experiential session to bring attention and magnification to the process. It is called `*Badam Chapana*' *or 'Almond Chewing'*. I give an almond to each student and ask them to hold it in their hand and imagine/ visualise chewing it without actually eating it.

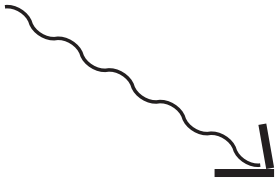
Then they are asked:

Are you able to imagine and recall the aroma of Almond?
Do you recall the texture as you ate?

After this they actually eat the Almond slowly and experience the eating!

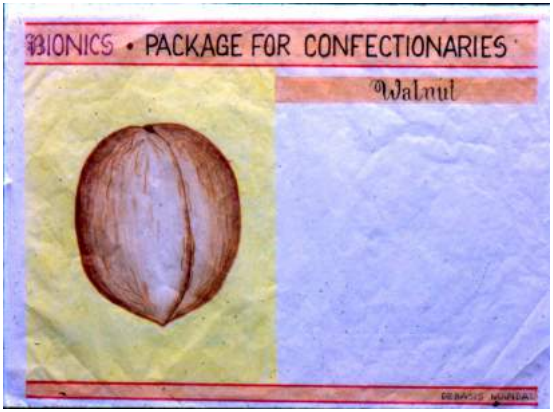
Most of my students still remember this exercise even after 15, 20years!

Translating the abstraction demanded an innovation in understanding materials and manufacturing processes. Since the product was to be designed as a consumer product, Aesthetics and ergonomics found their place!



Let us look into details of each solution.

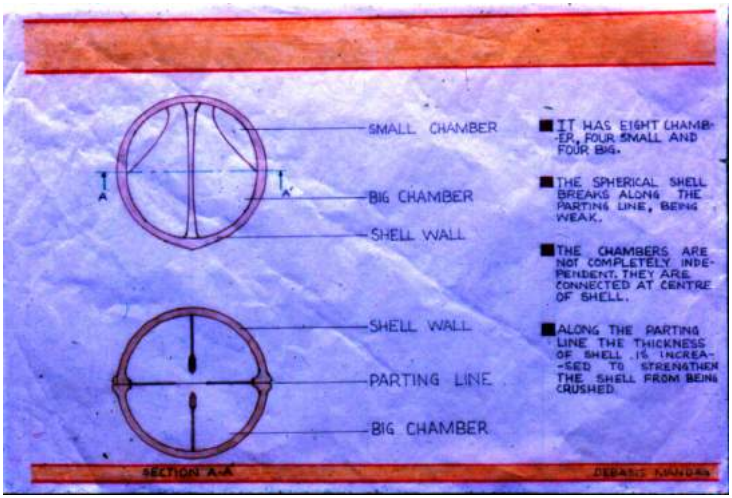
A reflection based on the creative approaches adopted in the solutions could help us to identify the tacit rules behind.



Walnut1

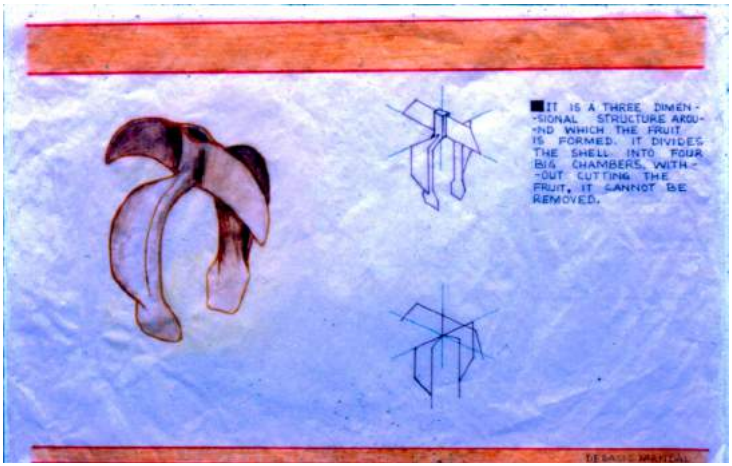
student: Debasis Mandal

Mandal's engineering mind quickly abstracted the inside structure and decoded the unique mechanism of the Nature which allows the clean breaking of the shells into two halves with a mild hit on the centre line.



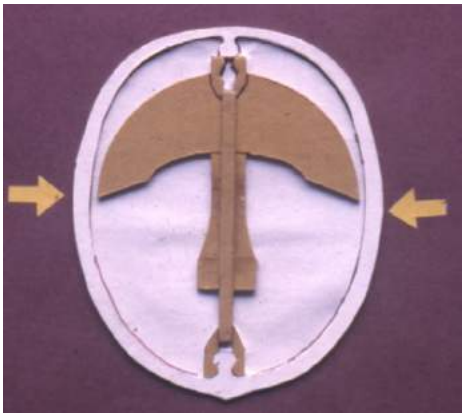
His observations in the diagrams

1. It has eight chambers, four small and four big.
2. The spherical shell breaks along the parting line, it being weak.
3. The chambers are not completely independent. They are connected at the centre of shell.
4. Along the parting line there is increased thickness of the shell to strengthen and prevent the shell being crushed.

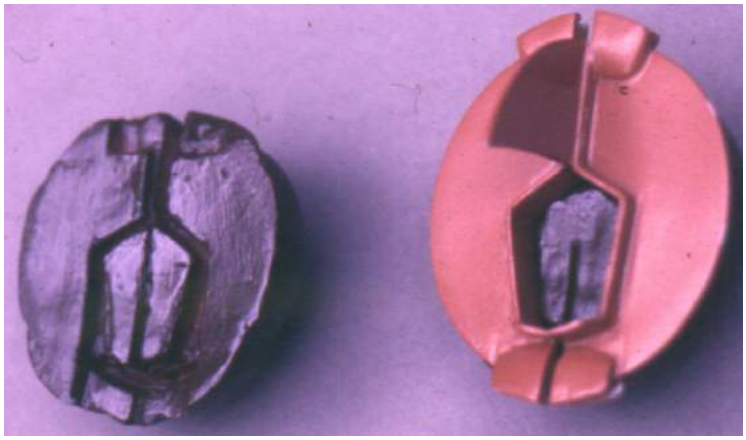


It is three dimensional structure around which the fruit is formed. It divides the shell and four big chambers. Without cutting, the fruit it can not be removed.

Debasis (Mandal) came up with an innovative, patentable package to be made in ABS or polystyrene by injection moulding. The chocolates in the shape of walnut kernels could be kept inside.

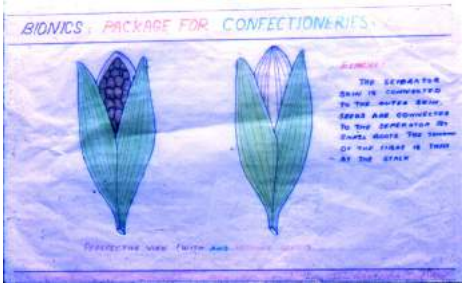


An innovative snap lock inside felicitates opening of the package. It was derived from the organic binding inside walnut .Just like the natural walnut the package opens by pressing/tapping on the middle line.



Elaichi1 (or Cardamom)

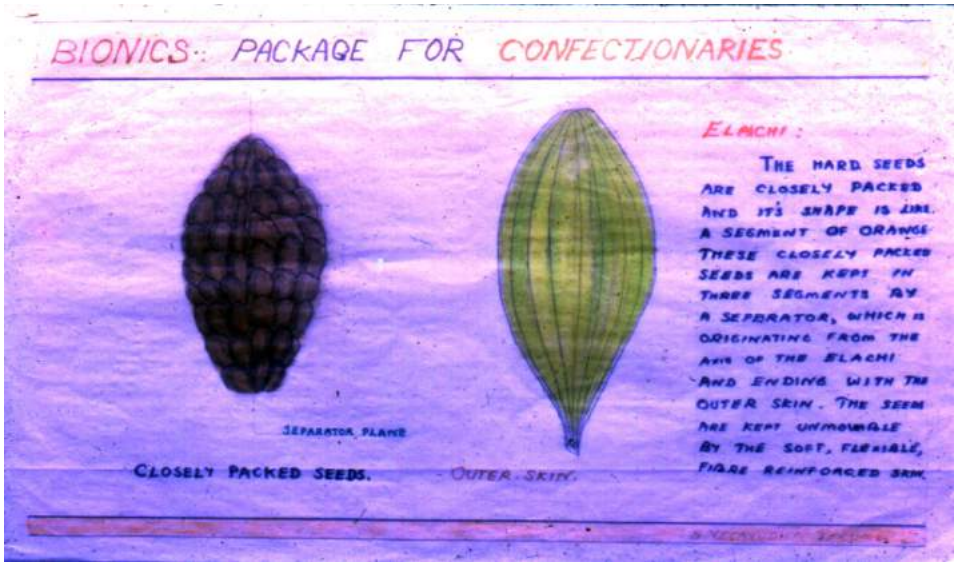
student: Velayudhan Perumal(VP)

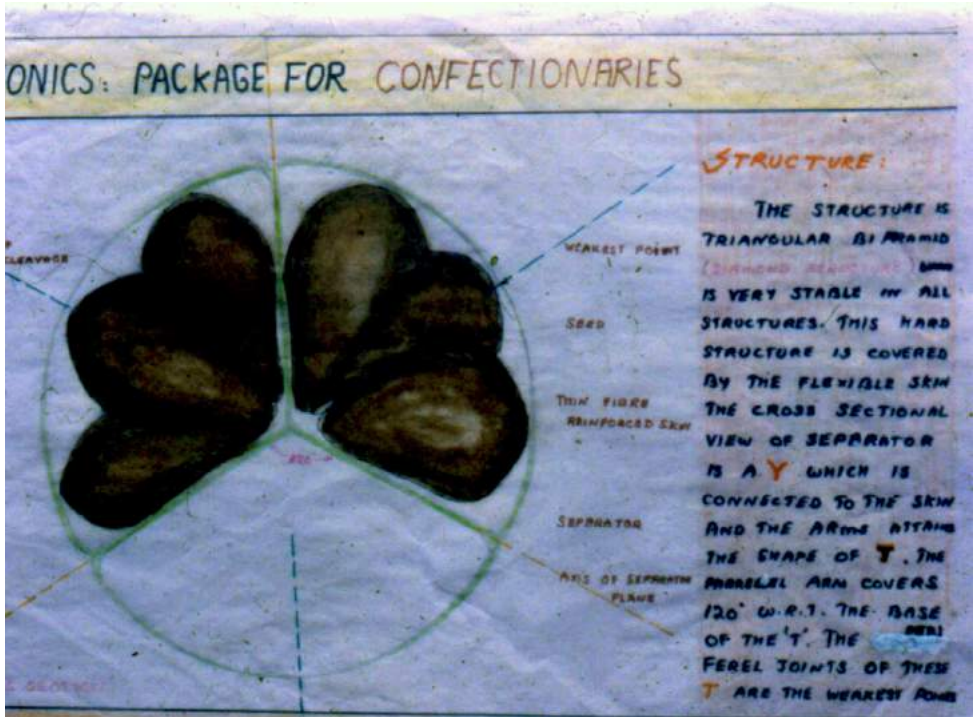


Observations by VP

- The separator skin is connected to the outer skin. Seeds are connected to the separator by small roots. The thickness of the fiber is thick at the stalk
-
- The Hard seeds are closely packed and its shape is like a segment of orange. These closely packed seeds are kept in three segments.

- A Separator is originating from the axis of the elaichi and ending with outer skin. The seeds are kept unmovable by the soft, flexible, fiber reinforced skin.





Structure.

The structure of the triangular Pyramid (Diamond structure) is very stable among all structures. This hard structure is covered by the flexible skin. The cross sectional view of separator is a Y which is connected to the skin and the arms attaining the shape of T. The parallel arms cover 120° with respect to the base of the 'T'. The peripheral joints of these 'T' are the weakest points.

Solution

In the proposed Bionic design, the cover derived from the soft peeling experience of a cardamom/elaichi was unique! Innovation of 'thin wire reinforced paper' gave similar 'feel of actual cardamom-peel' and it is possible to use it again and again. In effect this can result in an Innovation :

a new material WRP(Wire reinforced paper) akin to FRP (Fiber glass reinforced polyester)

Elaichi3

Elaichi 4

VP created a central rigid structure in moulded plastic. Chocolates rested on this structure.

The package without covers

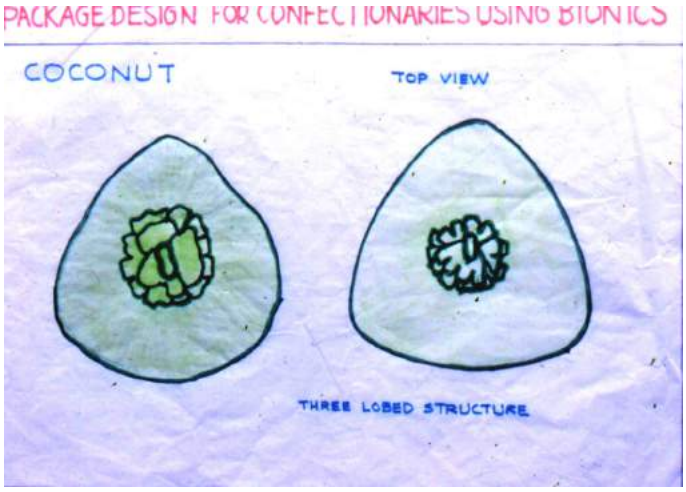
Coconut1

Student : N.Simha

Observations and Analysis:

Coconut has an outer cover with fibrous filaments (which is converted into coir) which protects the inside shell.
The inside shell is hard . It has to be broken to get the white pulp to eat. There is coconut water inside which is tasty and nutritious. In tender coconuts the inside shell is still thin and the water content is high. As it matures the shell becomes thicker with a thicker, dense layer of pulp.

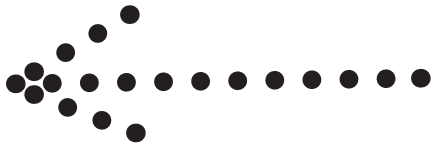
- Traditionally outer pith is cut open and removed. For religious offering the shell retains a portion of pith to act has a handle,symbolically.
- The hard shell is broken by hitting on a stone.
- It is also broken with a knife when large number of coconuts are to be dealt with.



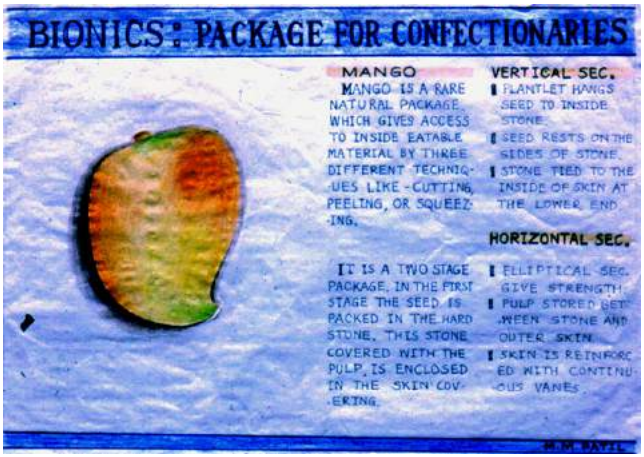
Coconut2

Solution

Simha came out with a unique solution. He had a package at two levels. One to represent the outer fibrous material. It was geometricized to look like an actual coconut built in three parts with thermocol(foamed polystyrene).
Inside was an injection moulded package to host the confectionery.
What is unique, is the metaphoric inspiration he took from its nature of breaking. The coconut shell is made of reinforced fibrous material. It has a tendency to break into irregular shapes. Simha shaped the container with irregular geometric parts which became a unique solution. The mode of opening of the container was also inspired by Indian practice of breaking a Coconut.
His inside package has to be opened by hitting on a hard surface and it breaks into irregular geometric parts.
He broke the conventional horizontal/vertical-parting line which is chosen for economic reasons.



And what a Fun it would be for kids to break a chocolate box by banging on a hard surface!

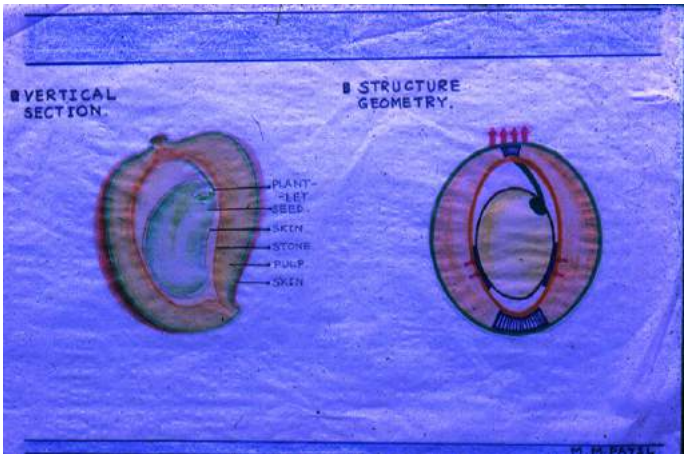


Mango1

student: M.M.Patil

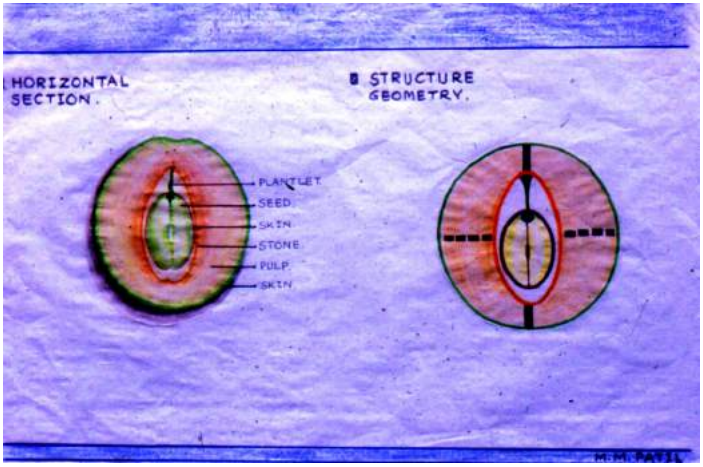
Observations and Analysis:

Mango is a rare natural package which gives access to inside eatable material by three different techniques like – cutting, peeling and squeezing. It is a two stage package. In the first stage the seed is packed in the hard stone. This stone covered with the pulp is enclosed in the skin covering.



Vertical Section

- Plant-let hangs seed to inside stone.
- Seed rests on the sides of stone.
- Stone tied to the inside of skin at the lower end.



Horizontal section

- Elliptical section gives strength.
- Pulp stored between stone and outer skin.
- Skin is reinforced with continuous vanes.

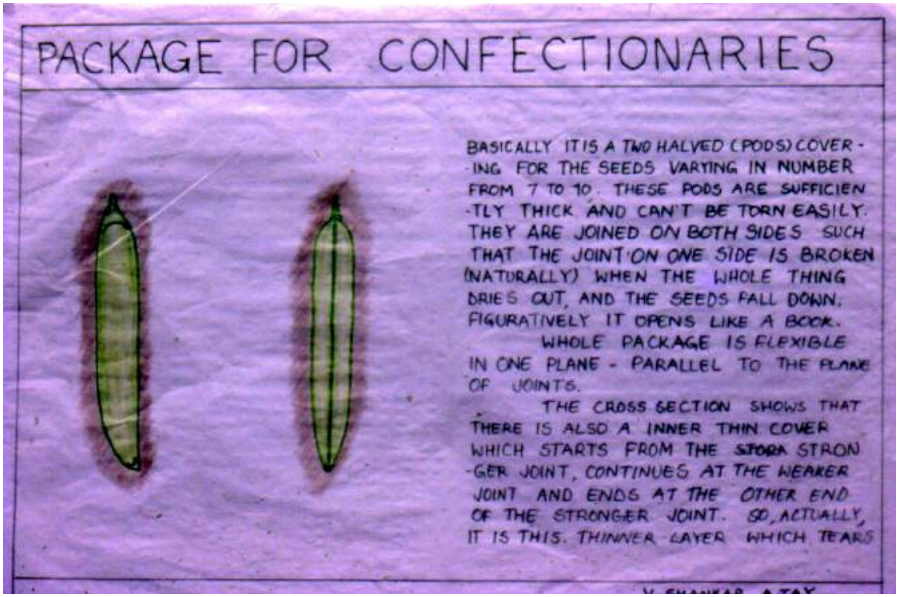
Final Solution

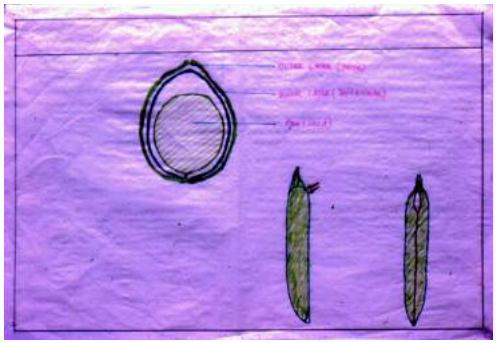
MM Patil's solution had a thin rigid plastic shell for the outer cover looking like a mango, with a stem at the top to hold. It had two parts divided in the middle. Interesting part was the shell opened with a squeezing action. Inside was a chocolate resting on a plastic base representing the seed.
It is a practical, mechanically feasible solution. Form chosen for the 'squeezing action' needed a better response. Mangoes are of many types. Only few types are squeezed to get the juice. The squeezing types also have a softer form, often green in colour. The solution seems to depict the firmer type which are cut and eaten.

An inventive eye, relating 'form' to the chosen action(ie squeezing) perhaps could have given more challenging framework for design innovation!

Pea pod1

student: Ajay Shankar





sectional views

Observations and Analysis:

Basically it is a 'two halved (PODS) covering' for the seeds varying in number from 7 to 10. These pods are sufficiently thick and can't be torn easily. They are joined on both sides such that the joint breaks(naturally) when the whole thing dries out, and the seeds fall down. Figuratively it opens like a book. Whole packaging is flexible in one plane parallel to the plane of joints The cross section shows that there is also an inner thin cover which starts from the stronger joint, continuous at the weaker joint and ends at the other end. It is this thinner layer which tears and opens the Pods. The most common way of opening results in a gap and using the gap the rest of the joint is peeled off.

Pea pod2

Solution

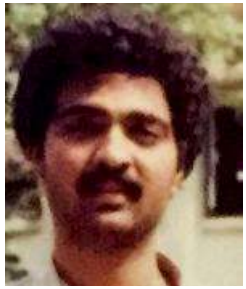
Ajay Shankar had a good observation of the opening of a pea pod. His metaphoric link to the opening of a book is interesting.

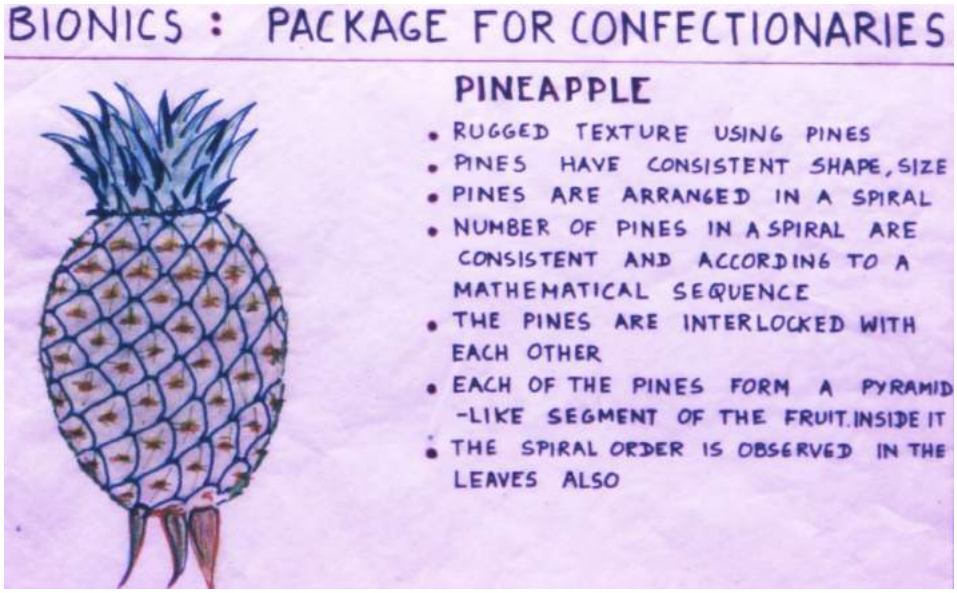
Experiencing with an 'Intension' prepares the mind for a creative jump.

Unconscious mind starts operating and metaphors/ analogies are picked up.

'Looking for the uniqueness in your fruit/nut suggested as a method' can act as a trigger.

Ajay also discovered a plastic detail to facilitate the opening with a small sound,.
The pea pod package gives 'Tup- sound' when pressed at one end, which makes it very interesting.





Pineapple1

student: Hingorani

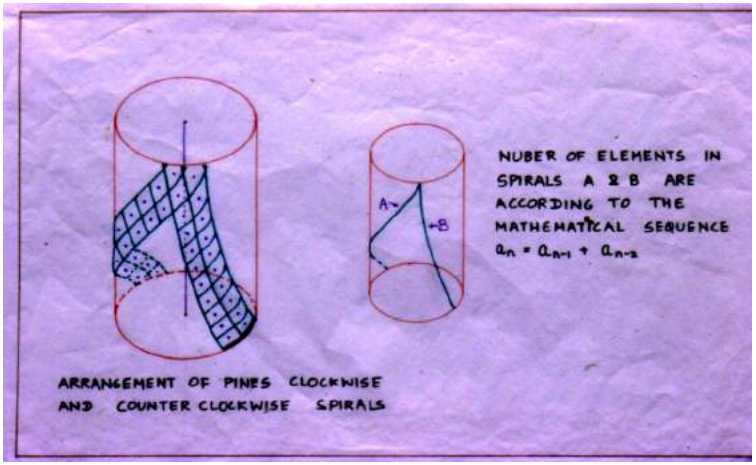
How do we look at the Pineapple with a new eye was the challenge in the task. The fruit has a beautiful pattern with uniform modules arranged in a spiral. So the first level of looking at is to see the 'Geometry' in the fruit. Then like a Biologist you can dissect it, see inside and decode the geometry.

This is what Hingorani did. The horizontal slices we cut to eat a pineapple do not reveal the 3D geometry so well.

Hingorani's observations

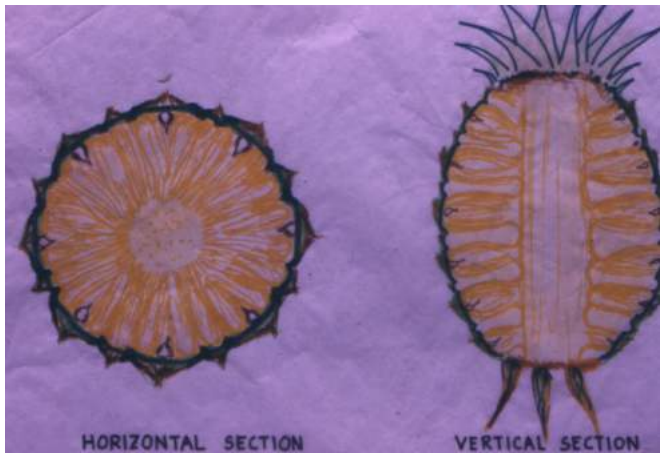
- .Rugged Texture using pines
- Pines have consistent shape, size
- Pines are arranged in a spiral
- Number of pines in spiral are consistent and according to a
- Mathematical Sequence.
- The pines are interlocked with each other
- Each og the pines form a pyramid like segment of the fruit inside
- The spiral order is observed in the leaves also.

Pineapple2

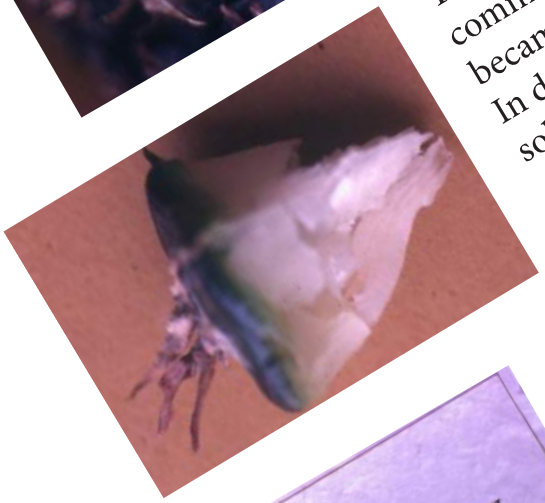


Hingorani described the analysis as seen above. He further decoded the 3D geometry and made a diagrammatic representation .

Abstraction as 'diagram' is an important process in any creative endeavour.



Somehow he did not connect the math sequence to Fibonacci series and its relation to golden proportion.
The number of spirals in the particular pineapple seems to be 8 which is 'Fibonacci' number in Fibonacci series: 1,1,2,3,5,8,13,21,.....
Each number is derived by adding previous two numbers and the ratio between the two adjacent numbers after 8 tends towards a constant number, called golden ratio/ proportion(1.618).



Pineapple3

The pine and its shape is commonly not known. So it became an important focus point for design. In design learning 'ability to see a potential solution demands *abductive reasoning, a kind of intuitive logic based on aesthetic sensitivity.*

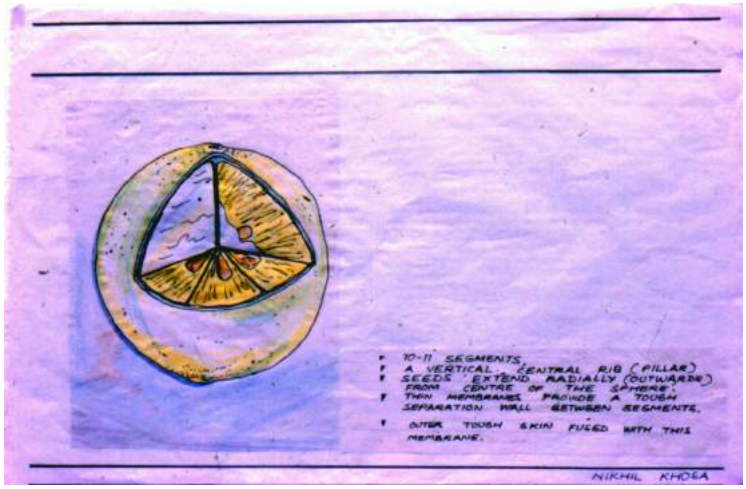
Here comes the role of a 'teacher' to point out ' to see' if the student has not yet seen and encourage him/her to proceed in the direction of right solution.

Often a teacher as an experienced designer is able to visualise the solution with in the constraints of product use, available materials and processes as well as broader significance

Generally a good teacher's role is to catalyze the thinking of the student rather than helping by giving a solution!

Pineapple4

The final solution was a pineapple shell in plastic in which the eatable confectionery can be placed. Each 'cone' becomes a unit to take out and eat.
children can store the container as a collection



But is the element of surprise was missing?

Lemon

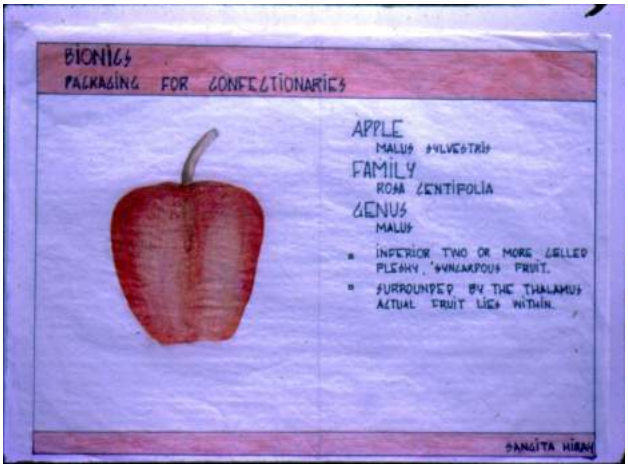
student: Nikhil Khosa
Observations and Analysis:
1. 10-11 segments.
2. A vertical central 'Rib' (Pillar)
3. Seeds extend radically (Out wards)
4. Thin members provide a Tough separation wall between segments.
5. Outer thick skin fused with the inside membrane.

Nikhil Khosa's solution was a plastic container looking like a lemon. He had adopted the geometric arrangement.
It was an adequate response to the 'brief'.
It served the objective.

The uniqueness of lemon experience of squeezing to get the juice or the pungent taste on the tongue of the juice did not seem to play any part in the solution.

Such solutions bring in provocative thoughts.

Will a computer with an artificial intelligence be able to come with a similar design?



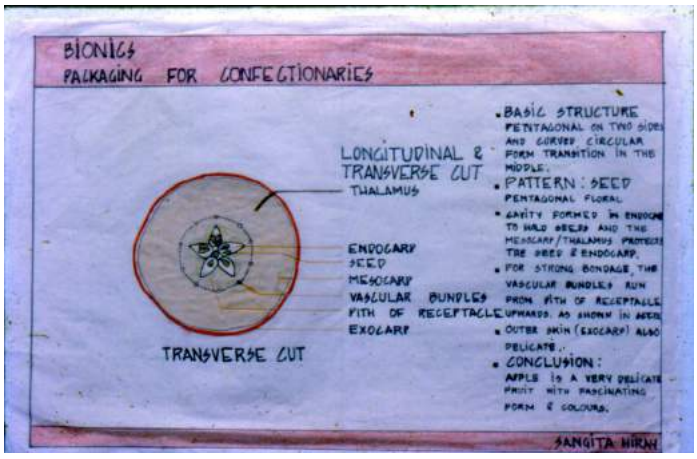
Apple1

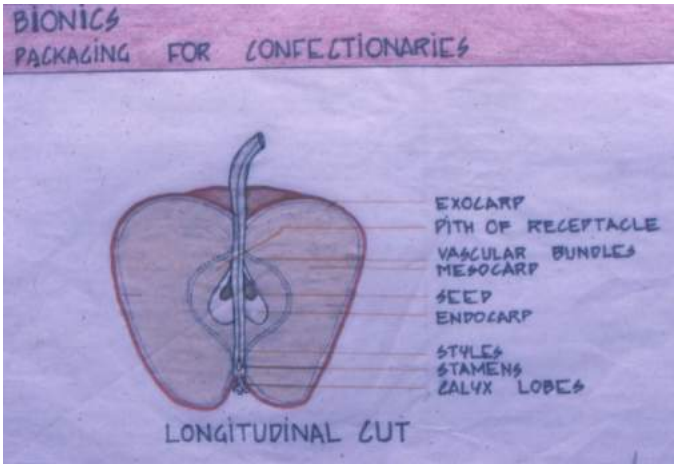
student: Sangita Hiray

Observations and Analysis:

Basic structure.
Pentagonal on the sides and curved circular form transition in the middle.

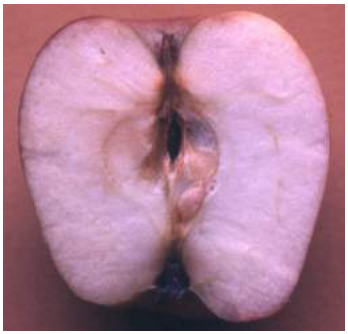
- Pattern : Seed Pentagonal Floral
- Cavity formed in 'Endocarp' to hold seeds and the endocarp.
- For strong bondage the vascular bundles run from pith of receptacle upwards as shown in dots.
- Outer skin (Exocarp) also delicate conclusion.
- Apple is a very delicate fruit with fascinating form and colours.

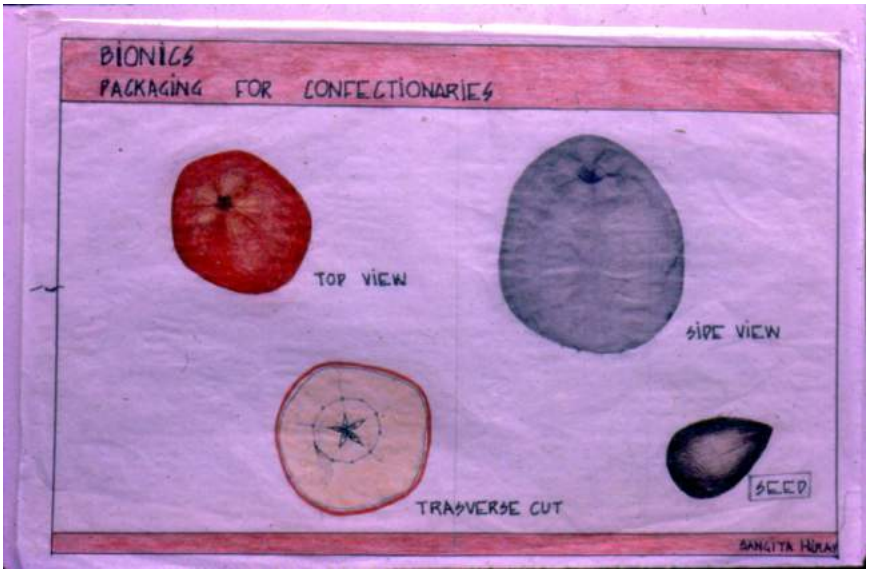




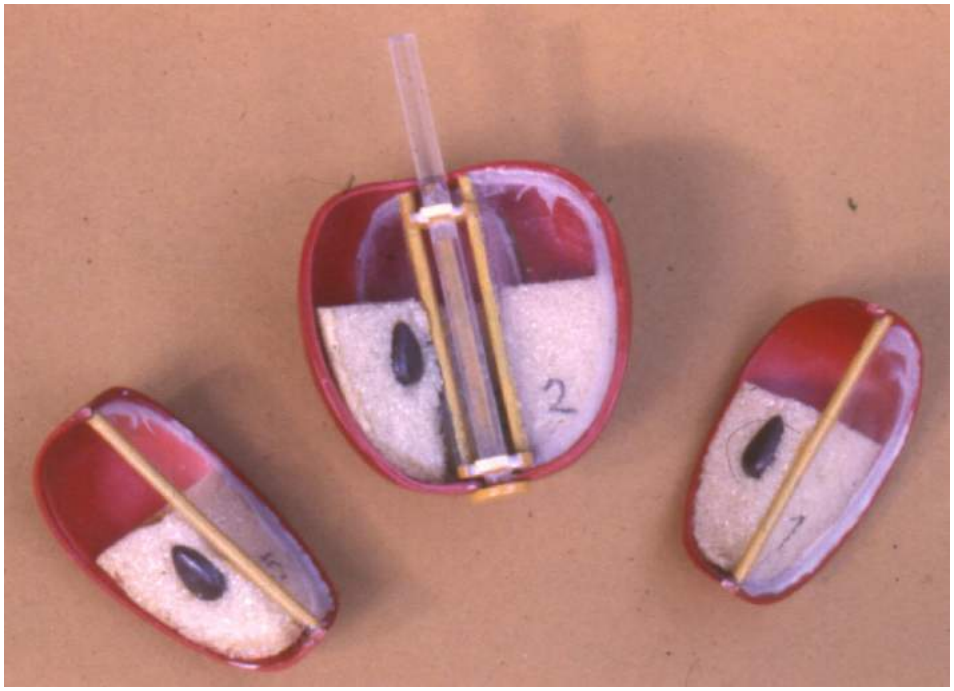
There is 3D geometry of the apple which engaged the designer.

If one does not penetrate the unique property, of eating, cutting, ... which has the encoded, unseen property one is likely to ***miss the opportunity to discover the element of Surprise!***





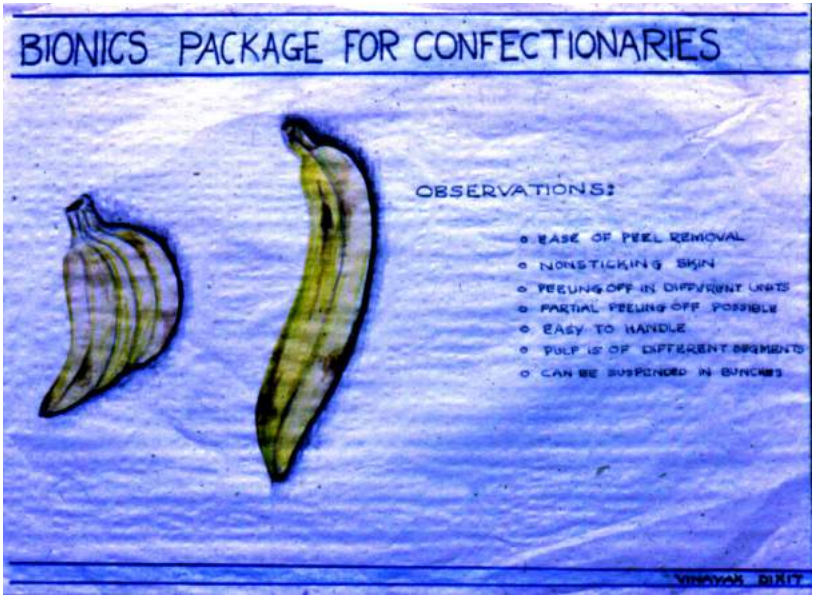
Apple2



Solution

Sangita tried to capture the unique pentagonal geometry of seed placement in an apple. She divided her package into 5 segments each segment housed a combination of white and black chocolate. The container looked like an apple.

Apple3



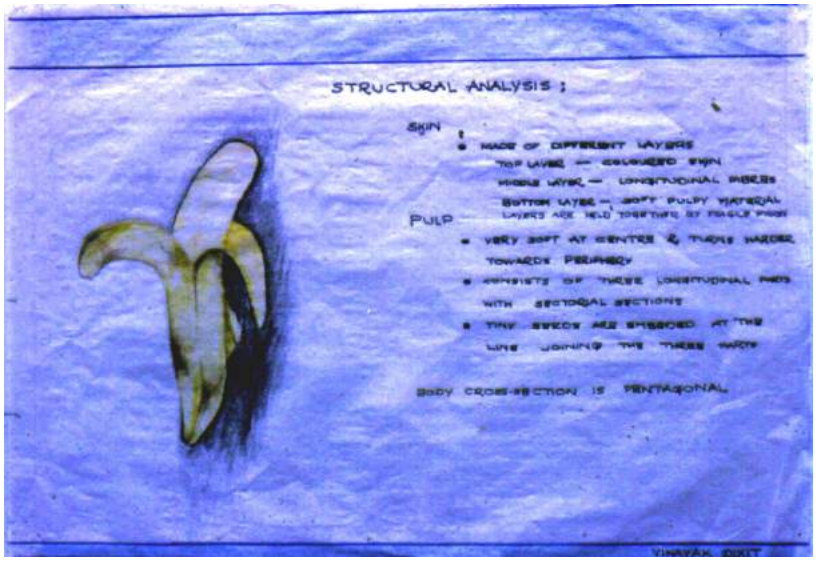
Banana1

student: Vinayak Dixit

Observations and Analysis:

- Ease of peel removal
- Non sticking skin
- 'Peeling off' in different units.
- Partial peeling off possible
- Easy to handle
- Pulp is of different segments
- Can be suspended in bunches

Skin Made of different layers
Top Layer – coloured skin
Middle layer – longitudinal fibers
Bottom layers – soft pulpy material lay-ers one held together by fragile fibers.



PULP

- Very soft at centre and turns harder towards periphery.
- Consists of three longitudinal parts with sections.
- Tiny seeds are embedded at the line joining the three parts. Body cross section is pentagonal

Banana2

Final Solution

Dixit addressed action of 'Peeling' . A rubberized joint simulated the action of 'banana peeling .The detail of the joint needed further refinement.
Here again we see the problem for designers. We are no match for 'Nature' which has evolved over millions of years!

So what is that a designer can do?
Look at with a magnifier!

Brain Storming originator, Alex Osborn's, 'Magnify' has a great relevance. Dixit's solution has brought attention to the possibility of a 'design innovation' in 'soft opening -joint'. Further application of design and development skills are required to bring in a refined solution suitable for mass manufacture.

The task could be taken up in a 'longer time frame'.

Orange

Student: Adurti Srinivas Rao

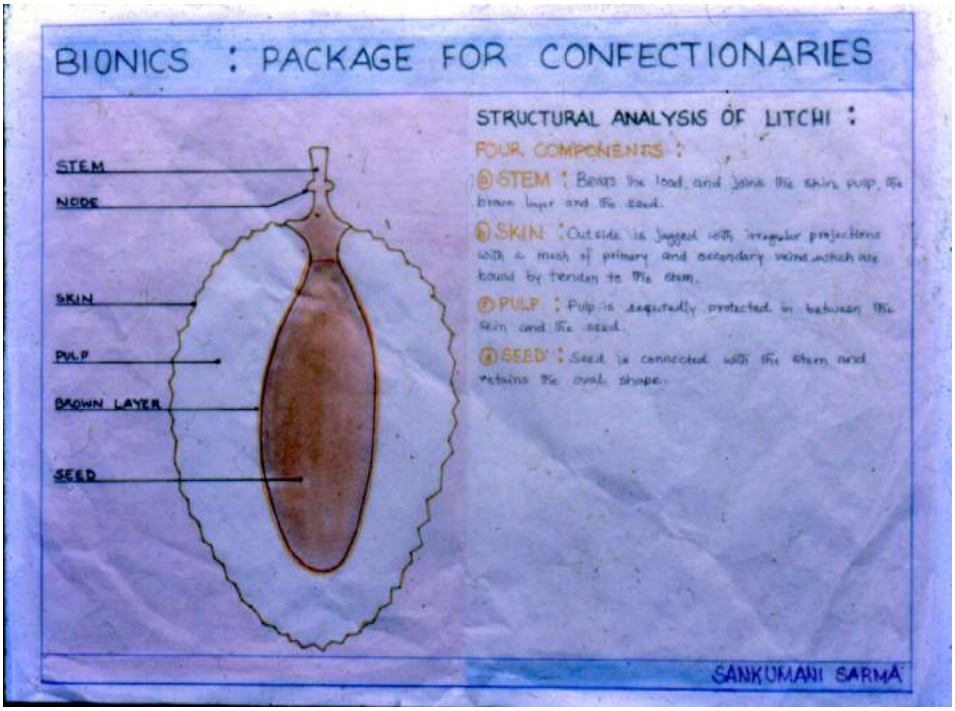
Adurti went through the analysis and made his observations, though his renderings done on tracings could not be traced!.
Final Solution addressed the unique property of orange peel! He tried to bring out the peel experience through foamed flexible plastic. He innovated pre-contoured inter locking units which make up the orange shape. But part of the peel also had organic form with complex contour which would be difficult to produce.

Skills of Abstraction, to bring in defined geometry become crucial in this context!
But the solution opened up a problem context for a 'design innovation' which could be pursued in a longer time frame!

Inside peppermints had a familiar shape of orange pulp segments which were inviting to eat!

Litchi1

student: Sankumani Sarma



Observations and Analysis:

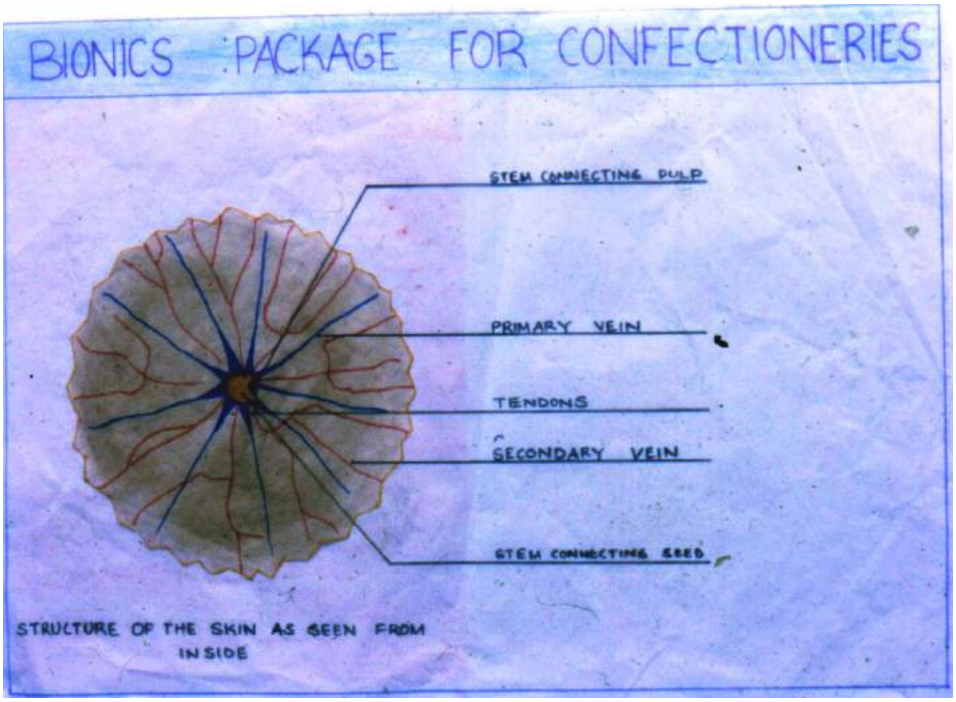
Four components.

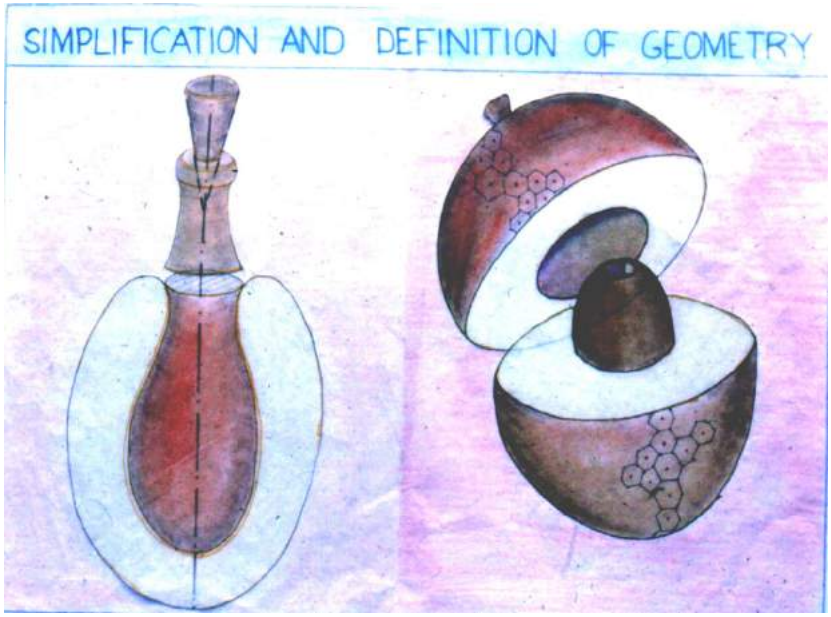
a. STEM : Beans the load and joints the skin, pulp the branch layer and the seed .

b. SKIN : out side is jagged with irregular projections with a mesh of primary and secondary veins which are bound by tend on to the stem.

c. PULP : Pulp is securely protected in between the skin and seed.

d. SEED : Seed is connected with the stem and retains the oval shape.





The fruit has a unique texture. It is peeled off or squeezed out after initial tearing of skin to eat the soft juicy pulp around the black seed which is not eaten.

Litchi3

Solution

Sankumani's solution tried to mimic the original rather literally. Outer plastic cover was textured similar to that in the fruit. Top plastic part locks the cover. The top part is pulled out to get the round shaped confectionery inside by squeezing the outer cover which has 4 cuts .
The focus stayed on the squeezing action, less attention being paid to the abstraction of the cover. A workable idea was demonstrated with fabricated PVC by vacuum forming!

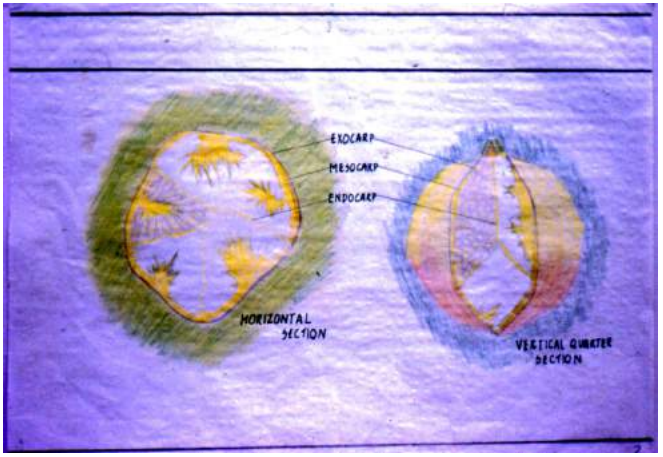
Here comes the demand for design skills, with knowledge of contemporary materials and processes. Bionic study provided a new context , with a demand and opportunity for 'product innovation'!

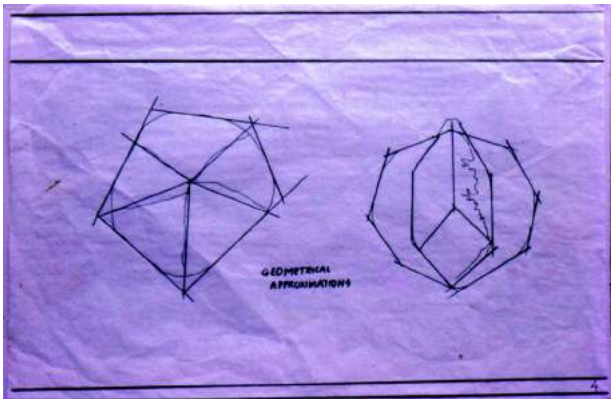
Further development in flexible plastic(or silicon rubber) could result in an attractive, user-friendly (injection) mouldable package!

Pomegranate1

student: Rajgopal

Pomegranate is a common fruit in India!
Its packaging properties are unique. It can remain fresh for weeks to months when not opened.

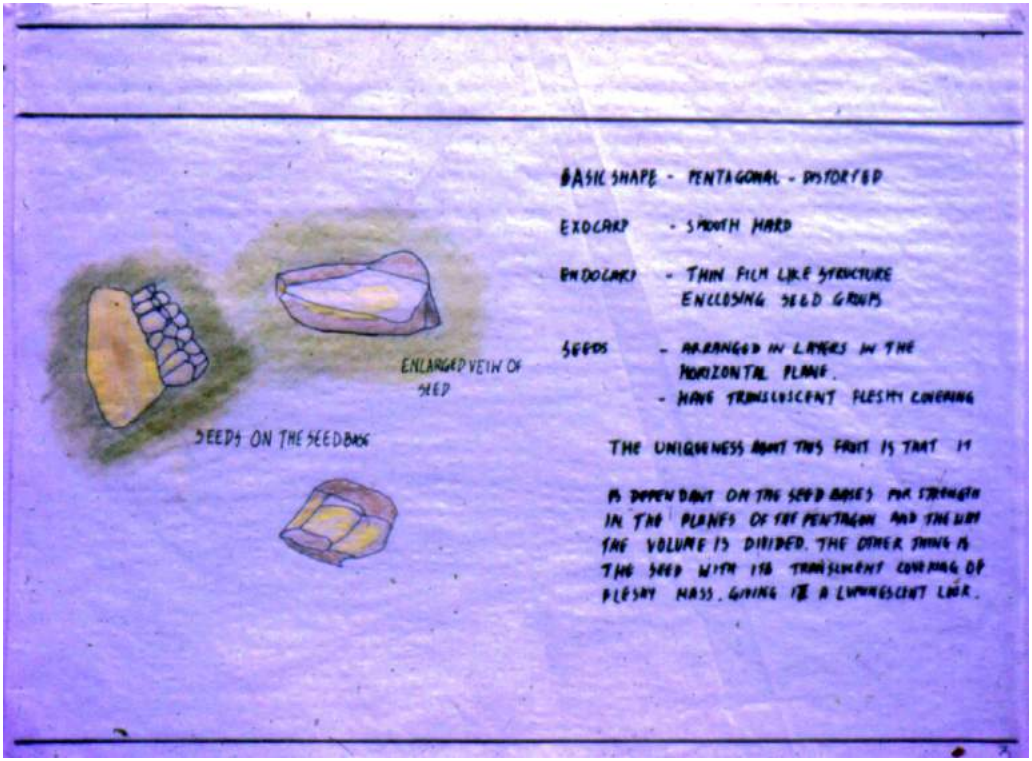


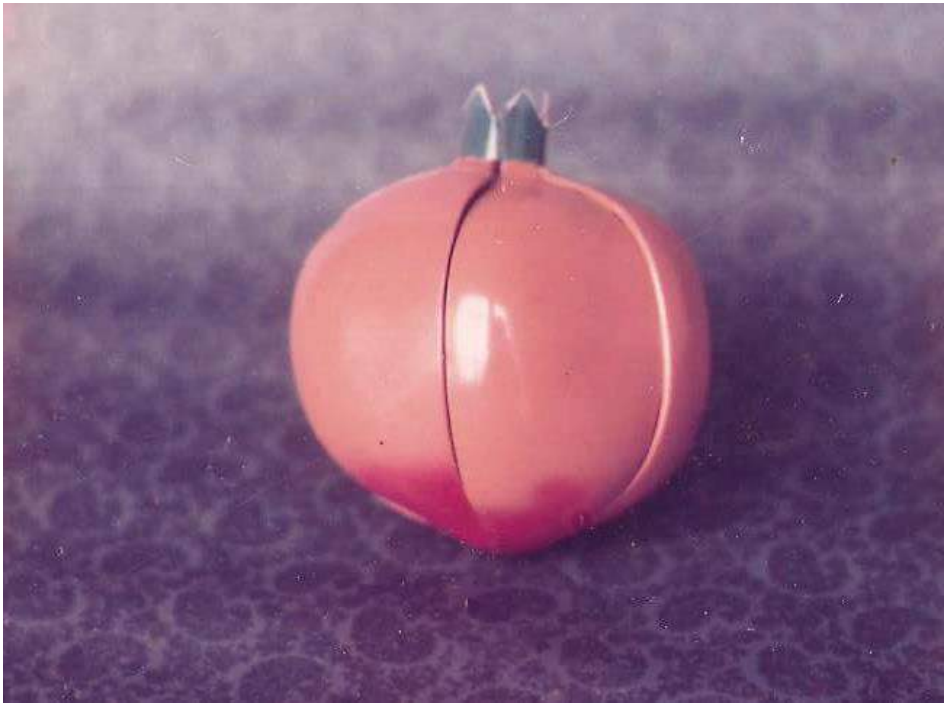


Observations and Analysis:

Basic shape – Pentagonal – Distorted
Exocalp : Smooth, Hard
Endo Calp : Thin film like structure enclosing seed groups.

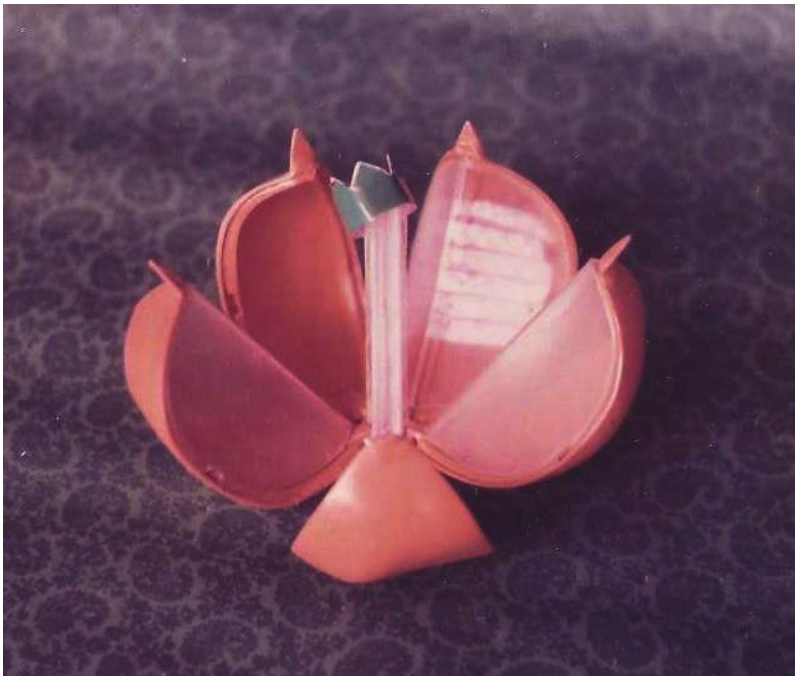
Seeds – Arranged in layers in the horizontal plane. Have transparent fleshy covering. The uniqueness about this fruit is that it is dependent on the seed bases for strength in the planes of the pentagon and where the volume is divided. The other thing is the seed with its transparent covering of fleshy-mass giving it a luminescent look.

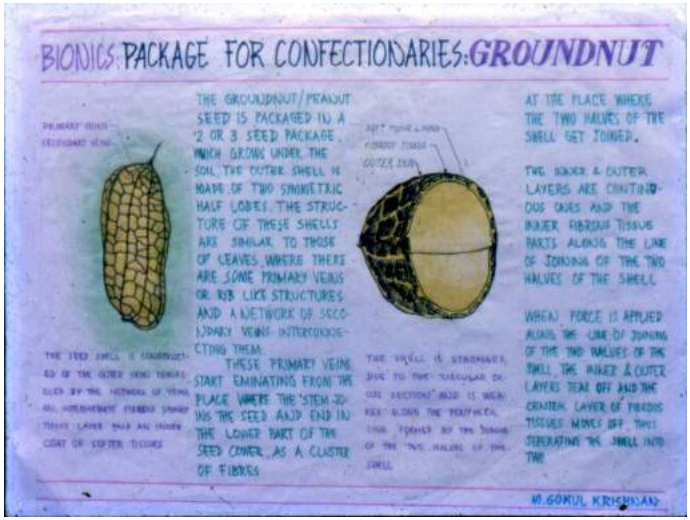




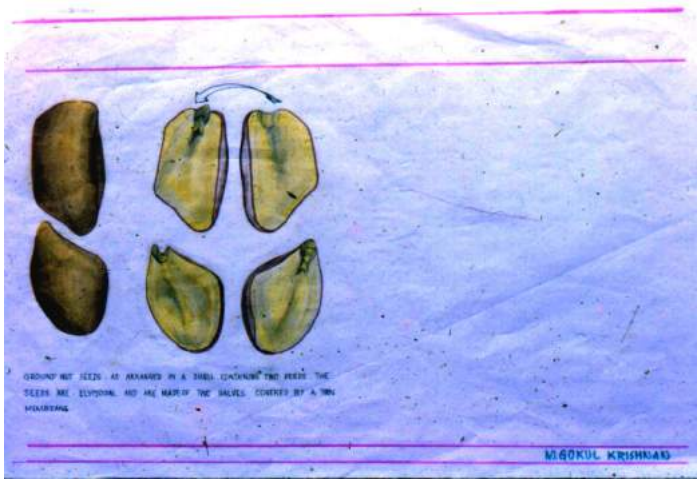
Solution

Rajgopal's solution got focused on its pentagonal geometry. The injection moulded package got divided into 5 segments, connected with a string to the centre. It was easy to open to get to the toffees inside.
The sophisticated, inside geometry was perhaps difficult to capture in the short time frame alloted to the project.





Pea-nut1



student: Gokul Krishnan

Observations and Analysis:

- The seed shed is constructed of the outer skin reinforced by the network of veins and intermittent fibrous spongy tissue layer and an inner coat of softer tissues.
- The shell is stronger due to the circular cross section and is weaker along the peripheral line formed by the joining of the two halves of the shell. The groundnut / peanut seed is packed in 2 or 3 seed package which grows under the soil. The outer shell is made of two symmetrical half lobes. The structure of these shells are similar to those of leaves where there are some primary veins or rib like structures and a network of secondary veins interconnecting them.
These primary veins start emanating from the place where the stem joins the seed and ends in the lower part of the seed cover, as a cluster of fibres at the place where the two halves of the shell gets connected
The inner and outer layer are continuous ones and the inner fibrous tissue parts along the like of joining of the two halves of the shell. When force is applied along the line of joining of the two halves of the shell the inner and outer layers tear off and the central layer of fibrous tissue moves off thus separating the shell into two.

Pea-nut2

Solution

Gokul based his package on the outside shell.
He adopted the unique texture on a injection moulded container. the eatable toffees were looking similar to peas inside. A snap joint which would open when pressed was suggested.

Reflections on Pedagogy

The challenge in 'Design Education' is to create right context for 'learning' at the required level of complexity for the group dealing with the problem.

The task needs to demand

- Imagination and application of creativity
- Empathy with the user, keen observation of the use of a product and reflection of oneself in the act of use.
- knowledge of material and production process
- knowledge of 3D Form (geometry)

For this task

- the student group was Mdes(Master of Design) students who had completed 1st year at IDC.
- All of them had a bachelor degree in Engineering or Architecture.
- They were well versed with solving given, defined problems.

Project frame work with one full month time was a special opportunity. We got excellent results with earlier batch which worked on telephones for a design competition by 'Sony'.
The problem I had posed had a demand for **'design research content**. Bionic studies done in Milan and elsewhere were being taken up in a longer time-frame. We had a challenge to bring out results in one month!

When this problem was given. There were two distinct responses.
Some (mostly with Architecture background) focused on the geometry of the fruit They looked for the 'geometry' of the fruit and converted it into a container! This approach produced workable, interesting package designs but operated in a limited, known semiotic framework.

Engineers were little lost in the beginning . Suggestion to consider 'unique experience' provided a new 'unknown frame' to them. Some looked at the mechanism of opening and others at the unique property of the material.

- Mondal discovered a unique mechanism in Walnut which helped him to come out with an 'Innovation' in his solution.
- Perumal invented a new material based on the cardamom cover which had a unique property.
- Simha brought in a break away geometric concept which opened the boundaries of injection moulding. The economy of keeping parting lines horizontal or vertical, is so established that only a novice engineer could break the boundary. That is what happened with Coconut!
- Ajay Shankar's solution for Pea-pod brought in an interesting way of opening a package based on a known locking detail in plastic. He effectively made use of the radius of pea- pod at the end to create an 'opening with sound' when pressed.
- Vinayak dixit's solution for Banana based package has the potential to come out with a 'new type of soft opening' using the material more effectively.
- Adurti Rao's package based on 'Orange' also has a potential of using 'soft or foamed ' material for the package. The 'curved geometry' in 3D, can act as a locking mechanism!.

- Shankumani Sarma's 'Lichi based package needed more exploration of the material used. The locking mechanism fell short of good design detail.
- M M Patil's Mango missed an opportunity of finding a solution based on soft sensuous squeezing experience of a 'Mango'.

Solutions for Apple, Lemon, Pomegranate and Pine apple were based on geometry of the fruit.
Only Pine-apple had revelation of unique mathematical property of geometry.
Solution for Lemon and pomegranate missed the opportunity to use the unique partitions in Lemon and Pomegranate.

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