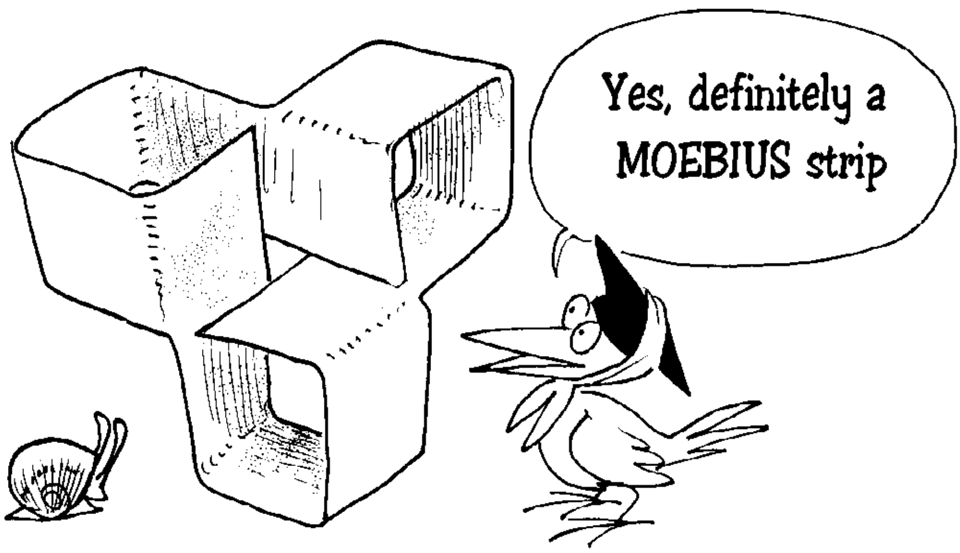
Knowledge without Border
(Ssavoir sans Frontières)

The Adventures of Archibald Higgins

TOPO THE WORLD

Jean-Pierre Petit



Translated by John Murphy

The Association Knowledge without Borders, founded and chaired by Professor Jean-Pierre Petit, astrophysicist, aims at spreading scientific and technical knowledge in as many countries as possible and in as many languages as possible. To this end, all his popular scientific works, which cover a period of thirty years, and more particularly the illustrated albums he has created, are now freely accessible. Anyone is now free to duplicate the present file, either in digital form or in the form of printed copies and circulate these copies to libraries , within the context of schools or universities or associations whose aims would be the same as the association , provided that they do not derive any profit from this circulation and that they do not have any political, sectarian or confessional connotations. These pdf files may also be put on line in the computer networks of school and university libraries.

Jean-Pierre Petit intends to create numerous other works which will be accessible to a larger audience. Even illiterate people will be able to read them because the written parts will “speak” when the readers click on them. Thus it will be possible to use these works to support literacy schemes. Other albums will be "bilingual" in so far as it will be possible to switch from one language to another selected language with a mere click. Hence another tool made available to develop language skills.

Jean-Pierre Petit was born in 1937. He made his career in French research. He worked as a plasma physicist, he directed a computer science centre, he has created softwares, he has published hundreds of articles in scientific magazines, dealing with subjects ranging from fluid mechanics to theoretical cosmology. He has published about thirty books which have been translated in numerous languages.

The association can be contacted on the following internet site:

http://savoir-sans-frontieres.com

Knowledge without Borders

Non-profit-making association created in 2005 and managed by two French scientists. Aim: to disseminate scientific knowledge using the band drawn through free downloadable PDFs. In 2020: 565 translations in 40 languages had thus been achieved. With more than 500,000 downloads.

Jean-Pierre Petit **Gilles d'Agostini**

The association is totally voluntary. The money donated entirely to the translators.

To make a donation, use the PayPal button on the home page:

http://www.savoir-sans-frontieres.com

PayPal
FAIRE UN DON

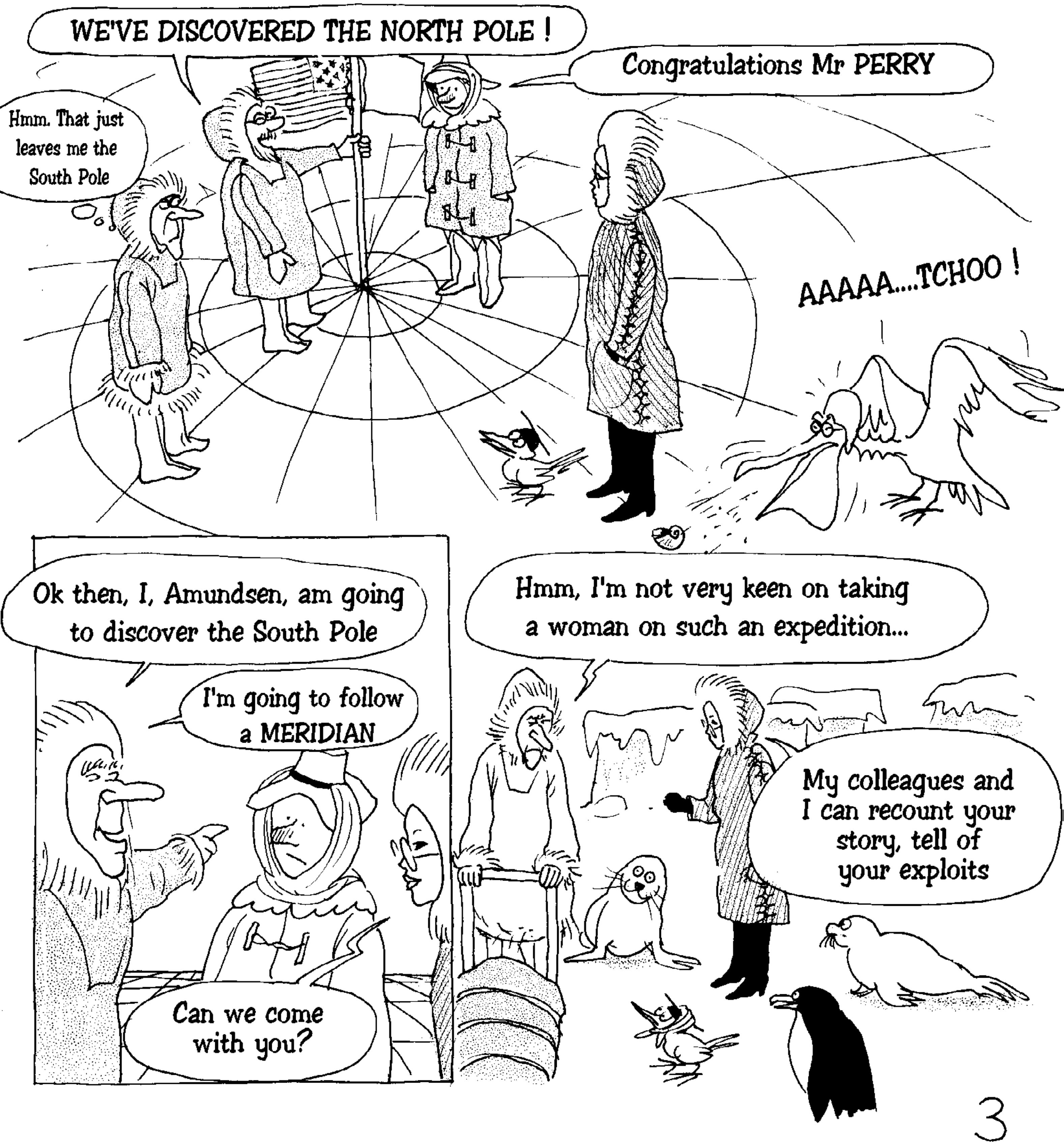
Warning to the reader

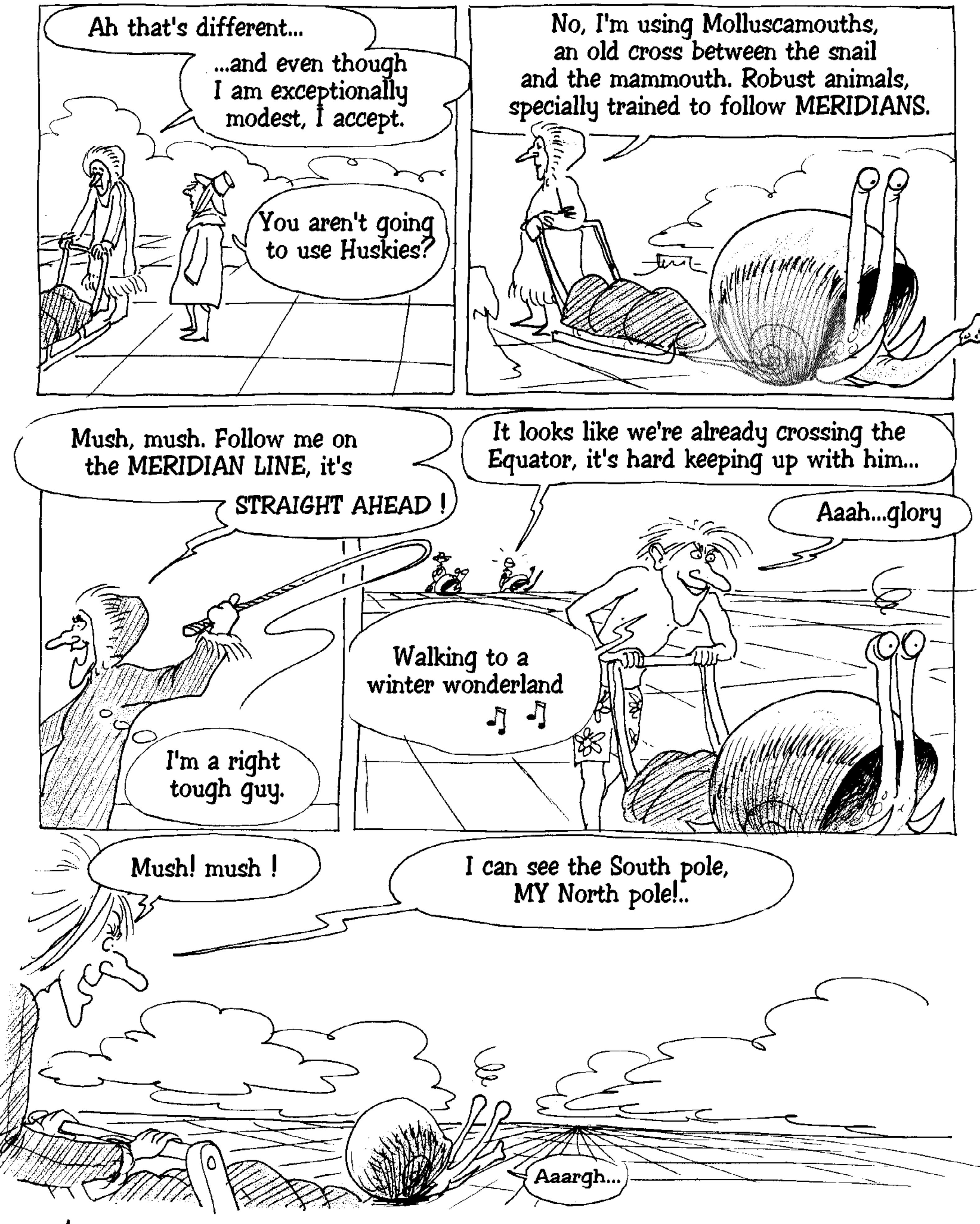
It si best to avoid reading this album :

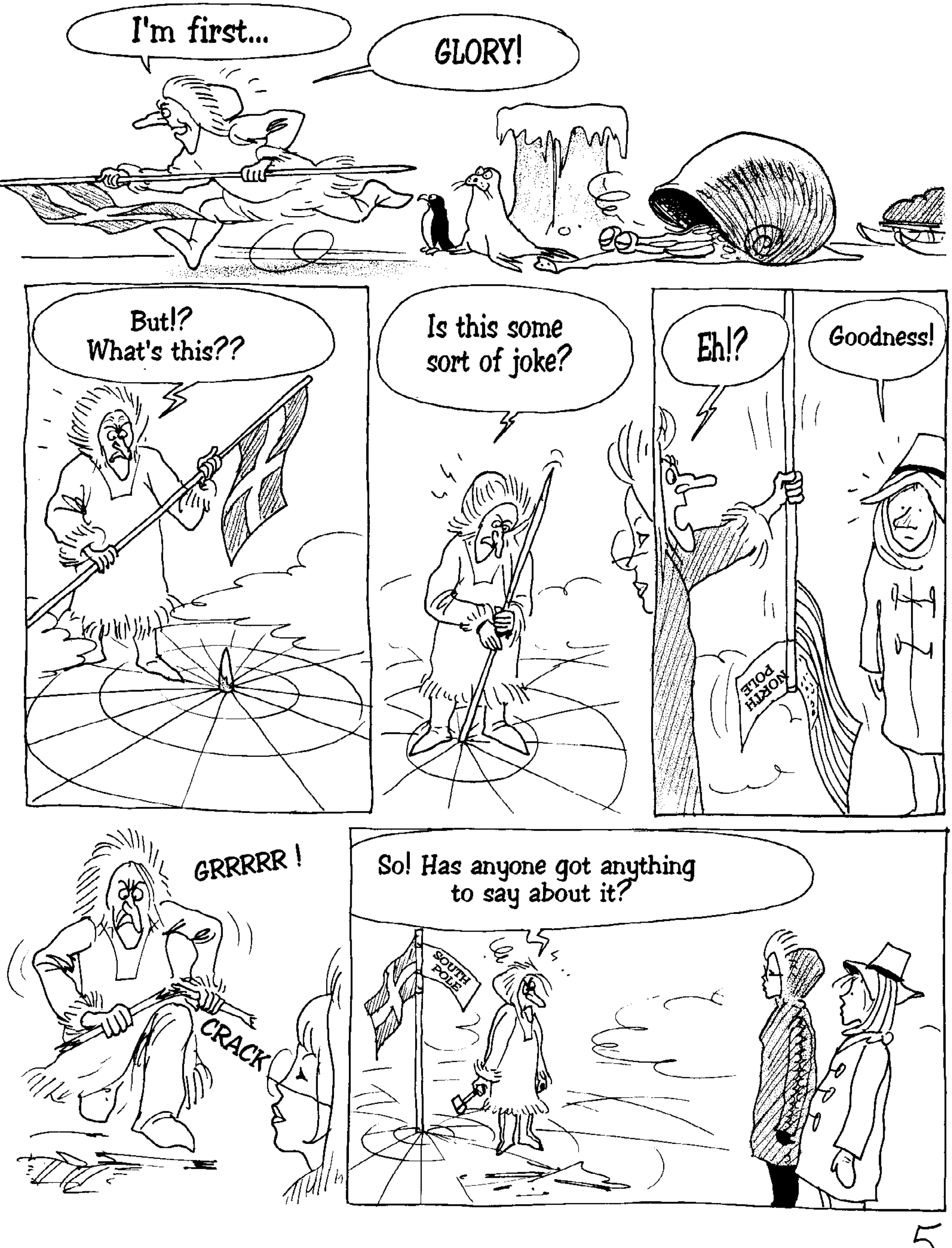
- In the evening before going to bed
- after a heavy meal
- or when you're certain about nothing, because this will only make it worse

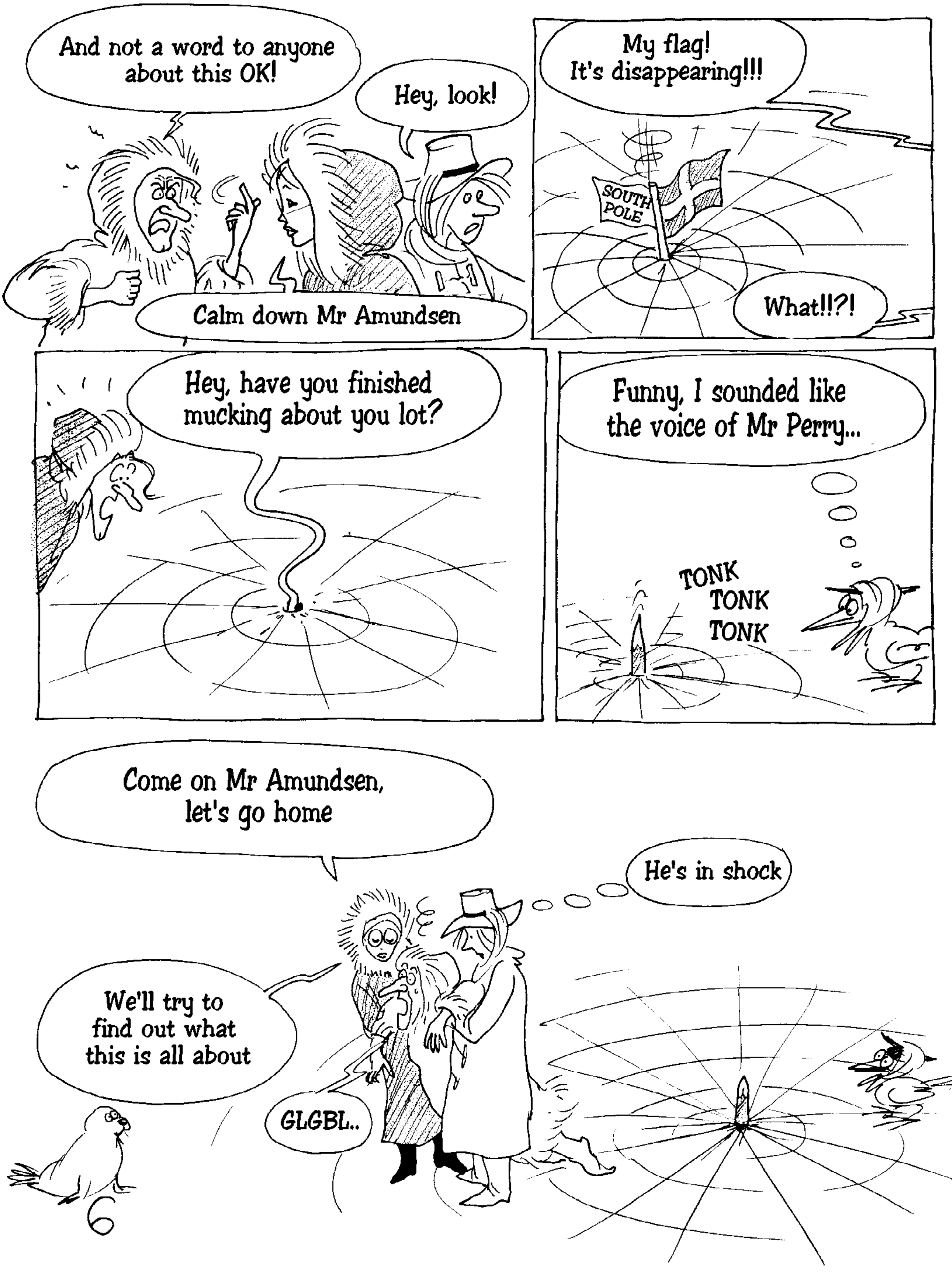
The author

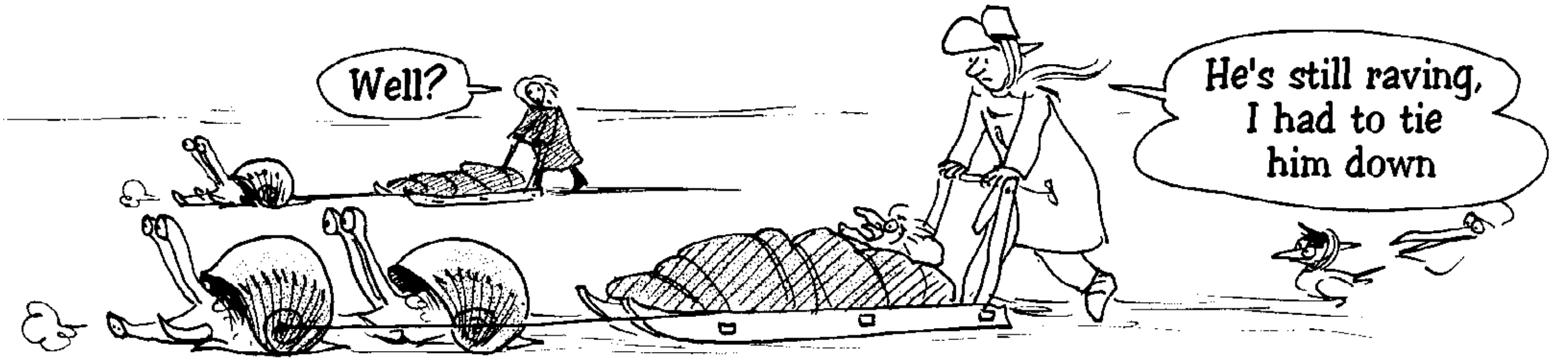
THE PLANET WITHOUT A SOUTH POLE



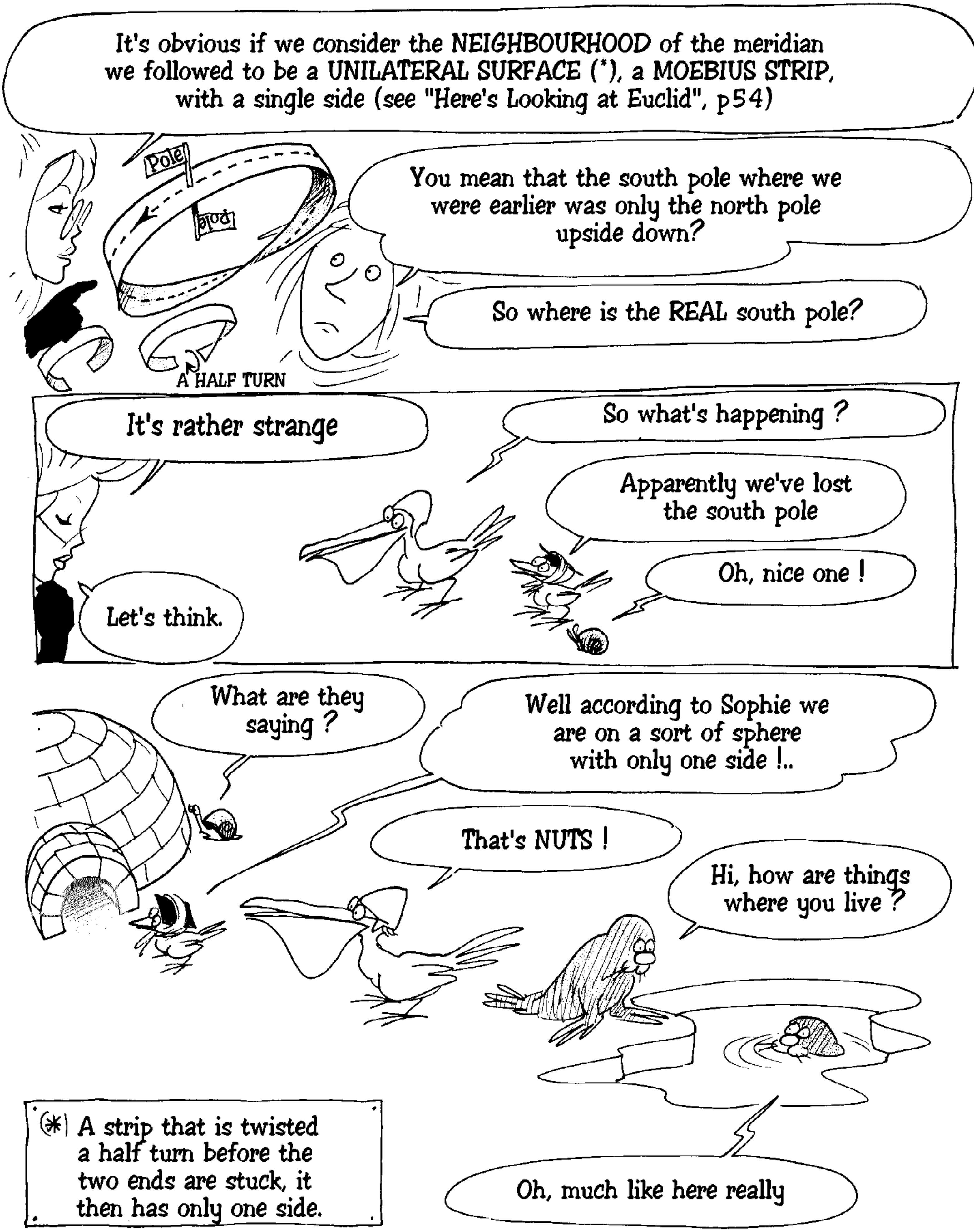

Ah that's different...
...and even though I am exceptionally modest, I accept.
You aren't going to use Huskies?
No, I'm using Molluscamouths, an old cross between the snail and the mammouth. Robust animals, specially trained to follow MERIDIANS.
Mush, mush. Follow me on the MERIDIAN LINE, it's STRAIGHT AHEAD !
I'm a right tough guy.
It looks like we're already crossing the Equator, it's hard keeping up with him...
Walking to a winter wonderland ♫ ♫
Aaah...glory
Mush! mush !
I can see the South pole, MY North pole!..
Aaargh...

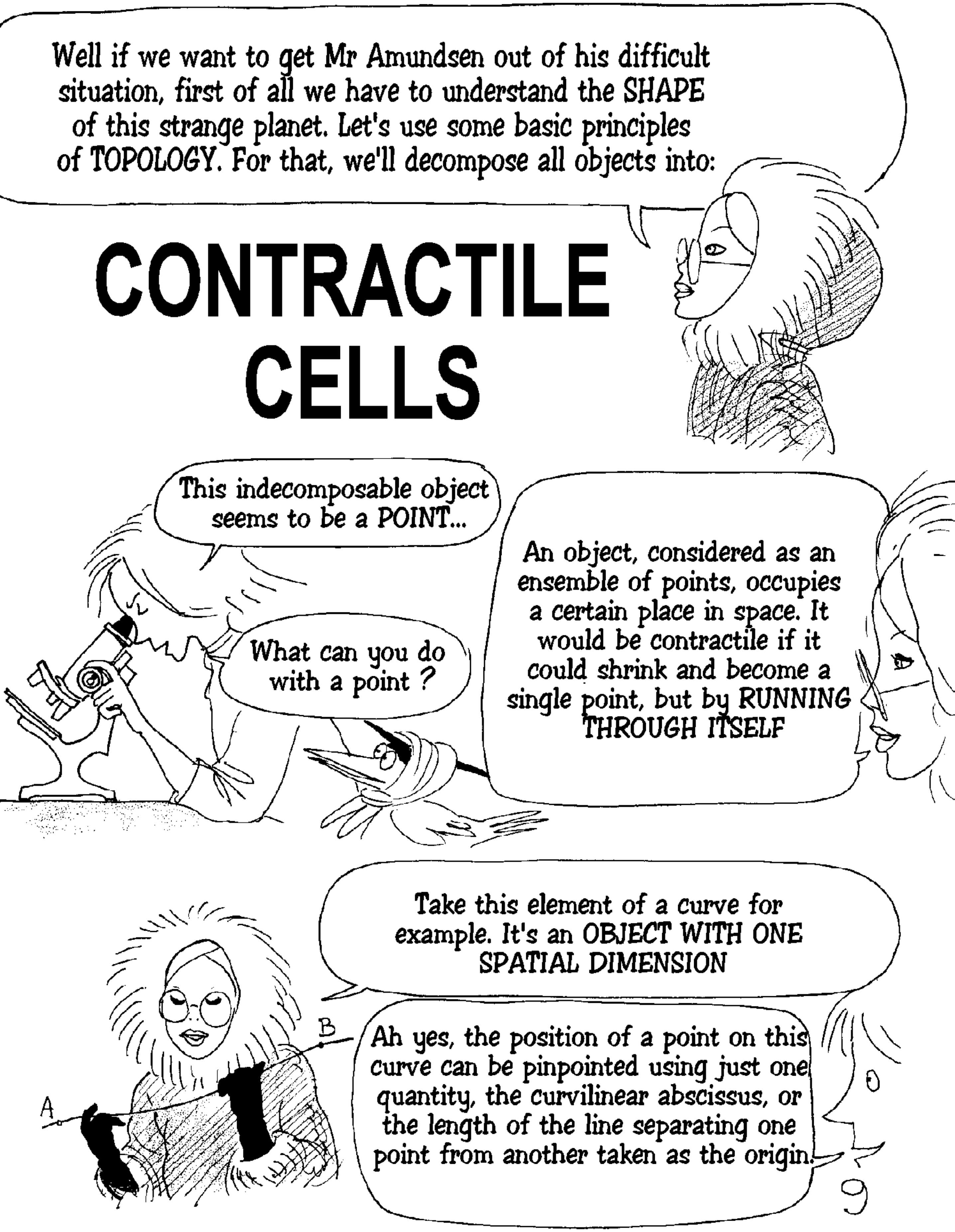

I'm first...
GLORY!
But!? What's this??
Is this some sort of joke?
Eh!?
Goodness!
NORTH POLE
GRRRRR !
CRACK
So! Has anyone got anything to say about it?
SOUTH POLE

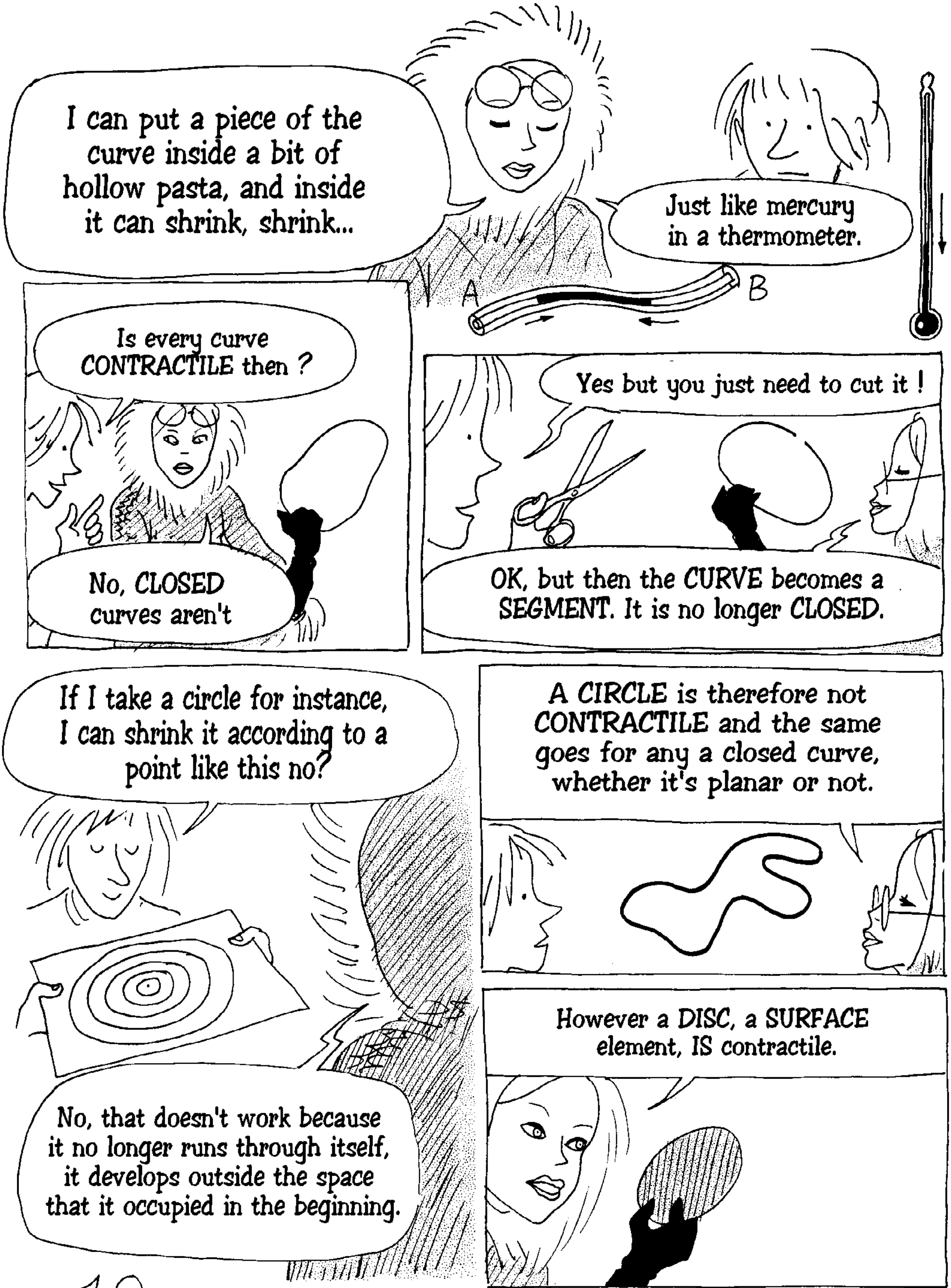

And not a word to anyone about this OK!
Hey, look!
Calm down Mr Amundsen
My flag! It's disappearing!!!
SOUTH POLE
What!!?!
Hey, have you finished mucking about you lot?
Funny, I sounded like the voice of Mr Perry...
TONK TONK TONK
Come on Mr Amundsen, let's go home
He's in shock
We'll try to find out what this is all about
GLGBL..



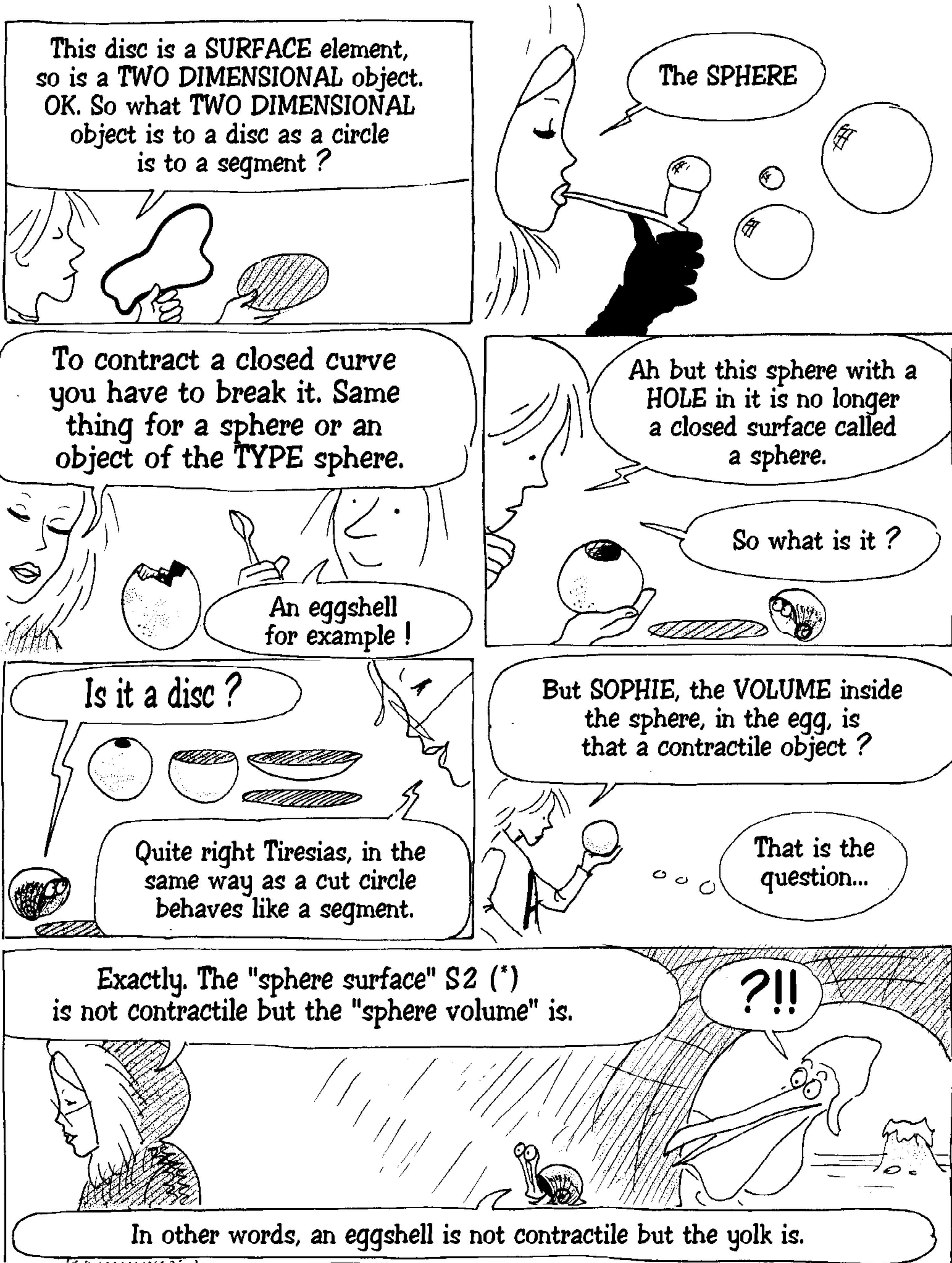
The Molluscamouths slid along without a sound on the frozen meridians


It's obvious if we consider the NEIGHBOURHOOD of the meridian we followed to be a UNILATERAL SURFACE (*), a MOEBIUS STRIP, with a single side (see "Here's Looking at Euclid", p54)
Pole
Pole
A HALF TURN
You mean that the south pole where we were earlier was only the north pole upside down?
So where is the REAL south pole?
It's rather strange
Let's think.
So what's happening ?
Apparently we've lost the south pole
Oh, nice one !
What are they saying ?
Well according to Sophie we are on a sort of sphere with only one side !..
That's NUTS !
Hi, how are things where you live ?
Oh, much like here really
(*) A strip that is twisted a half turn before the two ends are stuck, it then has only one side.

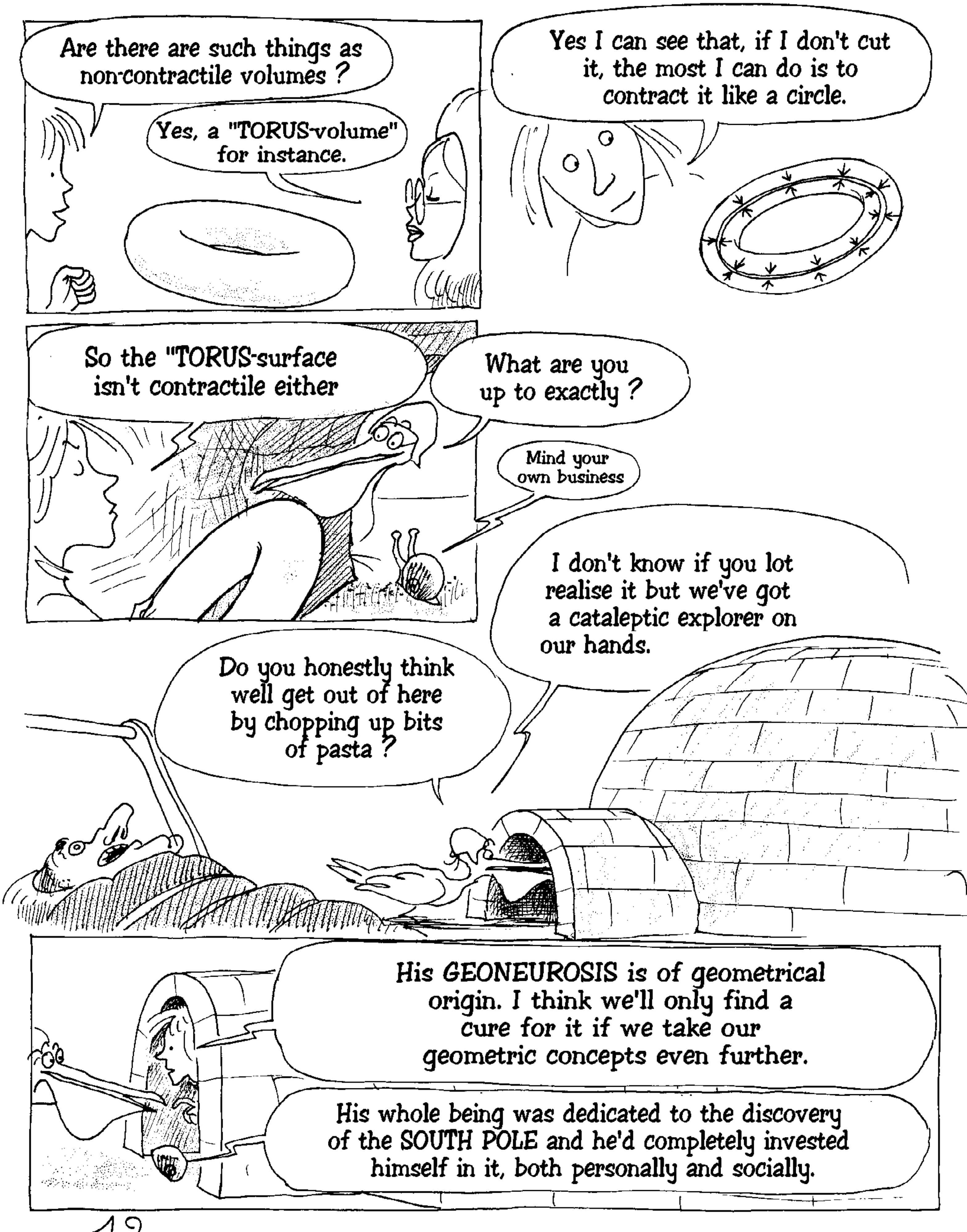

Well if we want to get Mr Amundsen out of his difficult situation, first of all we have to understand the SHAPE of this strange planet. Let's use some basic principles of TOPOLOGY. For that, we'll decompose all objects into:
CONTRACTILE CELLS
This indecomposable object seems to be a POINT...
What can you do with a point ?
An object, considered as an ensemble of points, occupies a certain place in space. It would be contractile if it could shrink and become a single point, but by RUNNING THROUGH ITSELF
Take this element of a curve for example. It's an OBJECT WITH ONE SPATIAL DIMENSION
B
A
Ah yes, the position of a point on this curve can be pinpointed using just one quantity, the curvilinear abscissus, or the length of the line separating one point from another taken as the origin.

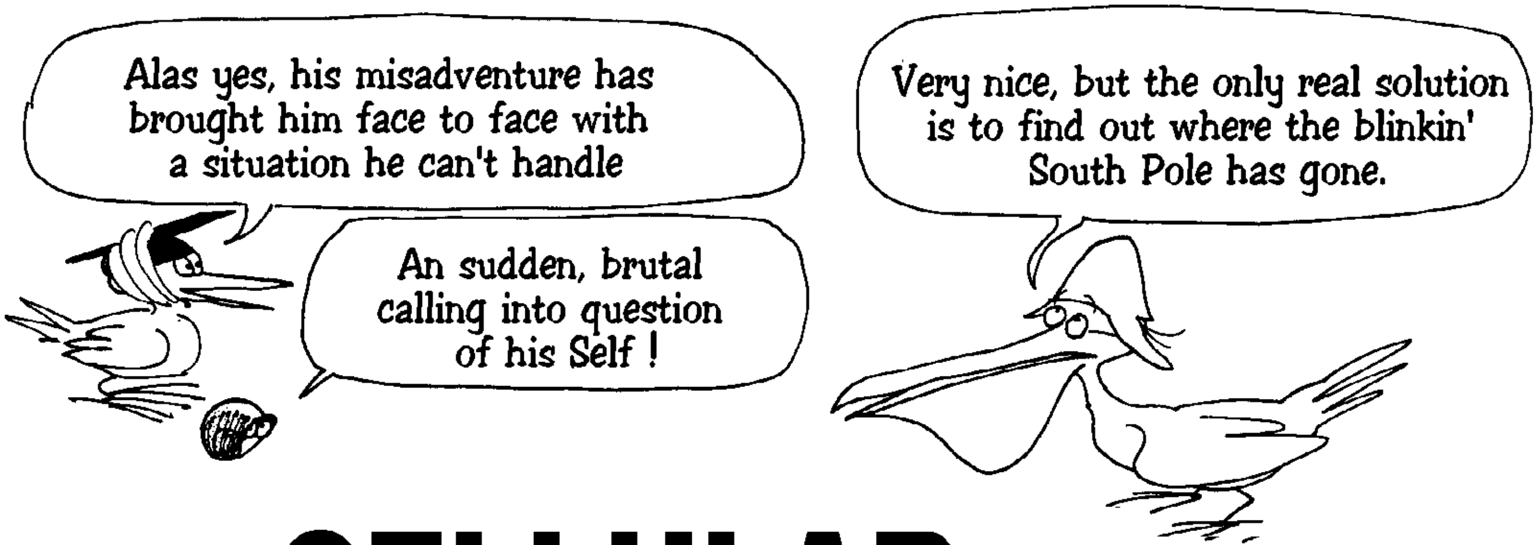


I can put a piece of the curve inside a bit of hollow pasta, and inside it can shrink, shrink...
Just like mercury in a thermometer.
A
B
Is every curve CONTRACTILE then ?
No, CLOSED curves aren't
Yes but you just need to cut it !
OK, but then the CURVE becomes a SEGMENT. It is no longer CLOSED.
If I take a circle for instance, I can shrink it according to a point like this no?
No, that doesn't work because it no longer runs through itself, it develops outside the space that it occupied in the beginning.
A CIRCLE is therefore not CONTRACTILE and the same goes for any a closed curve, whether it's planar or not.
However a DISC, a SURFACE element, IS contractile.

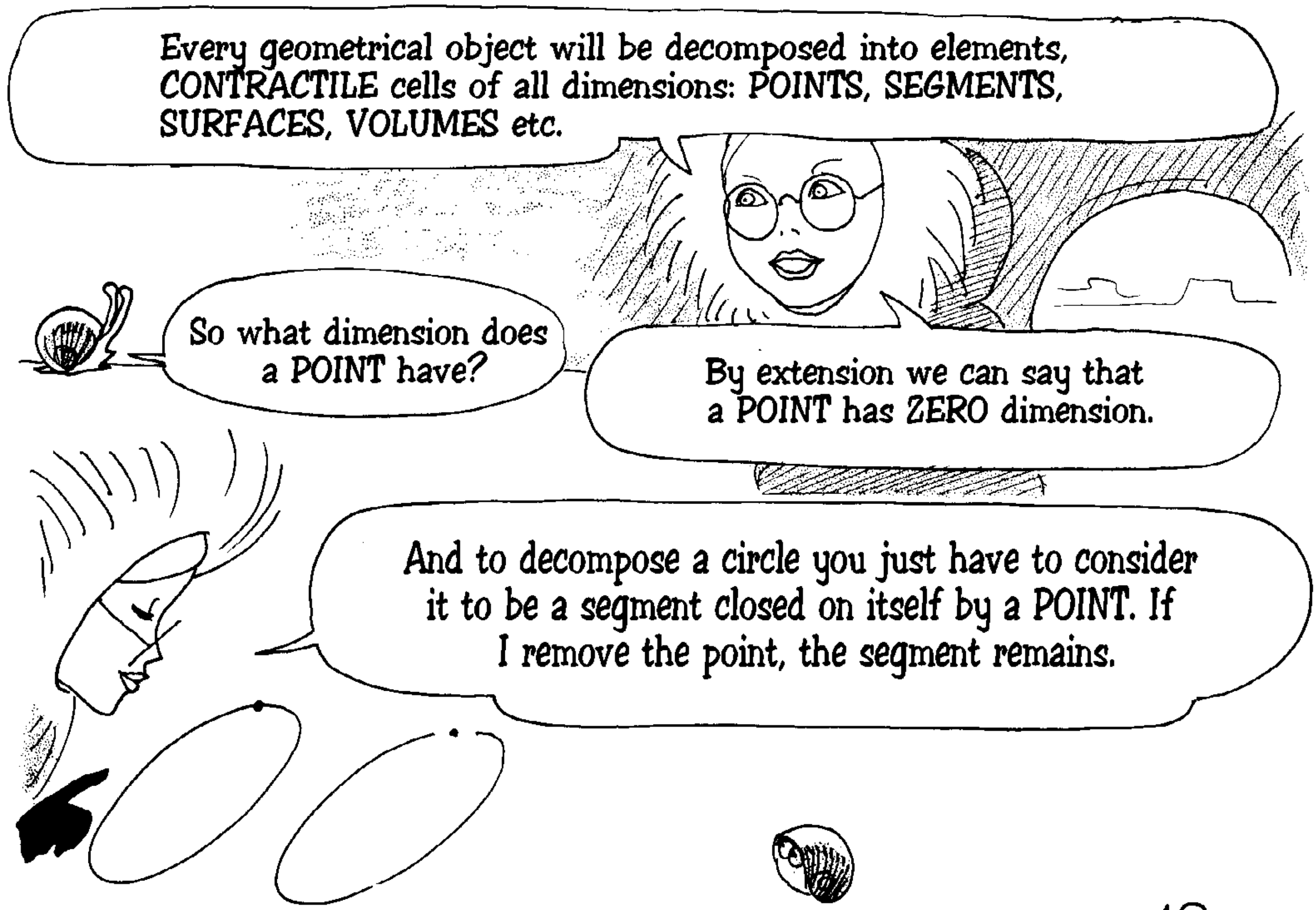


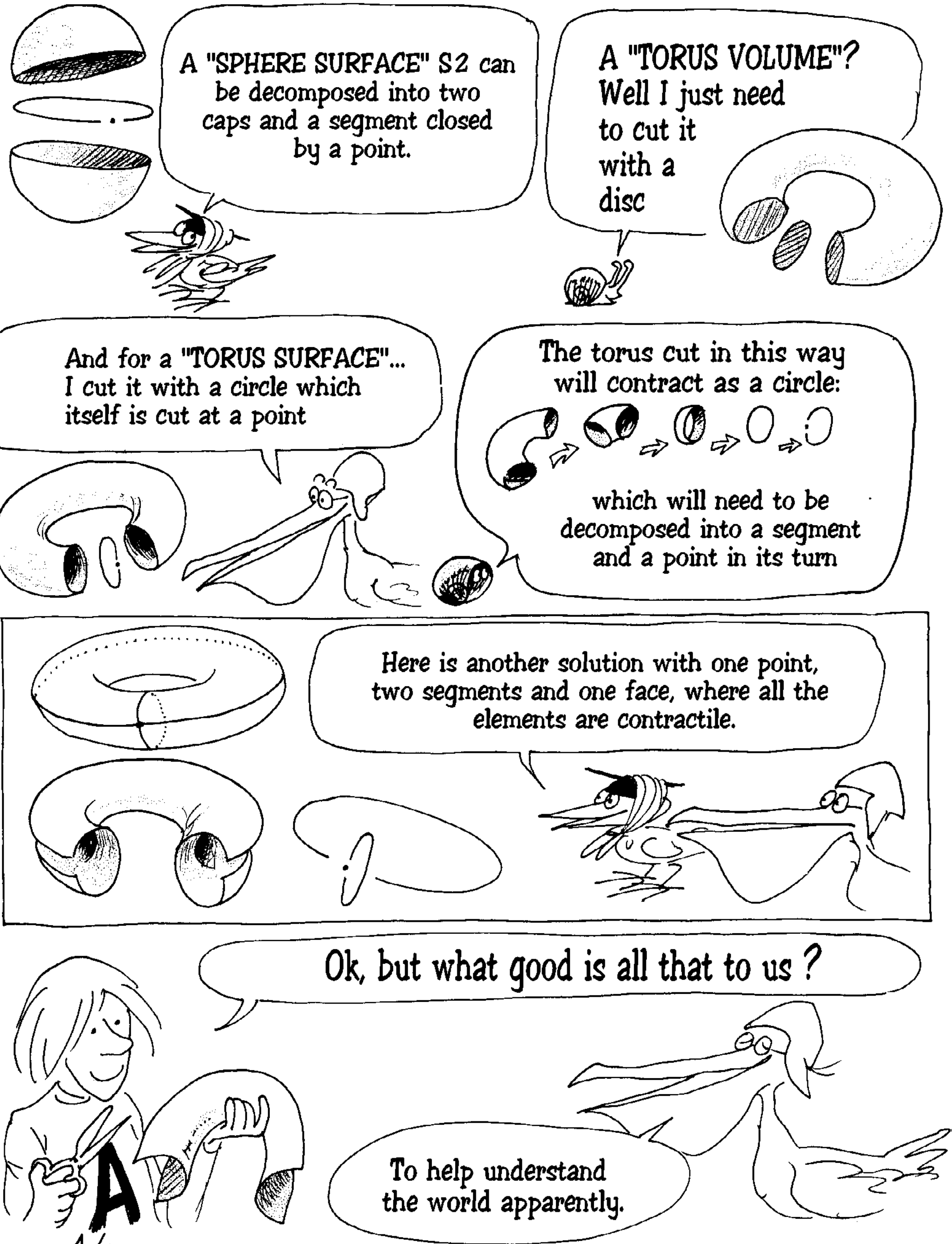
(*) See: HERE'S LOOKING AT EUCLID.


Are there are such things as non-contractile volumes ?
Yes, a "TORUS-volume" for instance.
Yes I can see that, if I don't cut it, the most I can do is to contract it like a circle.
So the "TORUS-surface isn't contractile either
What are you up to exactly ?
Mind your own business
I don't know if you lot realise it but we've got a cataleptic explorer on our hands.
Do you honestly think well get out of here by chopping up bits of pasta ?
His GEONEUROSIS is of geometrical origin. I think we'll only find a cure for it if we take our geometric concepts even further.
His whole being was dedicated to the discovery of the SOUTH POLE and he'd completely invested himself in it, both personally and socially.

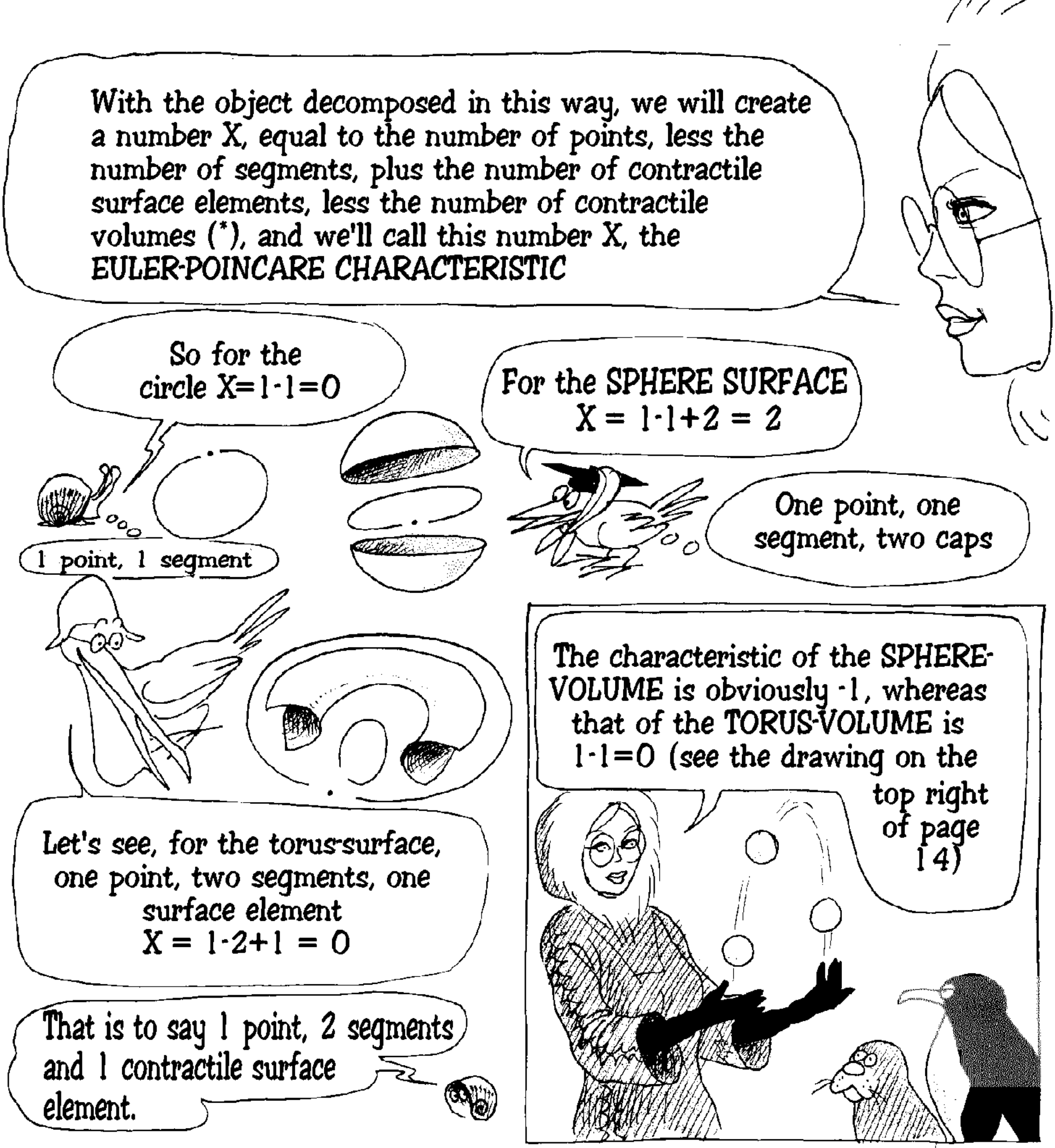


CELLULAR DECOMPOSITION

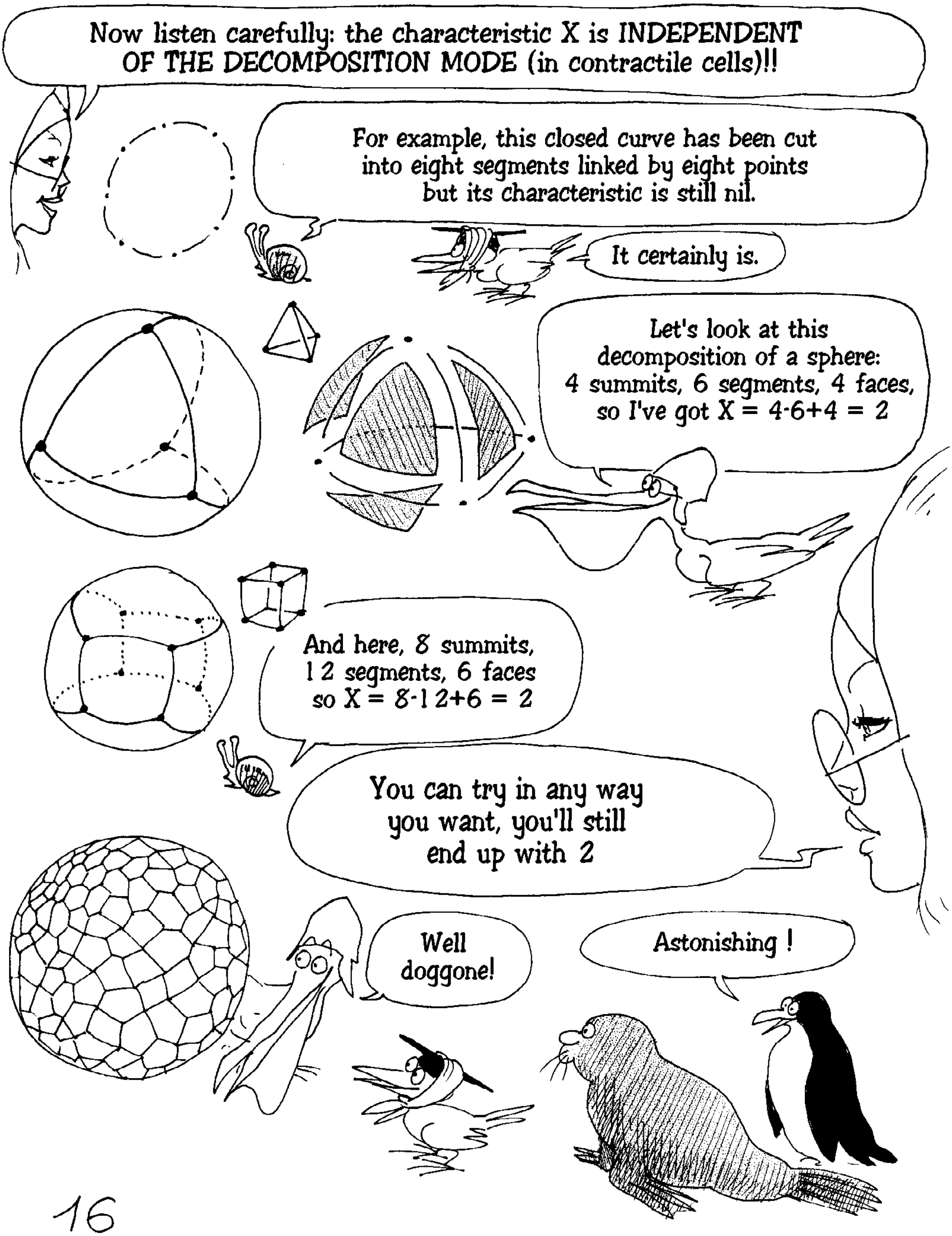


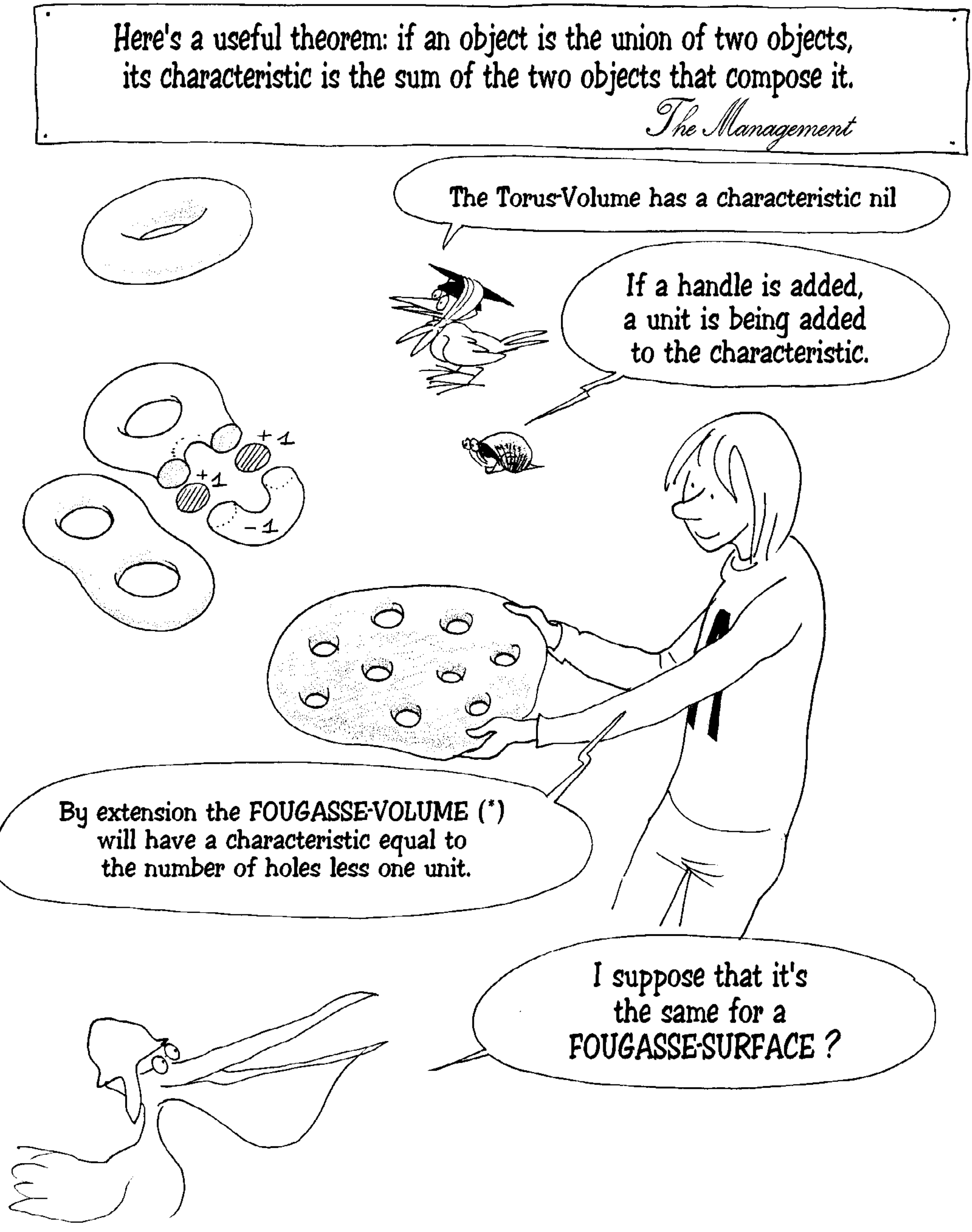

A "SPHERE SURFACE" S2 can be decomposed into two caps and a segment closed by a point.
A "TORUS VOLUME"? Well I just need to cut it with a disc
And for a "TORUS SURFACE"... I cut it with a circle which itself is cut at a point
The torus cut in this way will contract as a circle:
which will need to be decomposed into a segment and a point in its turn
Here is another solution with one point, two segments and one face, where all the elements are contractile.
Ok, but what good is all that to us ?
To help understand the world apparently.
A

THE EULER-POINCARE CHARACTERISTIC

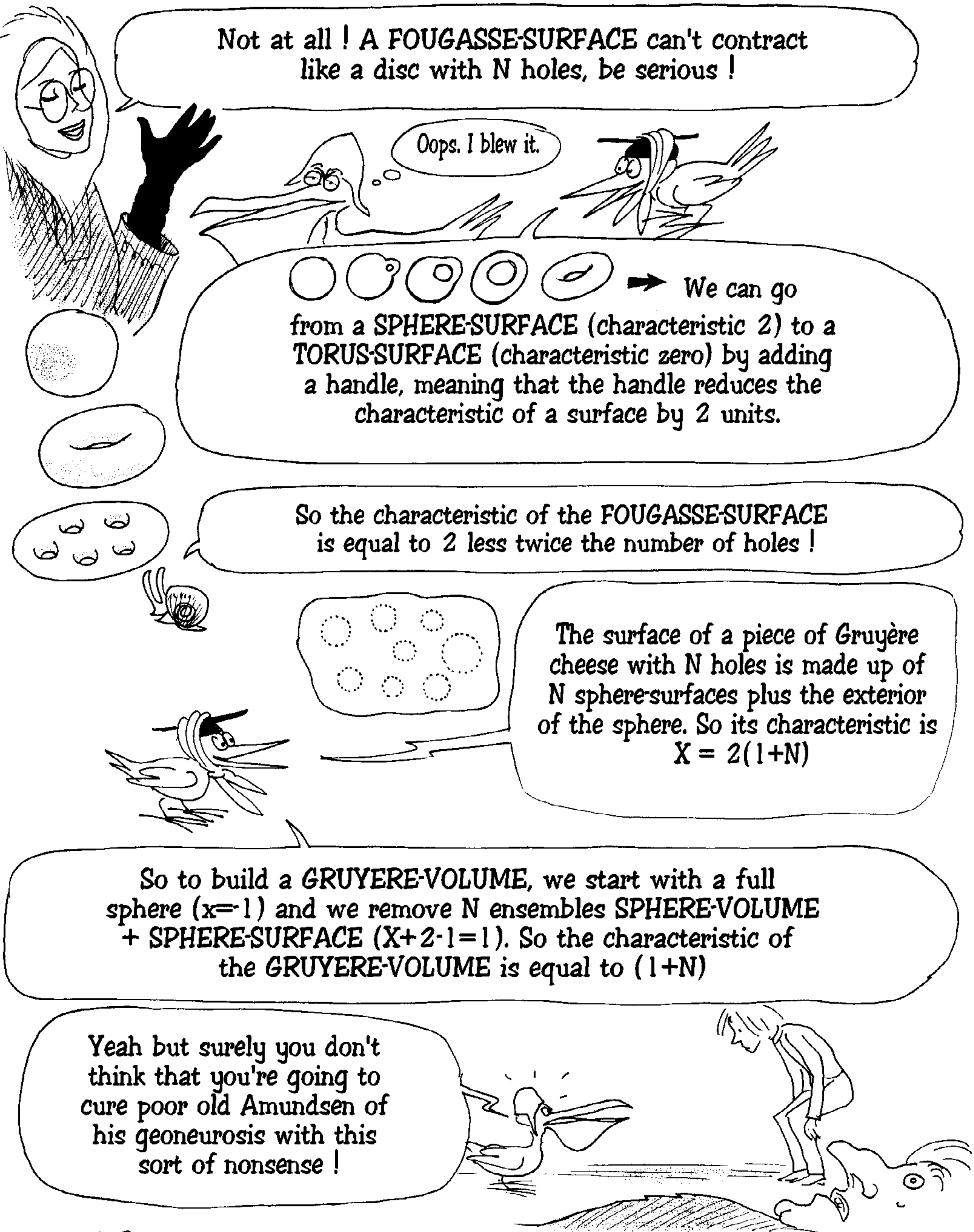


(*)Which immediately extends to a number of dimensions superior to three (it's an alternate sum)


Now listen carefully: the characteristic X is INDEPENDENT OF THE DECOMPOSITION MODE (in contractile cells)!!
For example, this closed curve has been cut into eight segments linked by eight points but its characteristic is still nil.
It certainly is.
Let's look at this decomposition of a sphere: 4 summits, 6 segments, 4 faces, so I've got X = 4-6+4 = 2
And here, 8 summits, 12 segments, 6 faces so X = 8-12+6 = 2
You can try in any way you want, you'll still end up with 2
Well doggone!
Astonishing !



* Fougasse: An olive oil based bread made in southern France

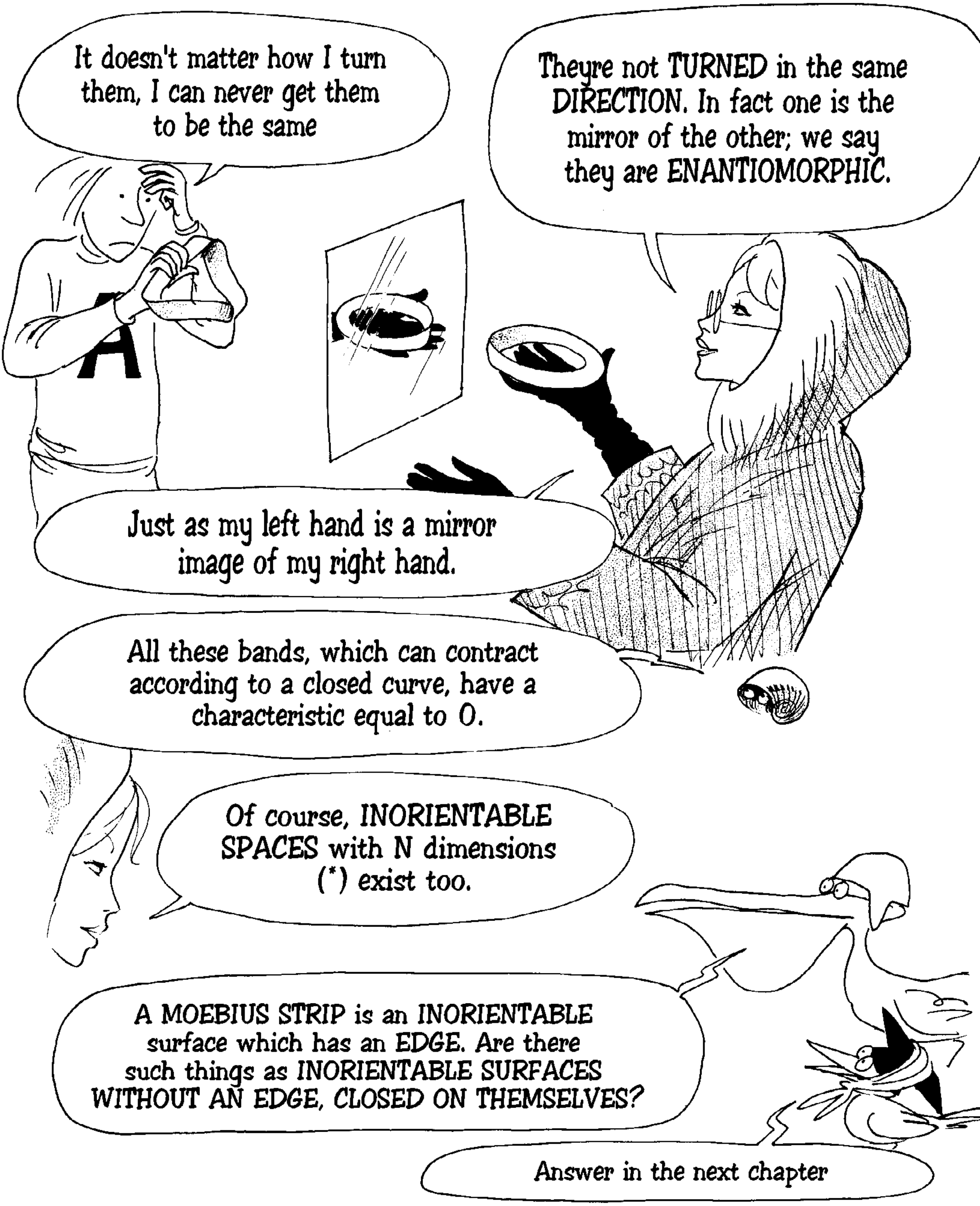


Not at all ! A FOUGASSE-SURFACE can't contract like a disc with N holes, be serious !
Oops. I blew it.
We can go from a SPHERE-SURFACE (characteristic 2) to a TORUS-SURFACE (characteristic zero) by adding a handle, meaning that the handle reduces the characteristic of a surface by 2 units.
So the characteristic of the FOUGASSE-SURFACE is equal to 2 less twice the number of holes !
The surface of a piece of Gruyère cheese with N holes is made up of N sphere-surfaces plus the exterior of the sphere. So its characteristic is X = 2(1+N)
So to build a GRUYERE-VOLUME, we start with a full sphere (x=-1) and we remove N ensembles SPHERE-VOLUME + SPHERE-SURFACE (X+2-1=1). So the characteristic of the GRUYERE-VOLUME is equal to (1+N)
Yeah but surely you don't think that you're going to cure poor old Amundsen of his geoneurosis with this sort of nonsense !

THE WORLD IN WHICH WE LIVE

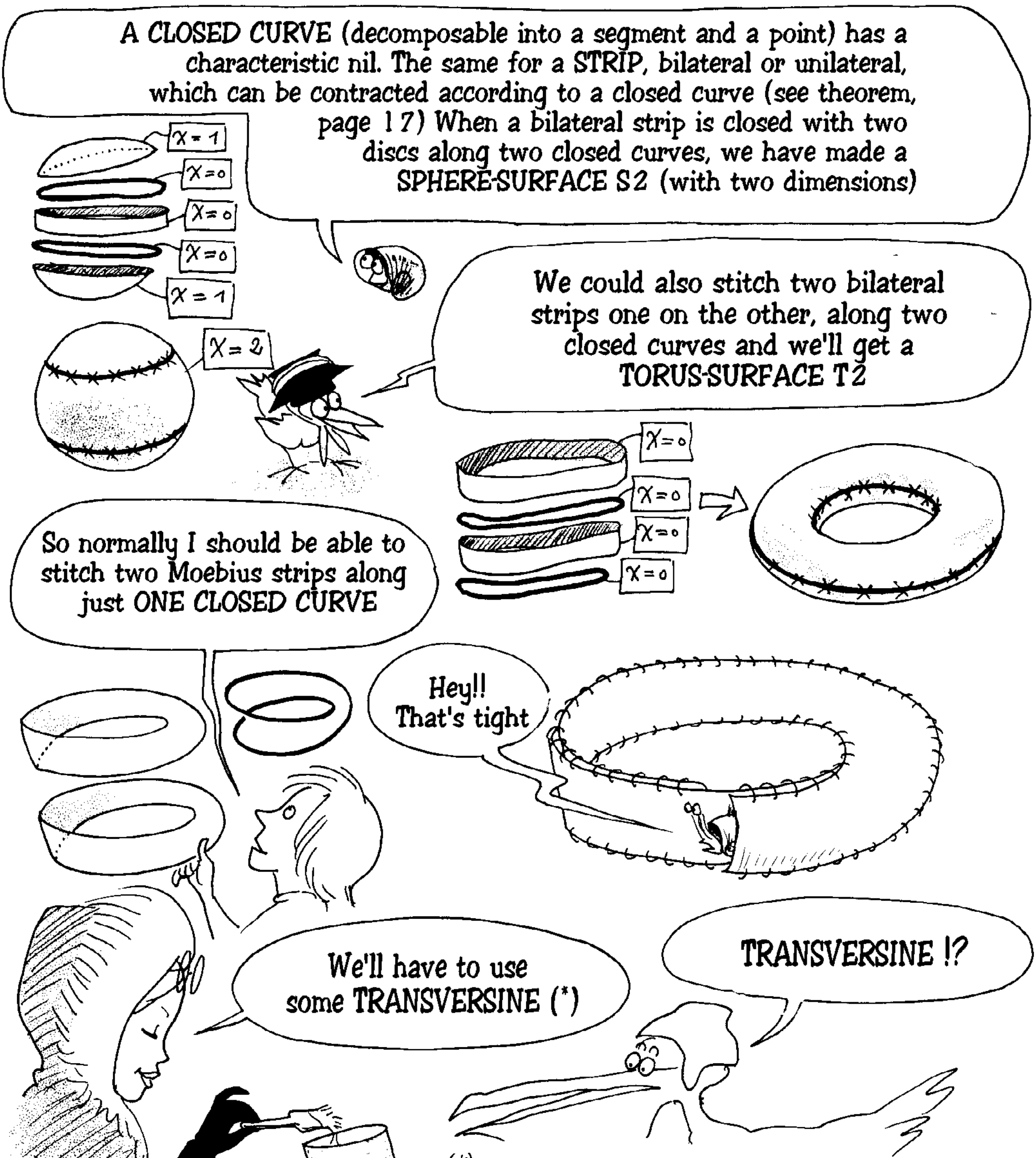
(*) See BIG BANG and FRIEDMANN's models on page 64


So this Euler-Poincaré characteristic has helped us put a bit of order into the jungle of geometrical objects
So the end of a cylinder is topologically identical to a disc with a hole in it, and its characteristic is nil.
But what do you think of this object ?
A MOEBIUS STRIP, which has only one side. As we can't give it a BACK or a FRONT we say that it is INORIENTABLE.
In fact any strip that has an ODD number of HALF-TURNS are Moebius strips and INORIENTABLE. But these two strips seem different somehow...

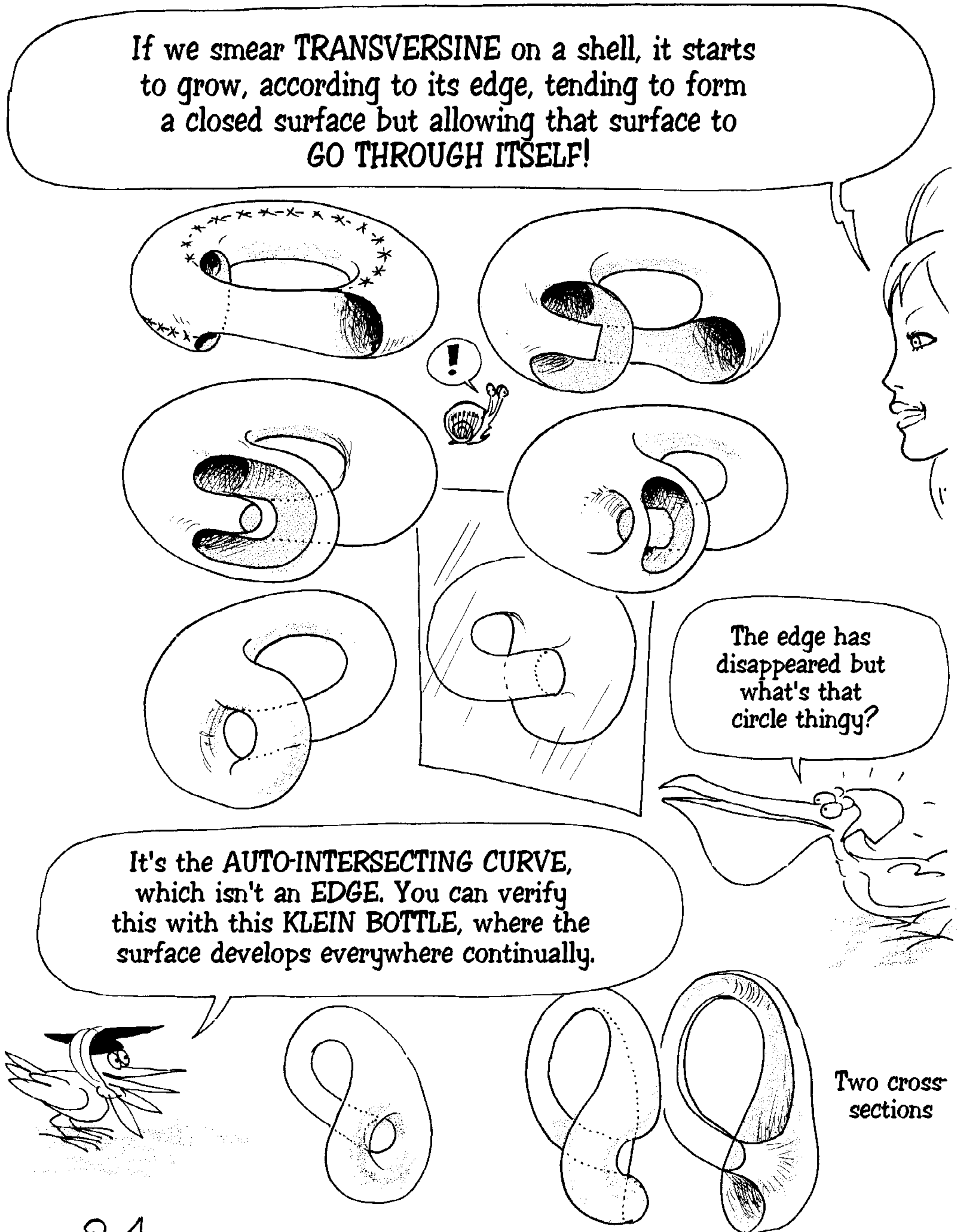


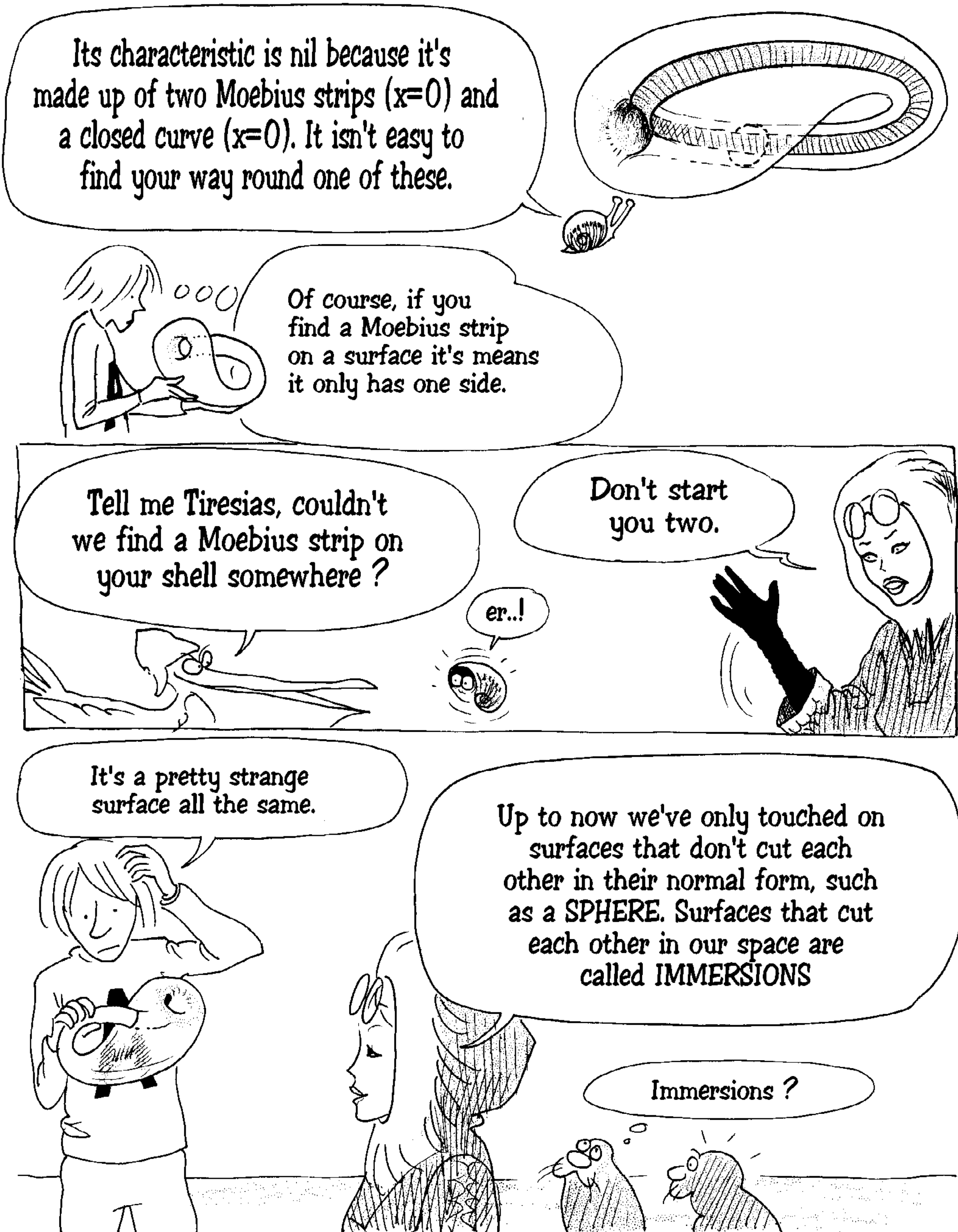
(*) See "HERE'S LOOKING AT EUCLID" page 59

EDGE ON EDGE



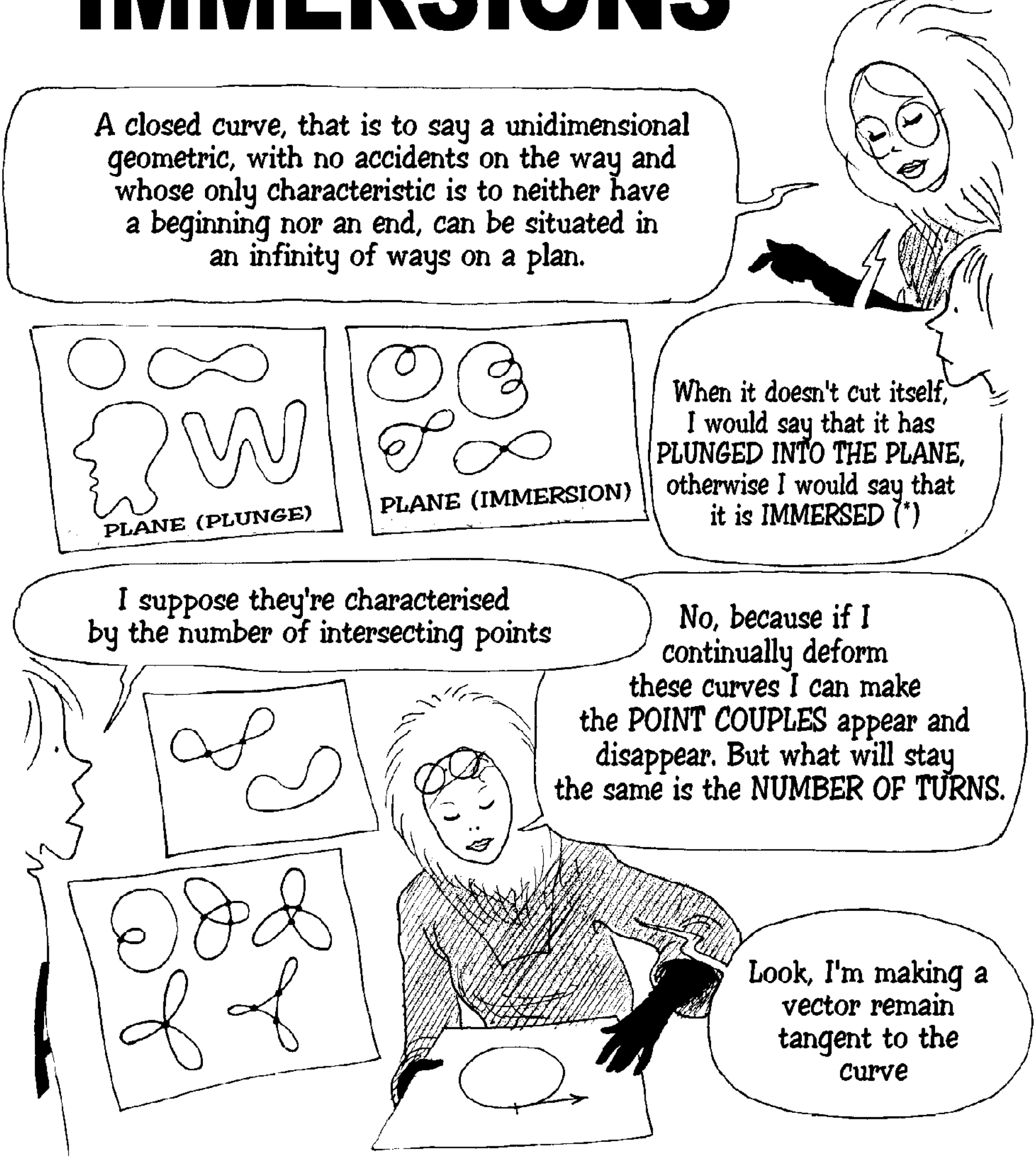
(*) TRANSVERSINE is extracted from the shells of HOMOMOLES


If we smear TRANSVERSINE on a shell, it starts to grow, according to its edge, tending to form a closed surface but allowing that surface to GO THROUGH ITSELF!
!
The edge has disappeared but what's that circle thingy?
It's the AUTO-INTERSECTING CURVE, which isn't an EDGE. You can verify this with this KLEIN BOTTLE, where the surface develops everywhere continually.
Two cross-sections

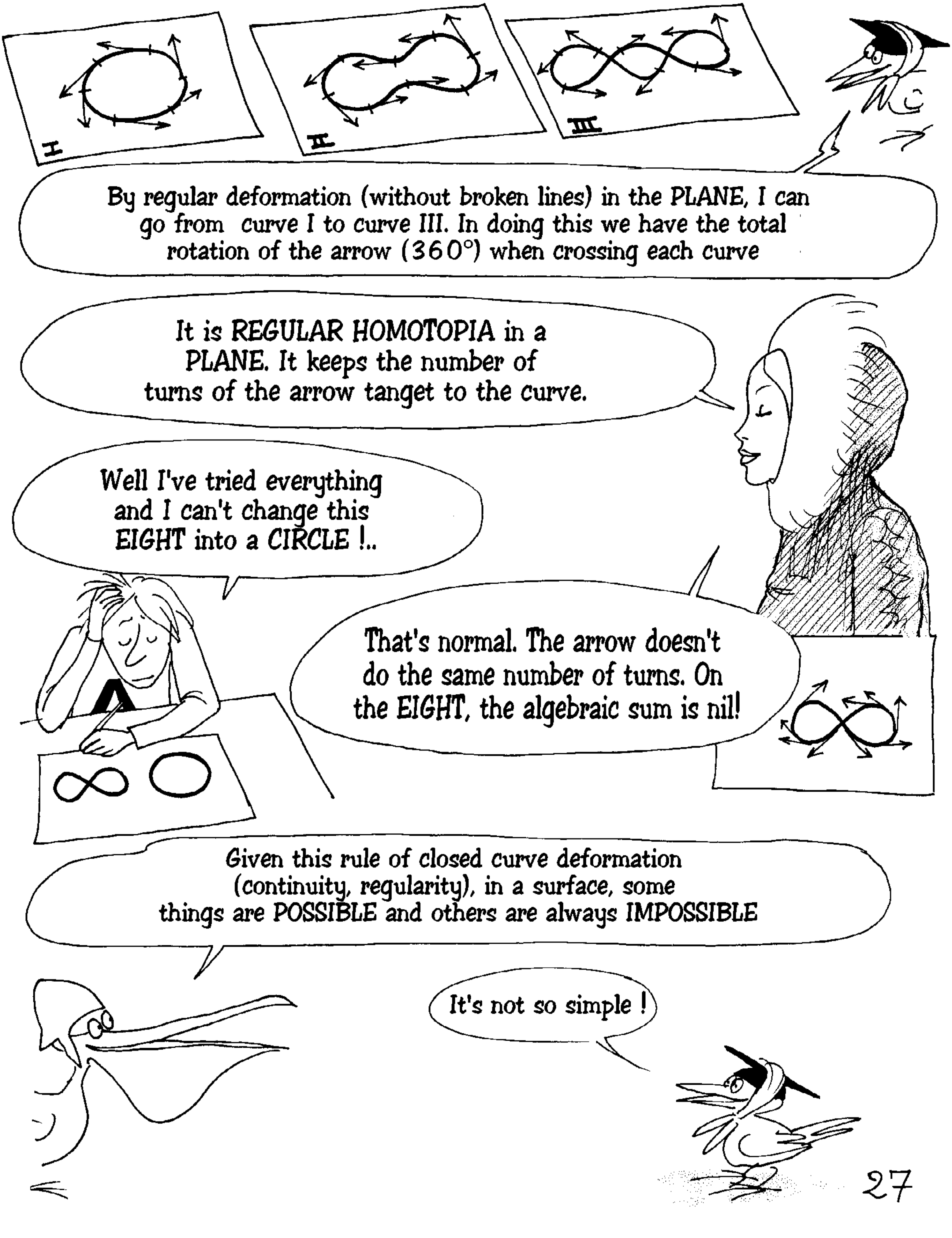


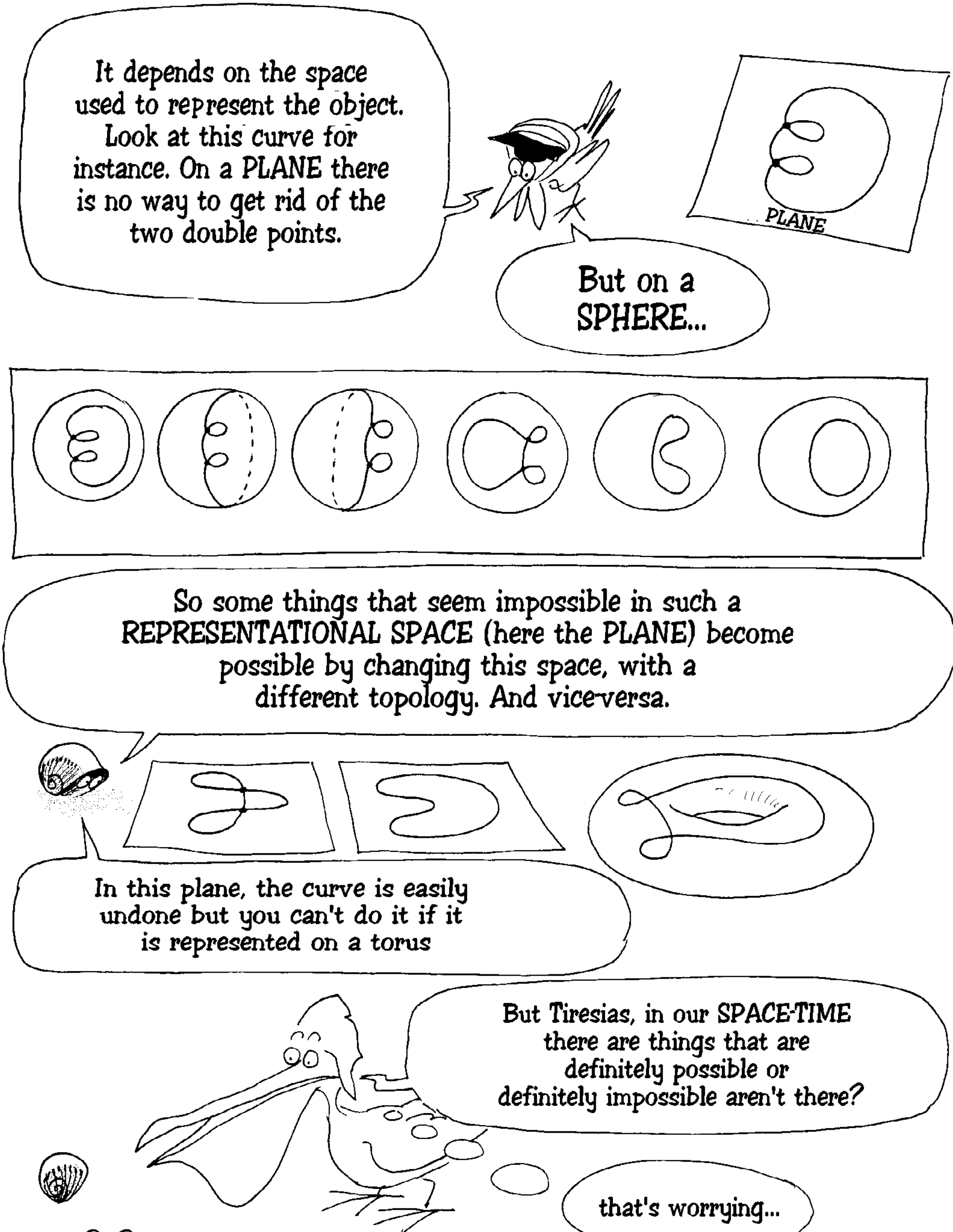
Its characteristic is nil because it's made up of two Moebius strips (x=0) and a closed curve (x=0). It isn't easy to find your way round one of these.
Of course, if you find a Moebius strip on a surface it's means it only has one side.
Tell me Tiresias, couldn't we find a Moebius strip on your shell somewhere ?
er..!
Don't start you two.
It's a pretty strange surface all the same.
Up to now we've only touched on surfaces that don't cut each other in their normal form, such as a SPHERE. Surfaces that cut each other in our space are called IMMERSIONS
Immersions ?

PLUNGES AND IMMERSIONS

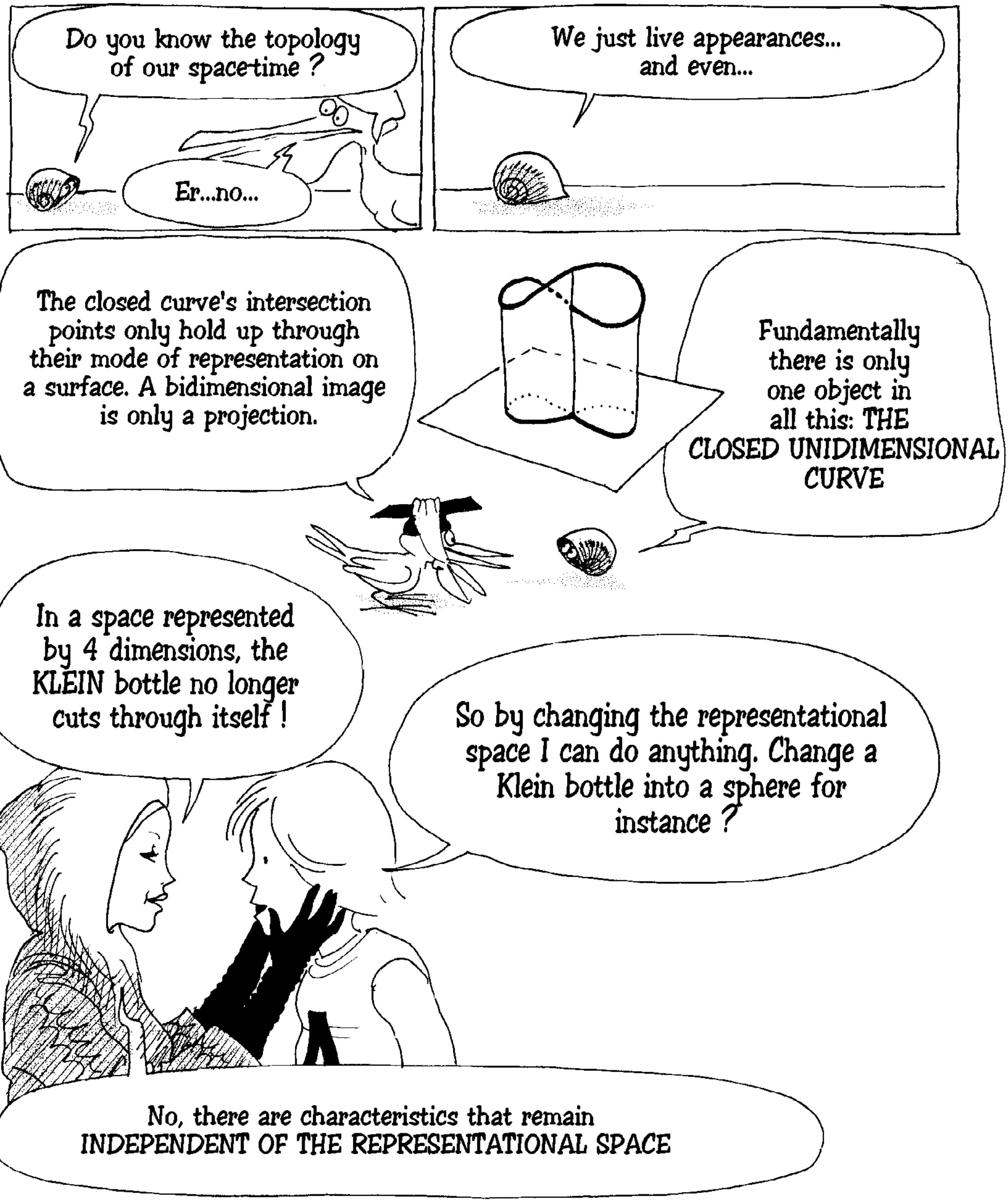


(*) a plunge is a special case of immersion


I
II
III
By regular deformation (without broken lines) in the PLANE, I can go from curve I to curve III. In doing this we have the total rotation of the arrow (360°) when crossing each curve
It is REGULAR HOMOTOPIA in a PLANE. It keeps the number of turns of the arrow tanget to the curve.
Well I've tried everything and I can't change this EIGHT into a CIRCLE !..
That's normal. The arrow doesn't do the same number of turns. On the EIGHT, the algebraic sum is nil!
Given this rule of closed curve deformation (continuity, regularity), in a surface, some things are POSSIBLE and others are always IMPOSSIBLE
It's not so simple !



It depends on the space used to represent the object. Look at this curve for instance. On a PLANE there is no way to get rid of the two double points.
PLANE
But on a SPHERE...
So some things that seem impossible in such a REPRESENTATIONAL SPACE (here the PLANE) become possible by changing this space, with a different topology. And vice-versa.
In this plane, the curve is easily undone but you can't do it if it is represented on a torus
But Tiresias, in our SPACE-TIME there are things that are definitely possible or definitely impossible aren't there?
that's worrying...

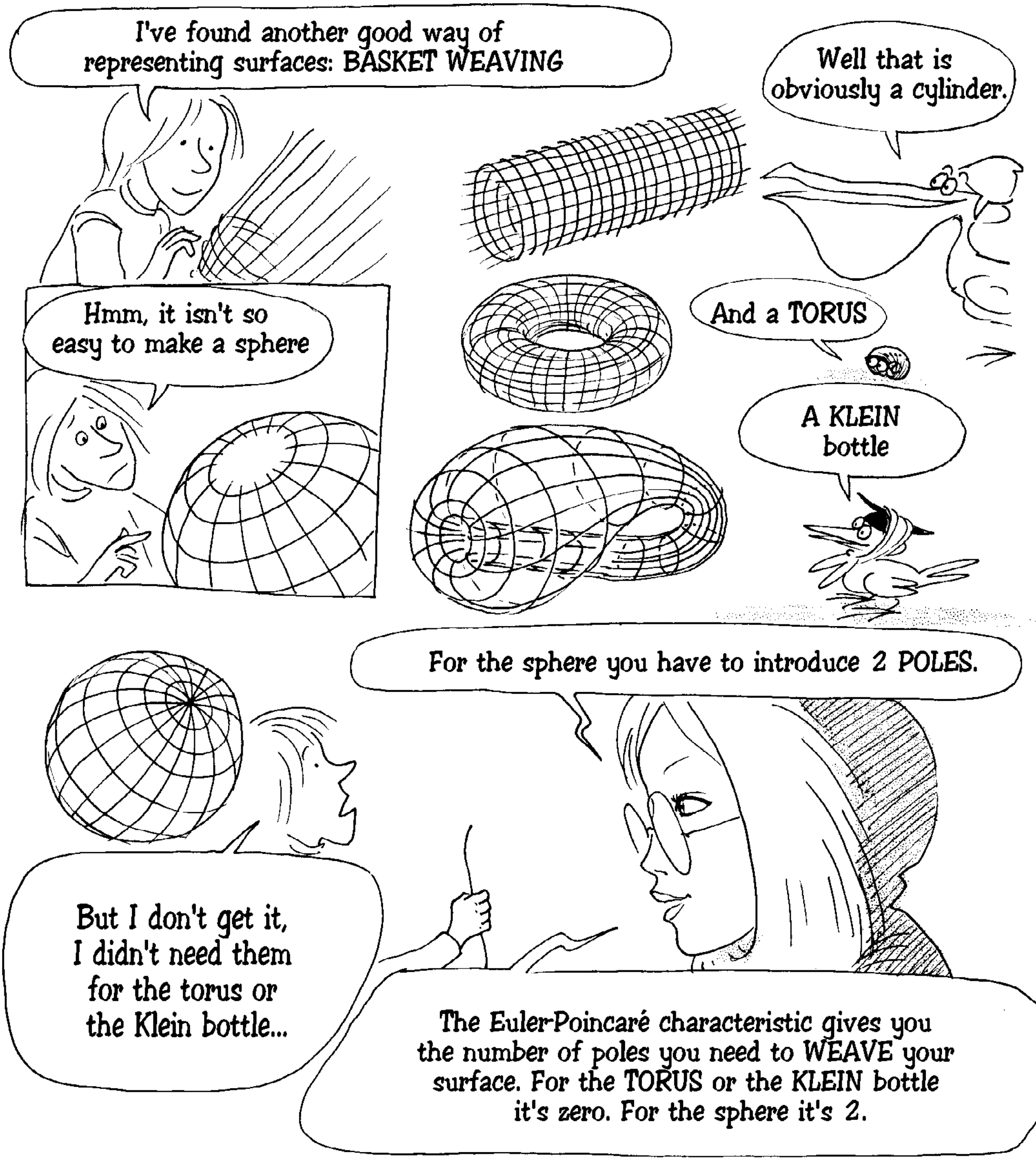


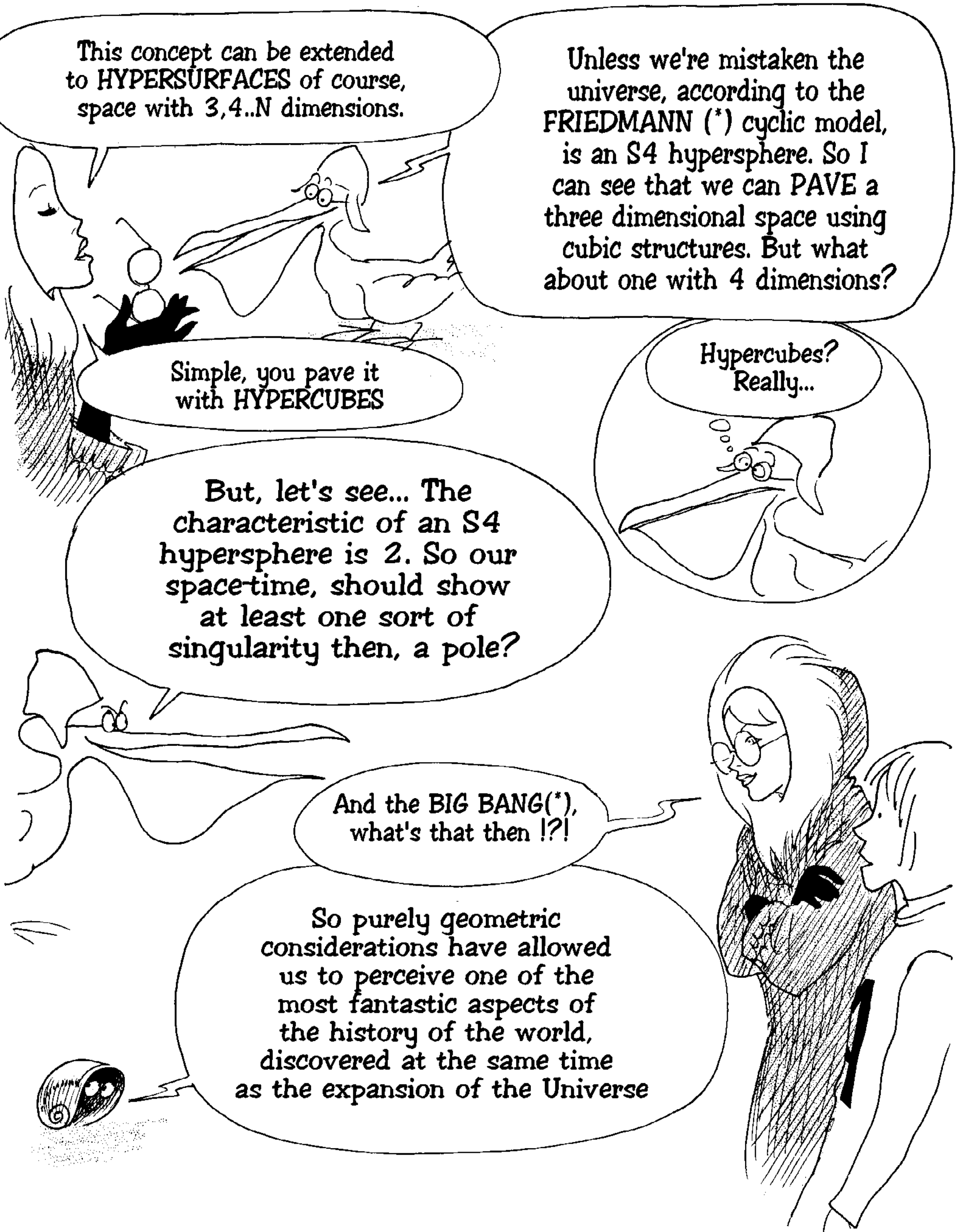
Do you know the topology of our space-time ?
Er...no...
We just live appearances... and even...
The closed curve's intersection points only hold up through their mode of representation on a surface. A bidimensional image is only a projection.
Fundamentally there is only one object in all this: THE CLOSED UNIDIMENSIONAL CURVE
In a space represented by 4 dimensions, the KLEIN bottle no longer cuts through itself !
So by changing the representational space I can do anything. Change a Klein bottle into a sphere for instance ?
No, there are characteristics that remain INDEPENDENT OF THE REPRESENTATIONAL SPACE

TOPOLOGY

Such as the Euler-Poincaré characteristic, orientability, closedness.
For objects of one dimension it all comes down to: A CURVE MUST BE OPEN OR CLOSED
So how's Amundsen ?
Nothing, still the same...
GEONEUROSIS? No, I diagnose a TOPONEUROSIS
Our mental structures, our LOGIC, our perception of the world, rest on geometrical foundations, which could give way at any moment.
I we can't bring back a minimum of coherence to our friend's view of things he'll continue to refuse the sensorial world.

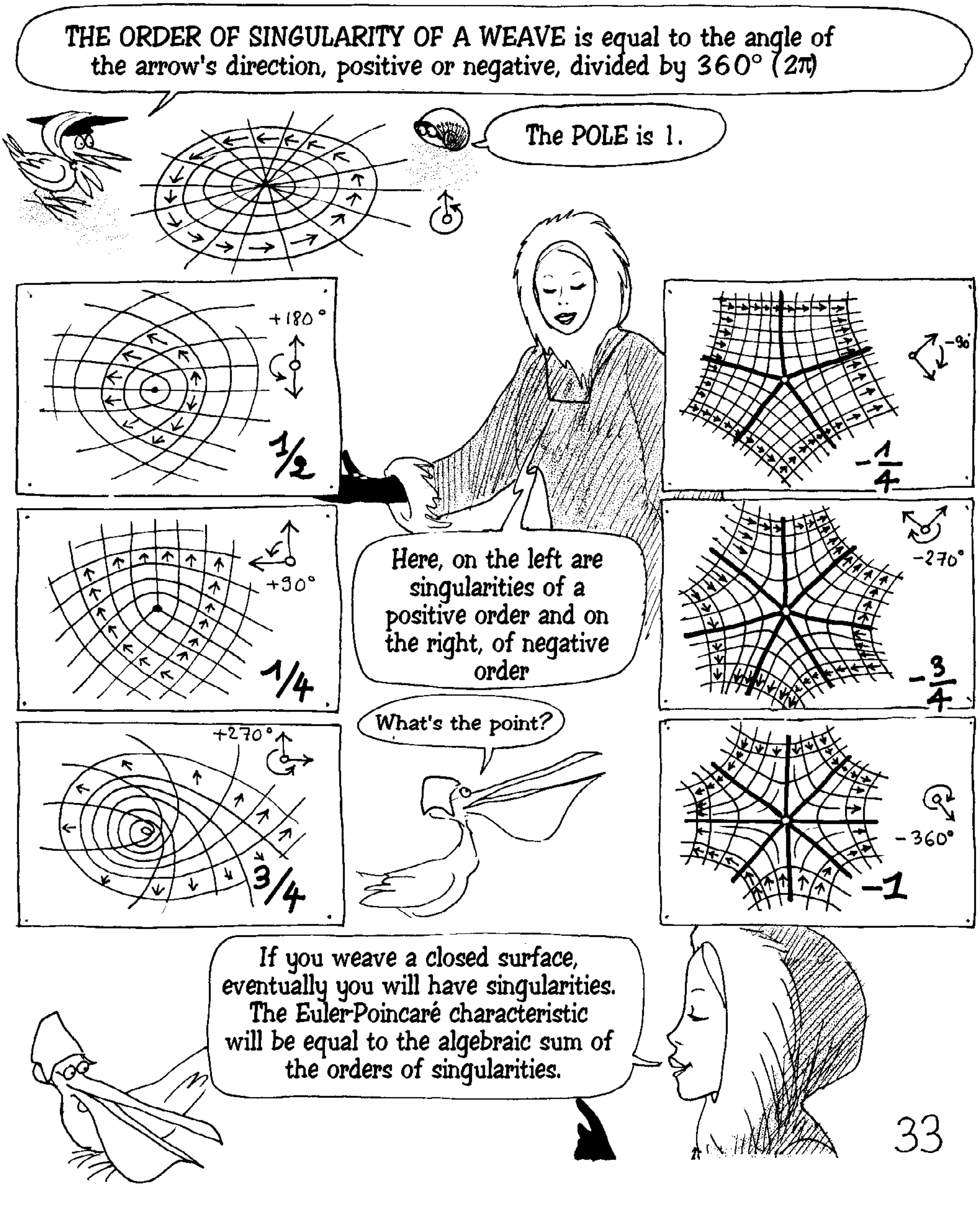
BASKET WEAVING

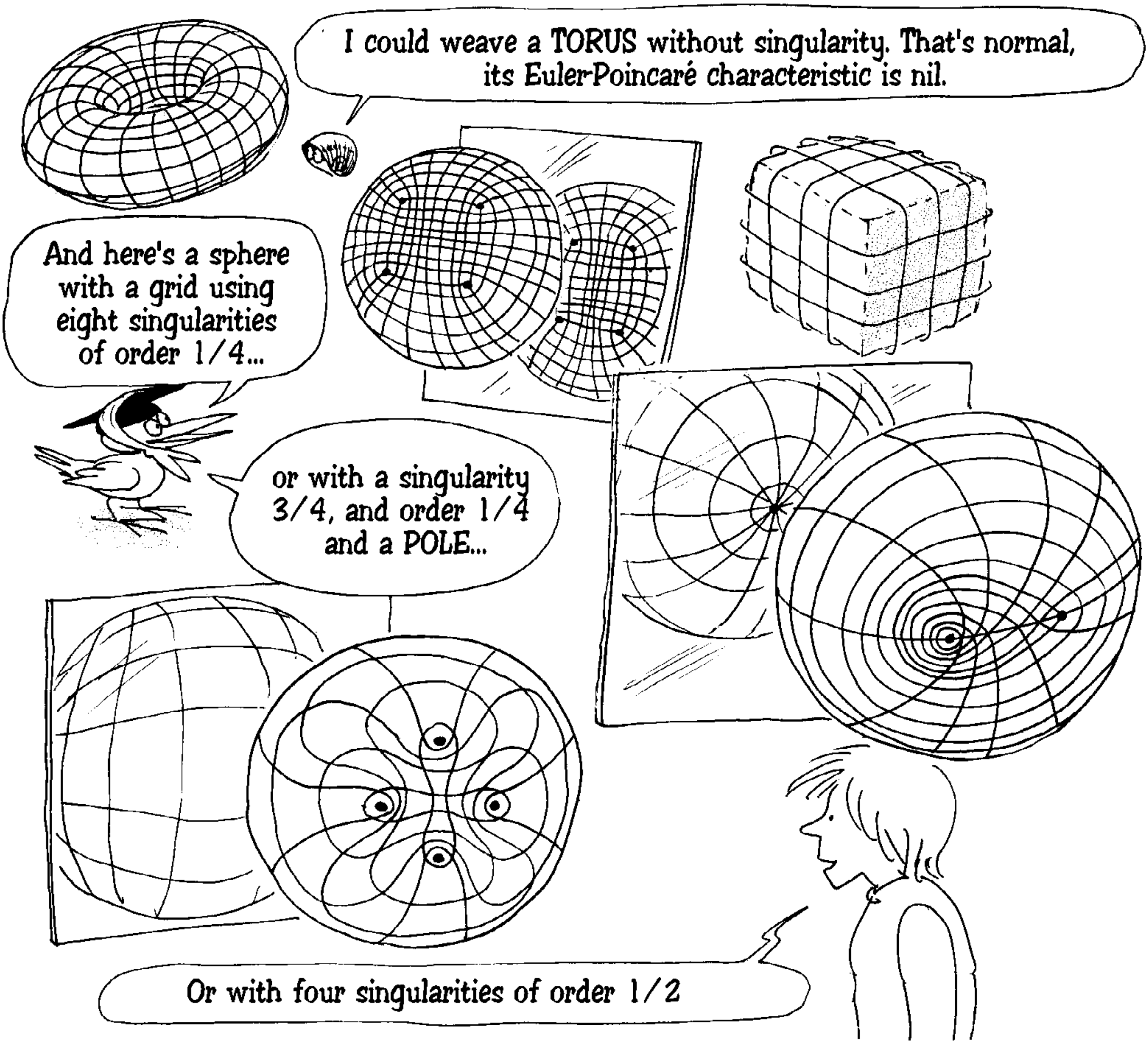




 (*) See the BIG BANG

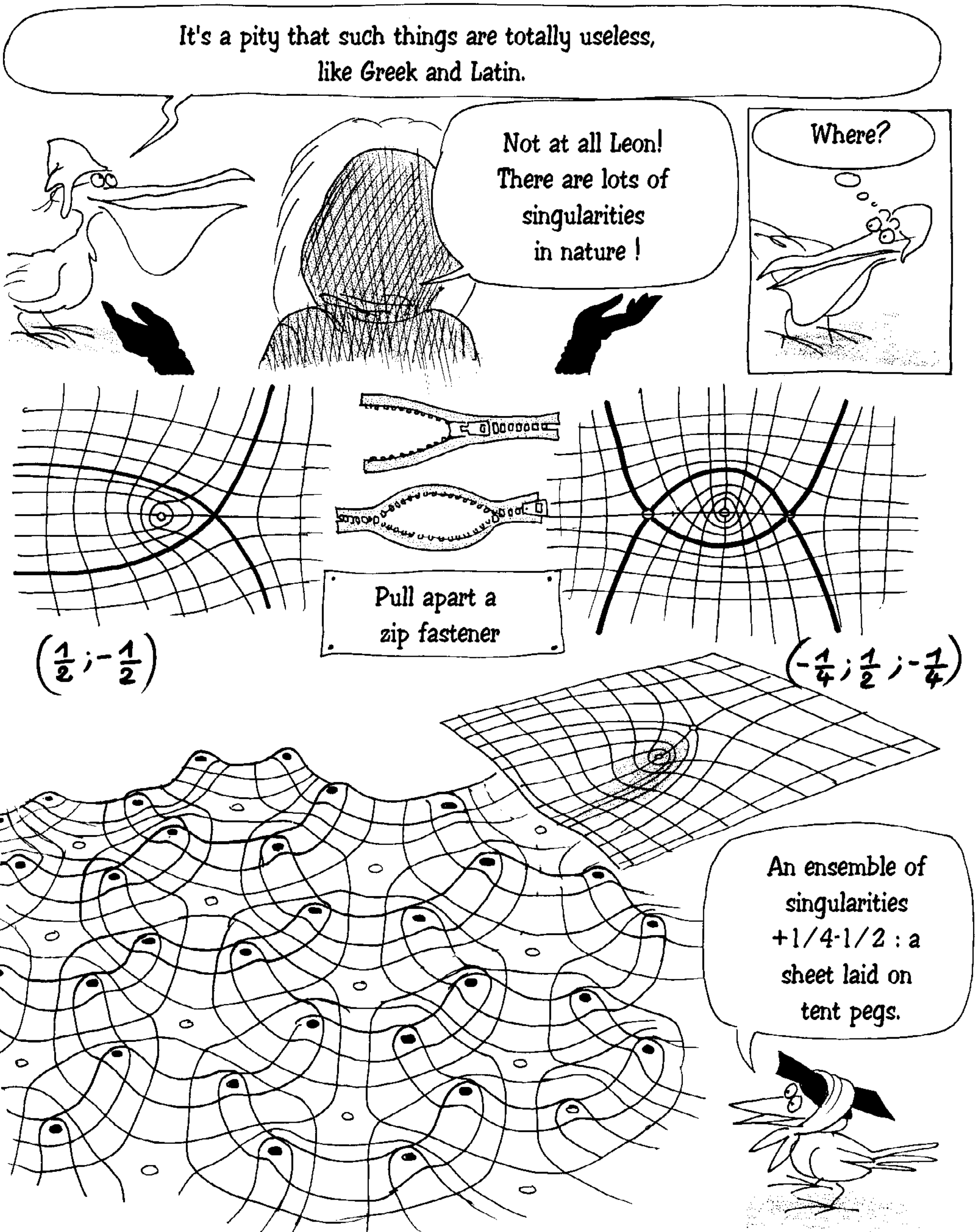
SINGULARITIES

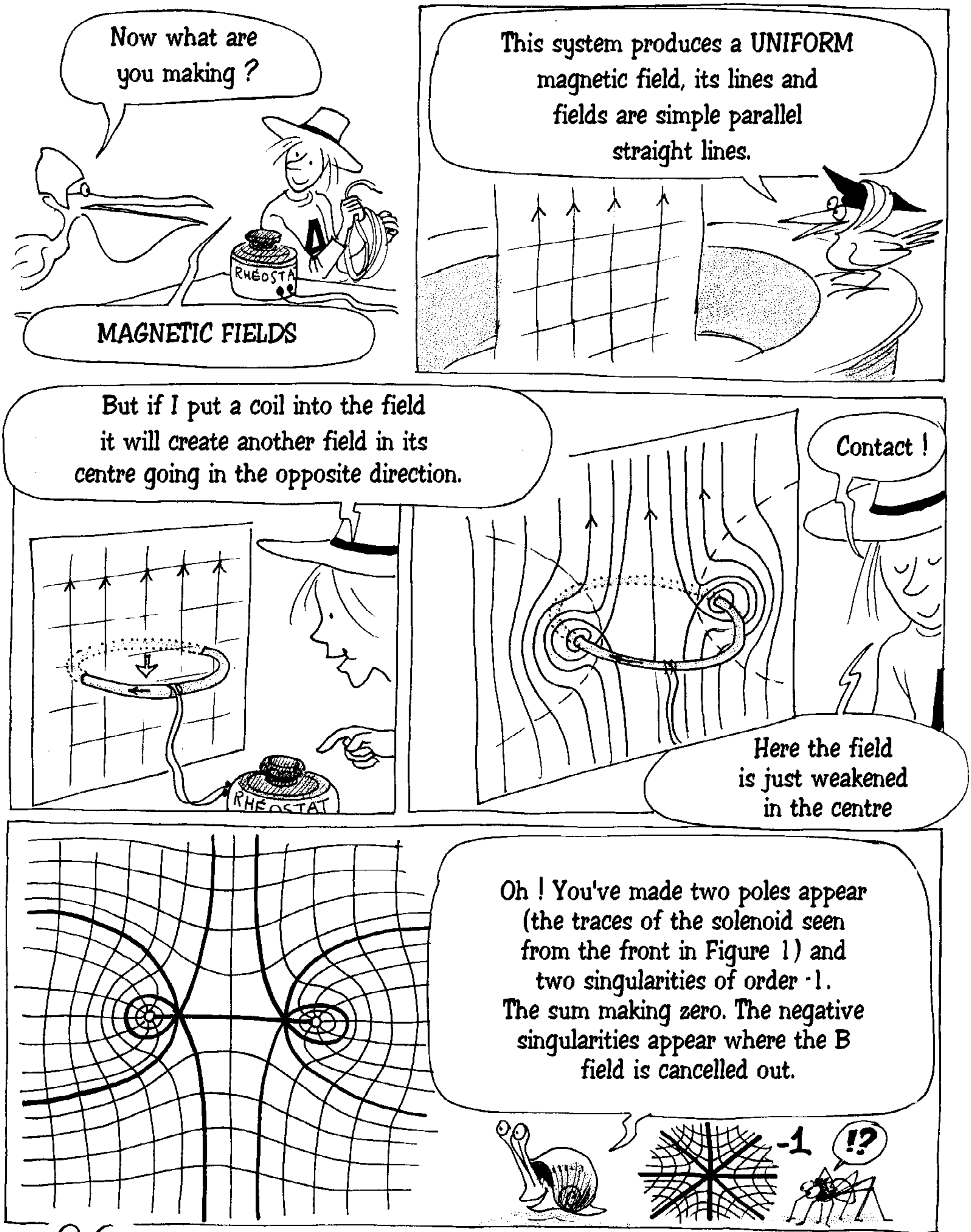


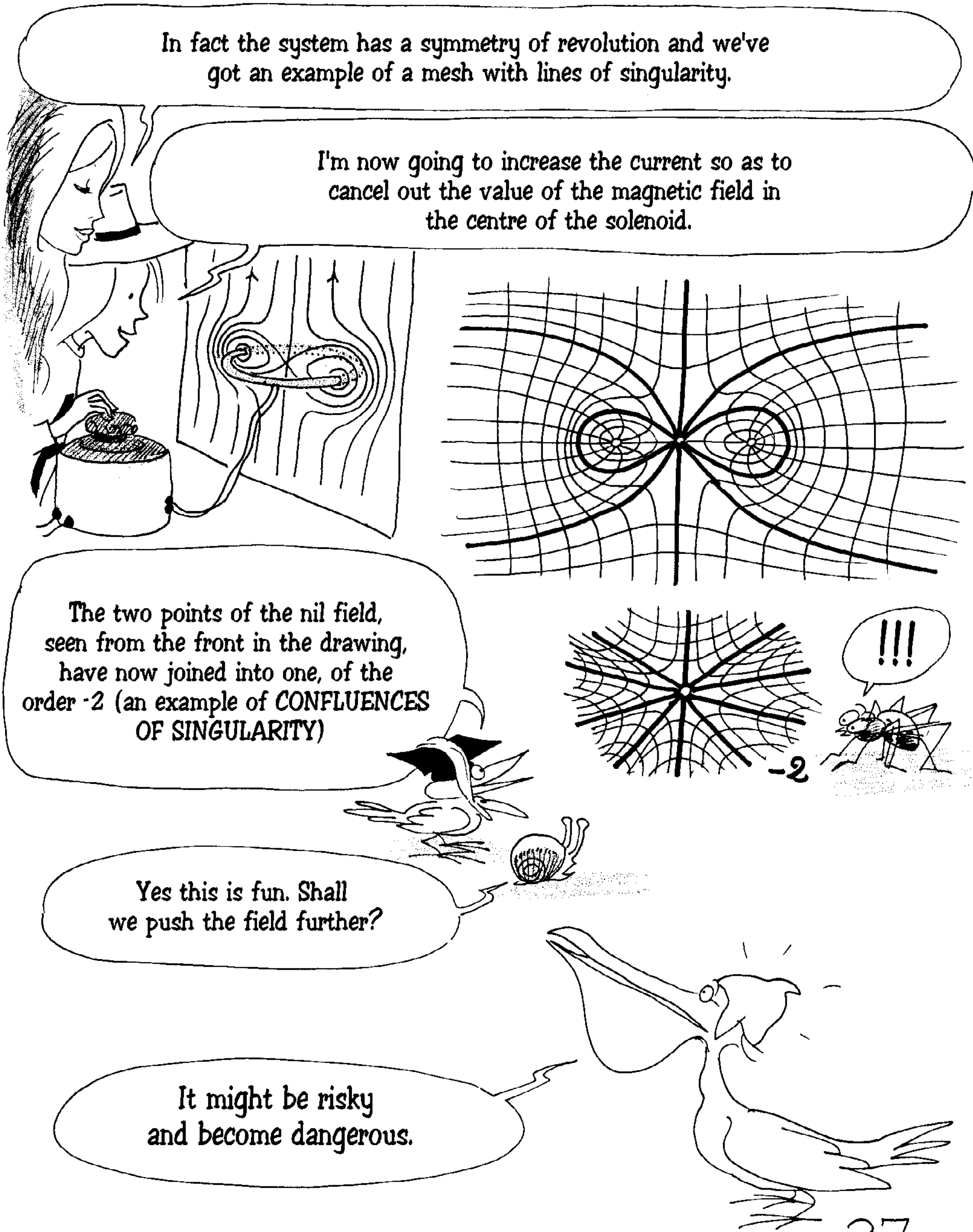


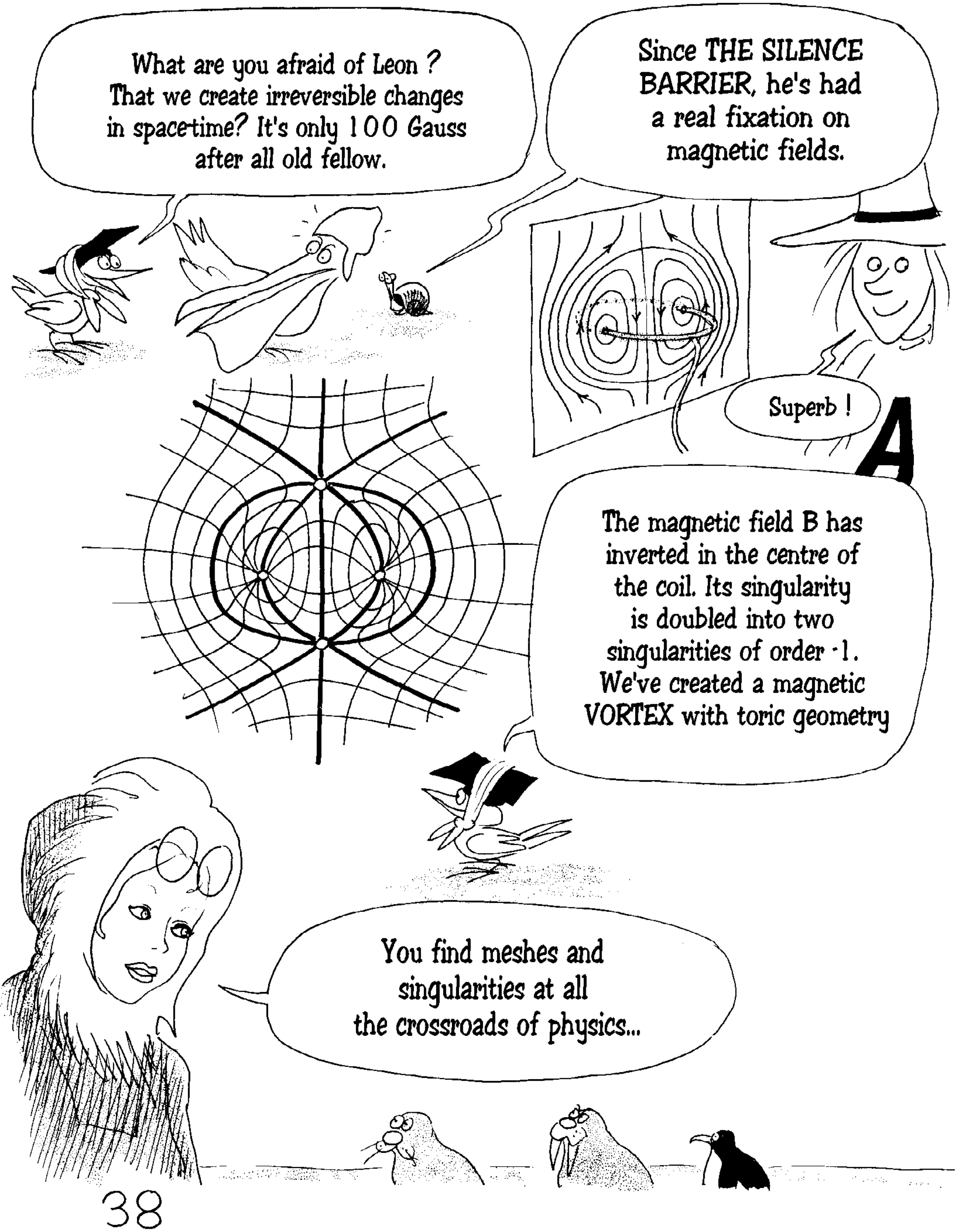
Note :

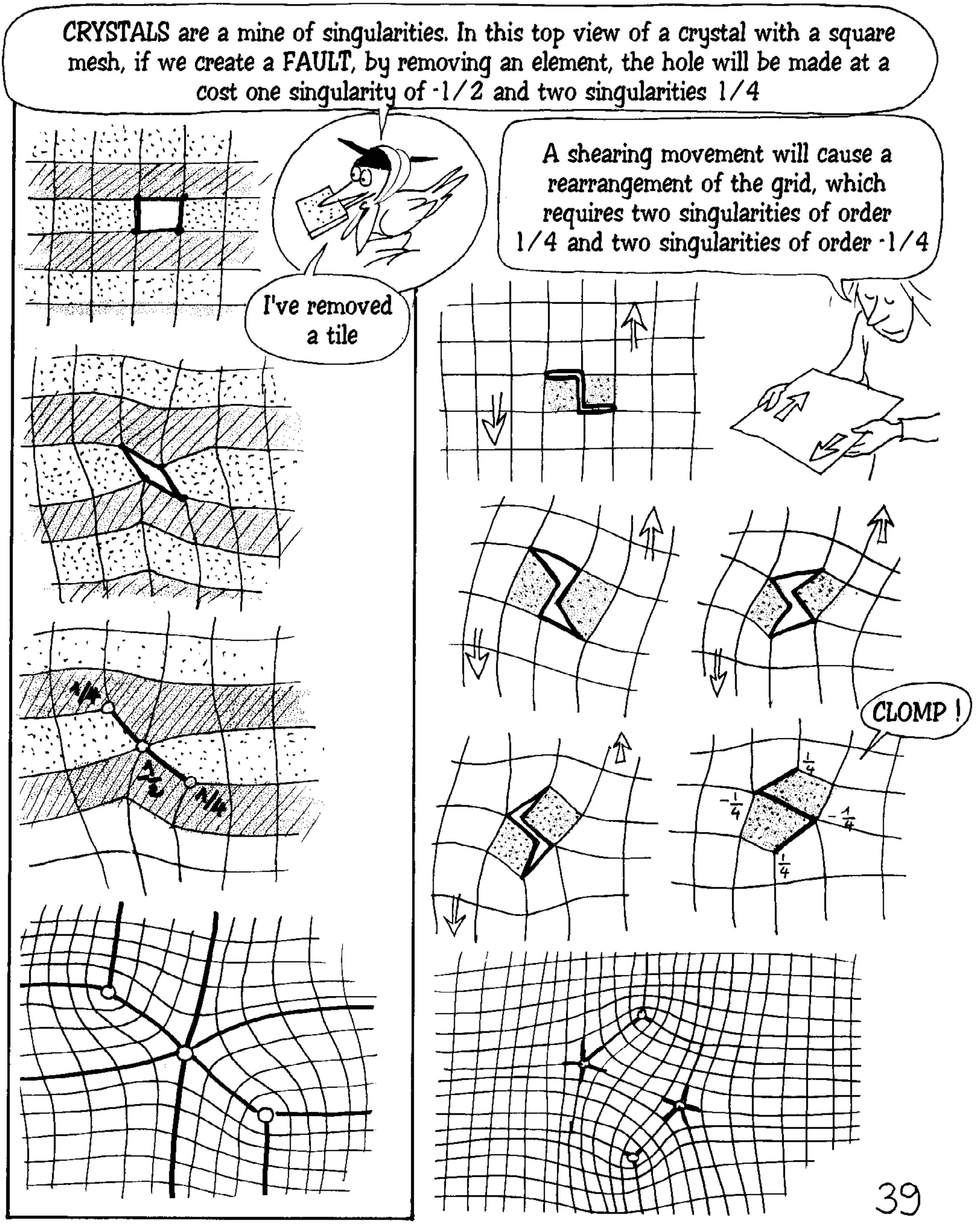
Those who have read BLACK HOLE, pages 14 to 36 will no doubt have noticed the similarity between the drawings of mesh singularities and those concerning POSICONES, NEGACONES and the curve. All these ideas, essentially ANGULAR, are closely linked to the TOTAL CURVATURE of a surface, represented in our space of three dimensions, which is exactly equal to the Euler-Poincaré characteristic multiplied by 360° (or by 2π)

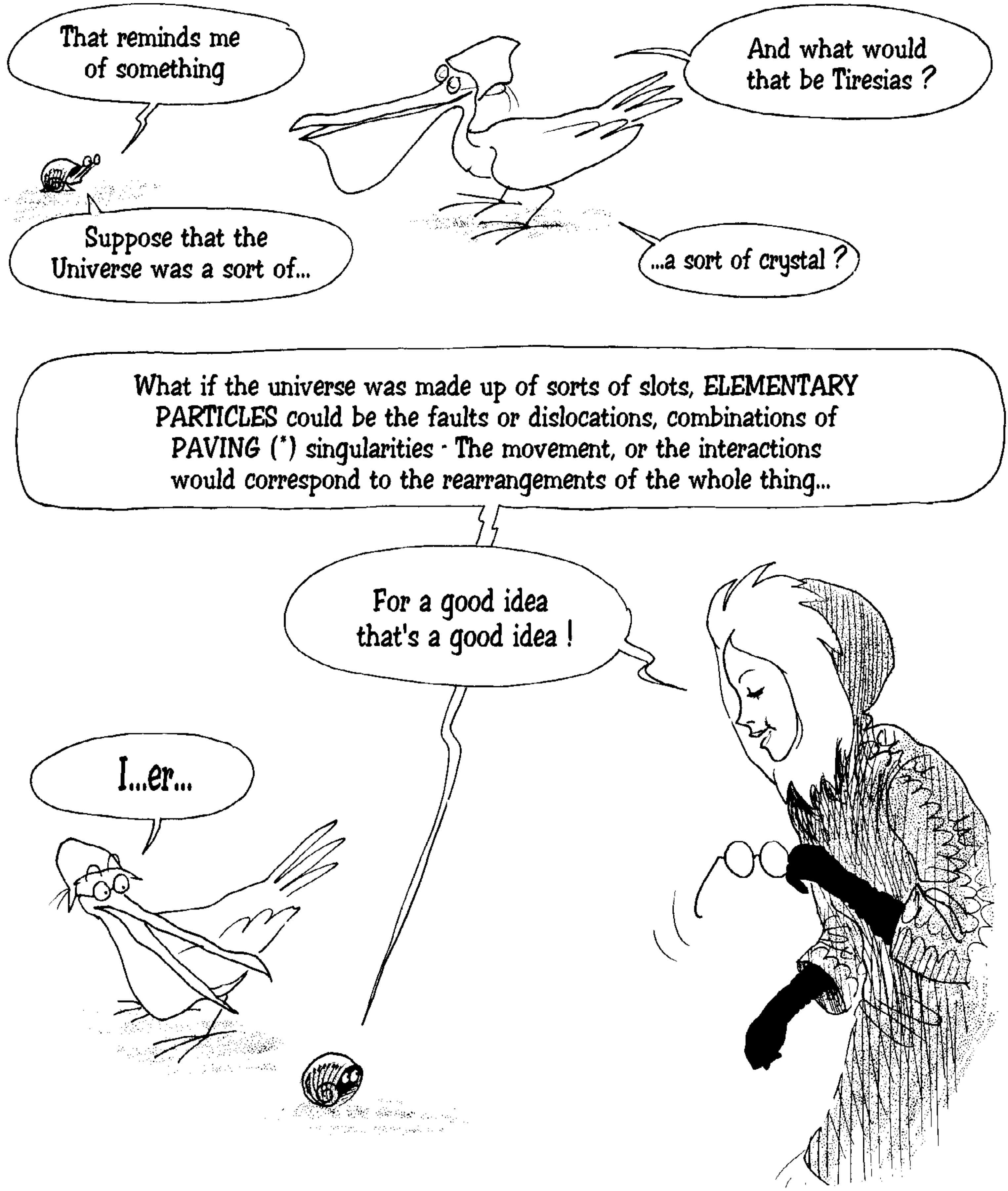

It's a pity that such things are totally useless, like Greek and Latin.
Not at all Leon! There are lots of singularities in nature !
Where?
Pull apart a zip fastener
(1/2 ; -1/2)
(-1/4 ; 1/2 ; -1/4)
An ensemble of singularities +1/4-1/2 : a sheet laid on tent pegs.


Now what are you making ?
RHÉOSTAT
MAGNETIC FIELDS
This system produces a UNIFORM magnetic field, its lines and fields are simple parallel straight lines.
But if I put a coil into the field it will create another field in its centre going in the opposite direction.
RHÉOSTAT
Contact !
Here the field is just weakened in the centre
Oh ! You've made two poles appear (the traces of the solenoid seen from the front in Figure 1) and two singularities of order -1. The sum making zero. The negative singularities appear where the B field is cancelled out.
-1
!?

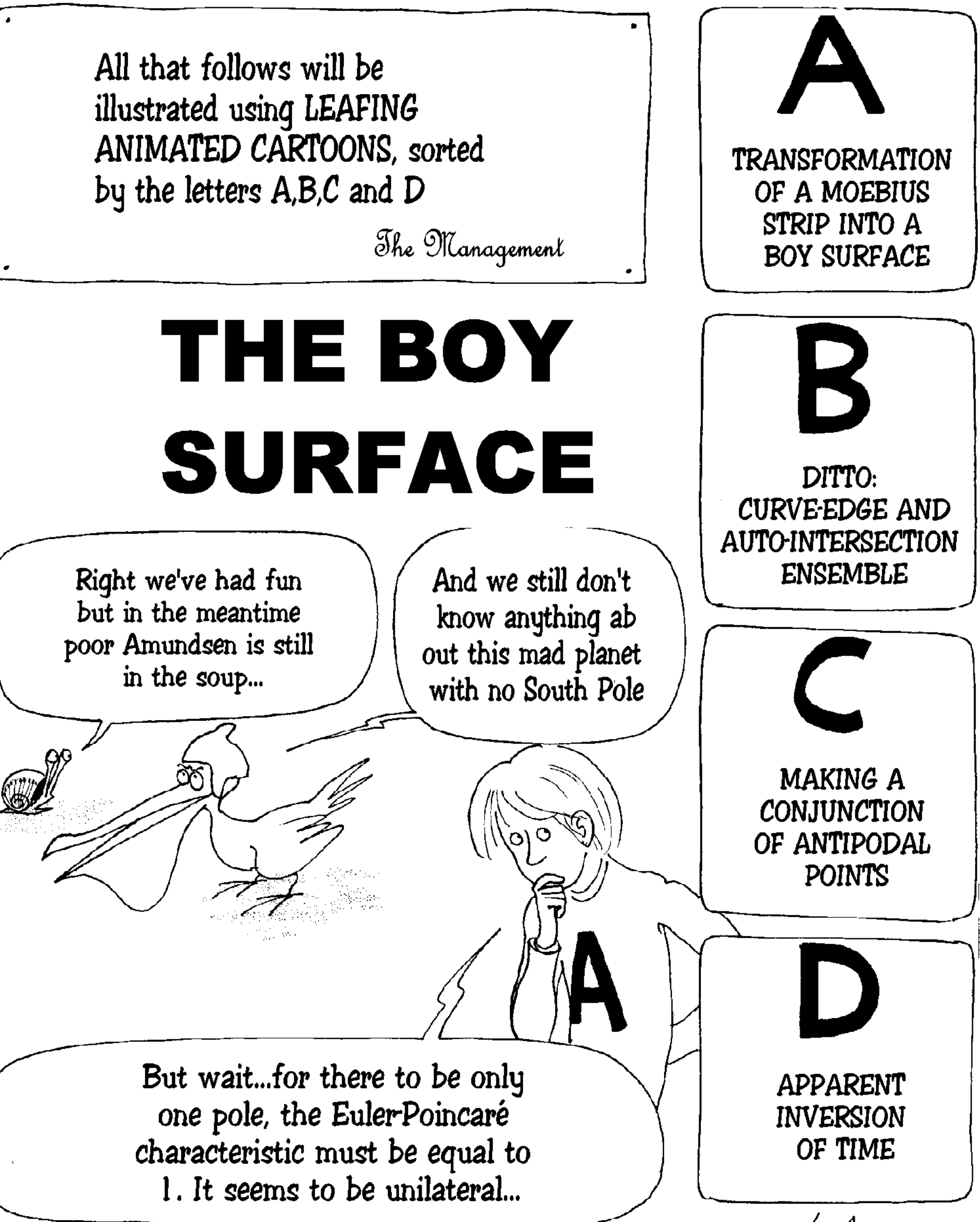

In fact the system has a symmetry of revolution and we've got an example of a mesh with lines of singularity.
I'm now going to increase the current so as to cancel out the value of the magnetic field in the centre of the solenoid.
The two points of the nil field, seen from the front in the drawing, have now joined into one, of the order -2 (an example of CONFLUENCES OF SINGULARITY)
-2
!!!
Yes this is fun. Shall we push the field further?
It might be risky and become dangerous.

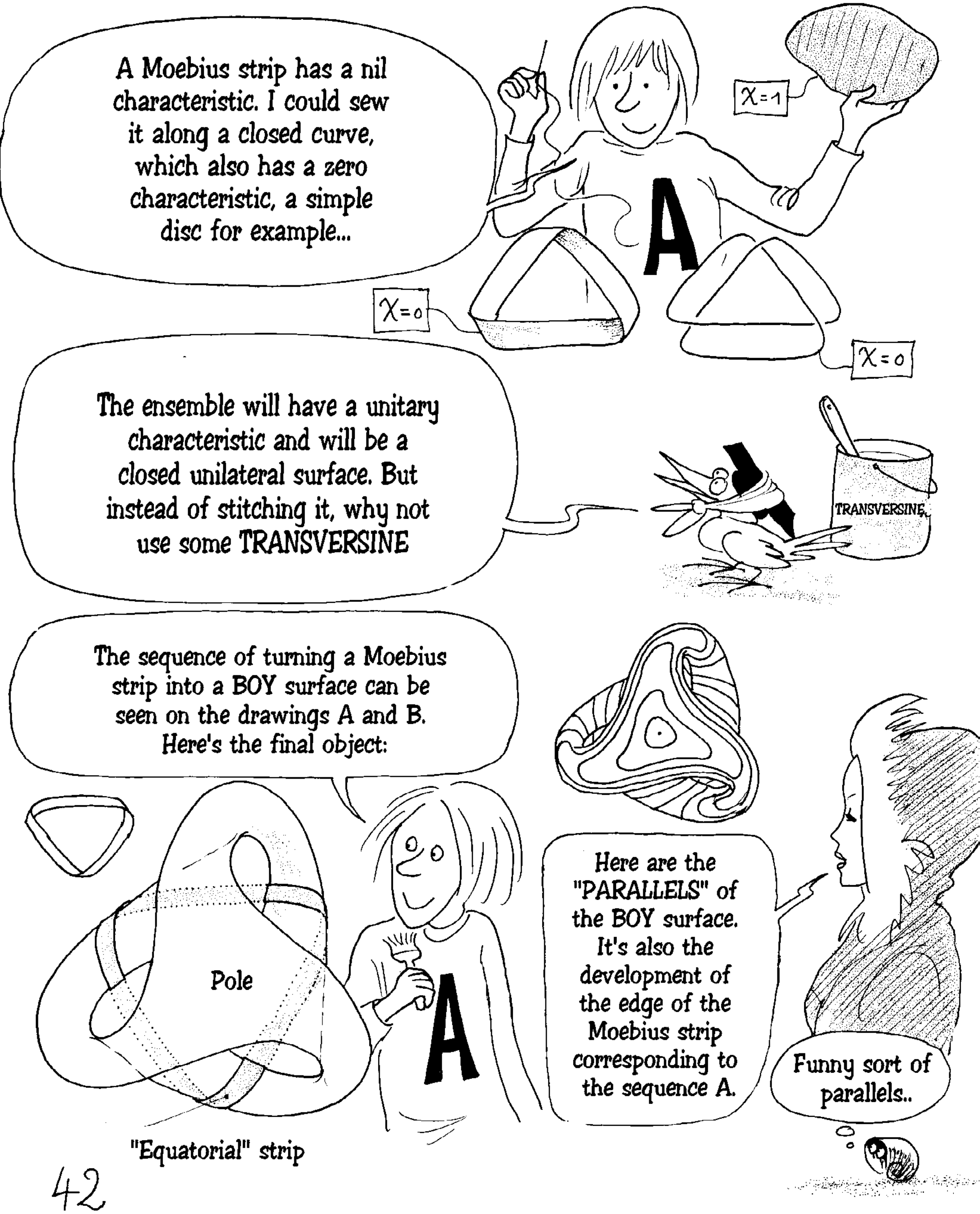

What are you afraid of Leon ? That we create irreversible changes in spacetime? It's only 100 Gauss after all old fellow.
Since THE SILENCE BARRIER, he's had a real fixation on magnetic fields.
Superb !
A
The magnetic field B has inverted in the centre of the coil. Its singularity is doubled into two singularities of order -1. We've created a magnetic VORTEX with toric geometry
You find meshes and singularities at all the crossroads of physics...


CRYSTALS are a mine of singularities. In this top view of a crystal with a square mesh, if we create a FAULT, by removing an element, the hole will be made at a cost one singularity of -1/2 and two singularities 1/4
I've removed a tile
A shearing movement will cause a rearrangement of the grid, which requires two singularities of order 1/4 and two singularities of order -1/4
CLOMP !
1/4
-1/4
-1/4
1/4

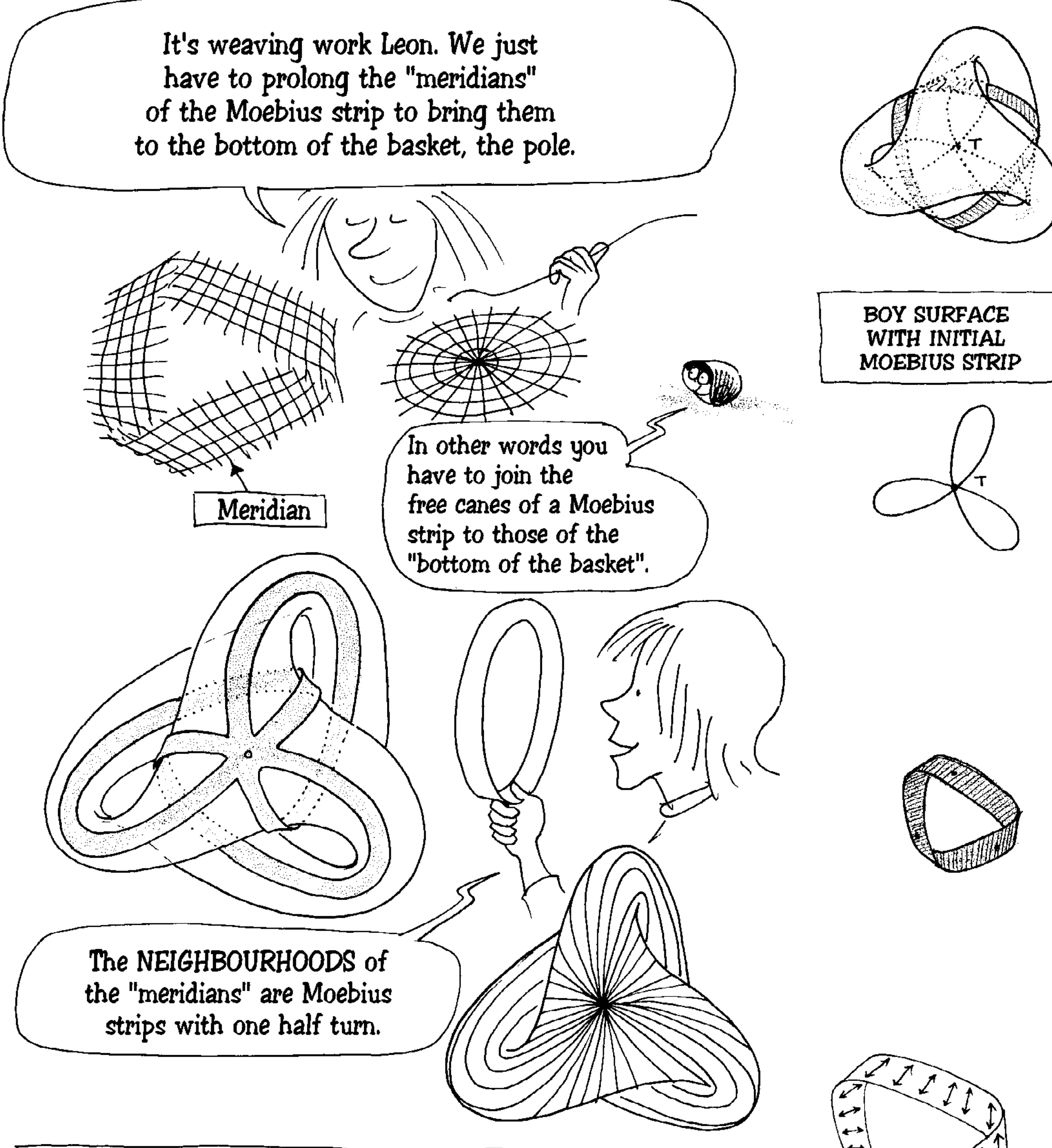


(*) MESH refers to objects with two dimensions. PAVING is the equivalent for a superior number of dimensions.


All that follows will be illustrated using LEAFING ANIMATED CARTOONS, sorted by the letters A,B,C and D
The Management
THE BOY SURFACE
A
TRANSFORMATION OF A MOEBIUS STRIP INTO A BOY SURFACE
B
DITTO: CURVE-EDGE AND AUTO-INTERSECTION ENSEMBLE
C
MAKING A CONJUNCTION OF ANTIPODAL POINTS
D
APPARENT INVERSION OF TIME
Right we've had fun but in the meantime poor Amundsen is still in the soup...
And we still don't know anything ab out this mad planet with no South Pole
A
But wait...for there to be only one pole, the Euler-Poincaré characteristic must be equal to 1. It seems to be unilateral...

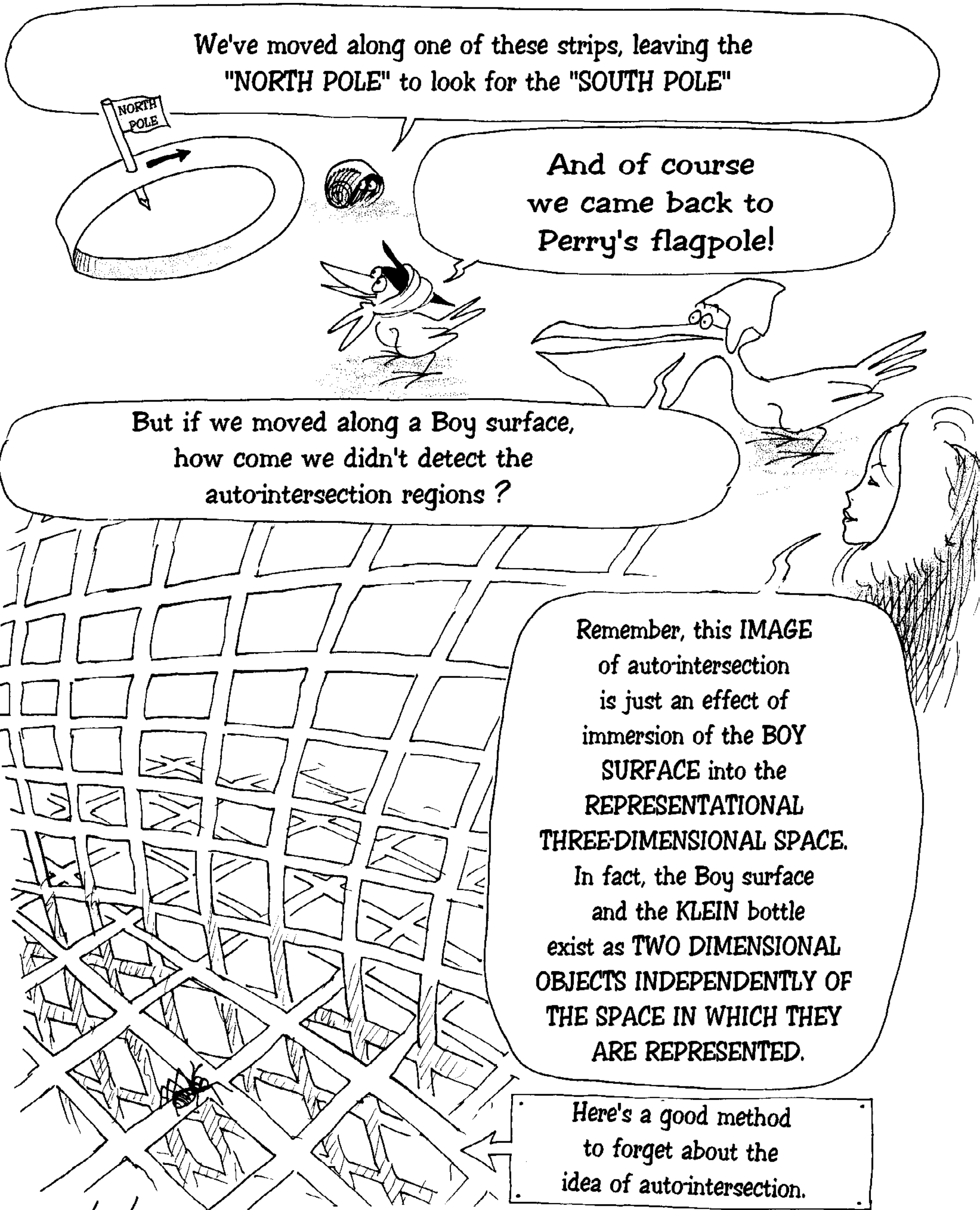


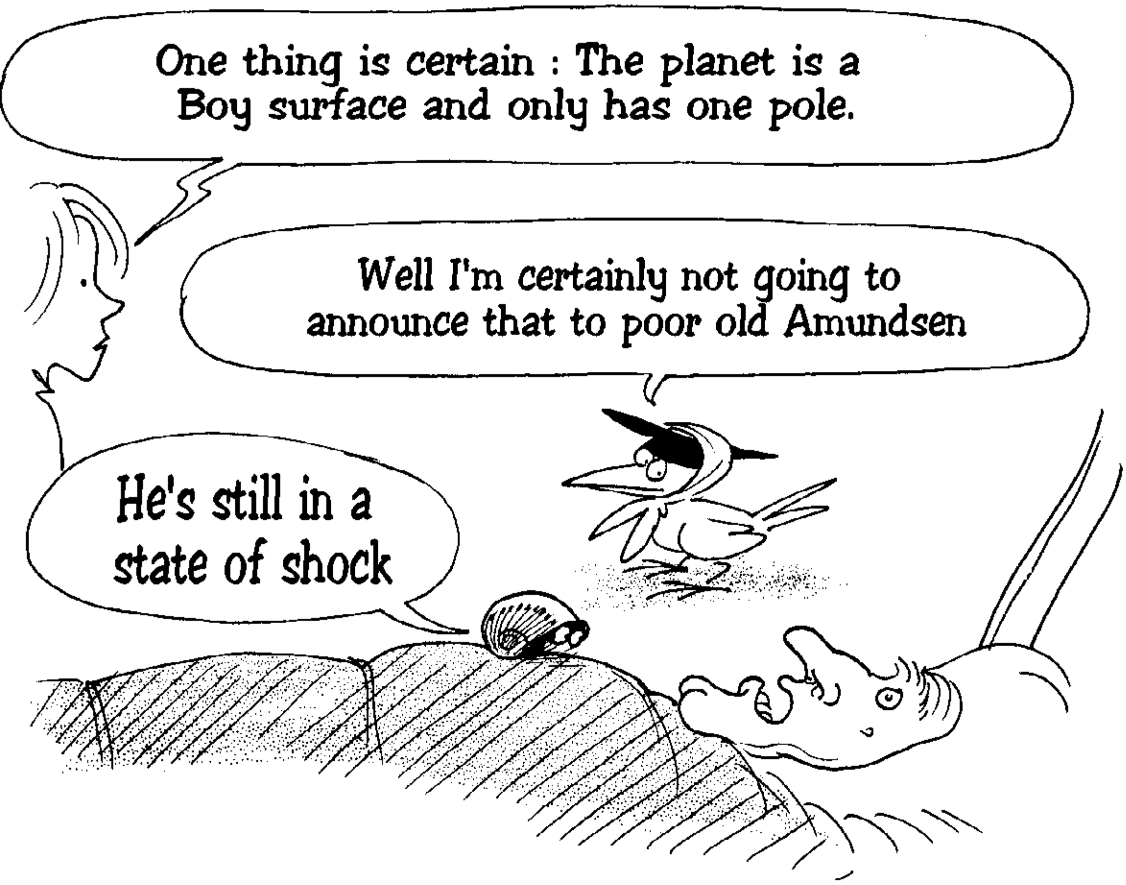
A Moebius strip has a nil characteristic. I could sew it along a closed curve, which also has a zero characteristic, a simple disc for example...
χ=1
χ=0
χ=0
The ensemble will have a unitary characteristic and will be a closed unilateral surface. But instead of stitching it, why not use some TRANSVERSINE
TRANSVERSINE
The sequence of turning a Moebius strip into a BOY surface can be seen on the drawings A and B. Here's the final object:
Pole
"Equatorial" strip
Here are the "PARALLELS" of the BOY surface. It's also the development of the edge of the Moebius strip corresponding to the sequence A.
Funny sort of parallels..

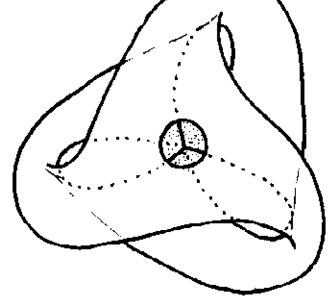


THE FIRST MODEL OF THE BOY SURFACE WITH ITS ENSEMBLE "MERIDIANS"+"PARALLELS", WAS IMAGINED BY THE AUTHOR. A FINE MODEL WAS THEN MADE BY THE SCULPTOR MAX SAUZE WHICH IS VISIBLE IN THE "πROOM" OF THE PALACE OF DISCOVERY in PARIS, FRANCE.

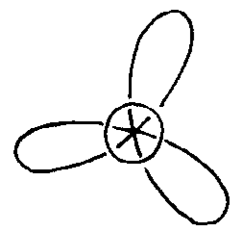
The Management


We've moved along one of these strips, leaving the "NORTH POLE" to look for the "SOUTH POLE"
NORTH POLE
And of course we came back to Perry's flagpole!
But if we moved along a Boy surface, how come we didn't detect the auto-intersection regions ?
Remember, this IMAGE of auto-intersection is just an effect of immersion of the BOY SURFACE into the REPRESENTATIONAL THREE-DIMENSIONAL SPACE. In fact, the Boy surface and the KLEIN bottle exist as TWO DIMENSIONAL OBJECTS INDEPENDENTLY OF THE SPACE IN WHICH THEY ARE REPRESENTED.
Here's a good method to forget about the idea of auto-intersection.

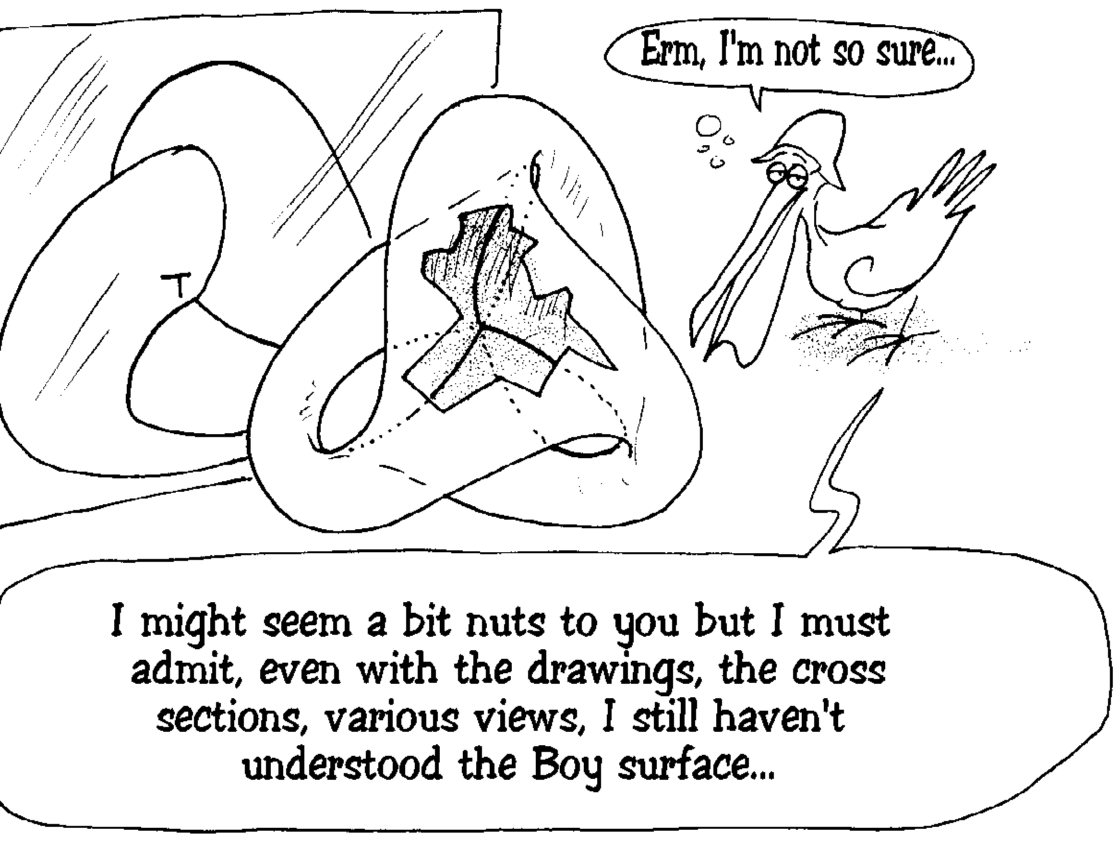


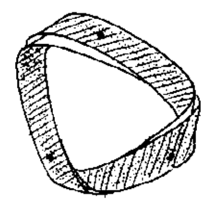


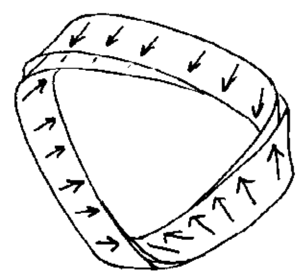
MOEBIUS STRIP WITH A CIRCULAR EDGE

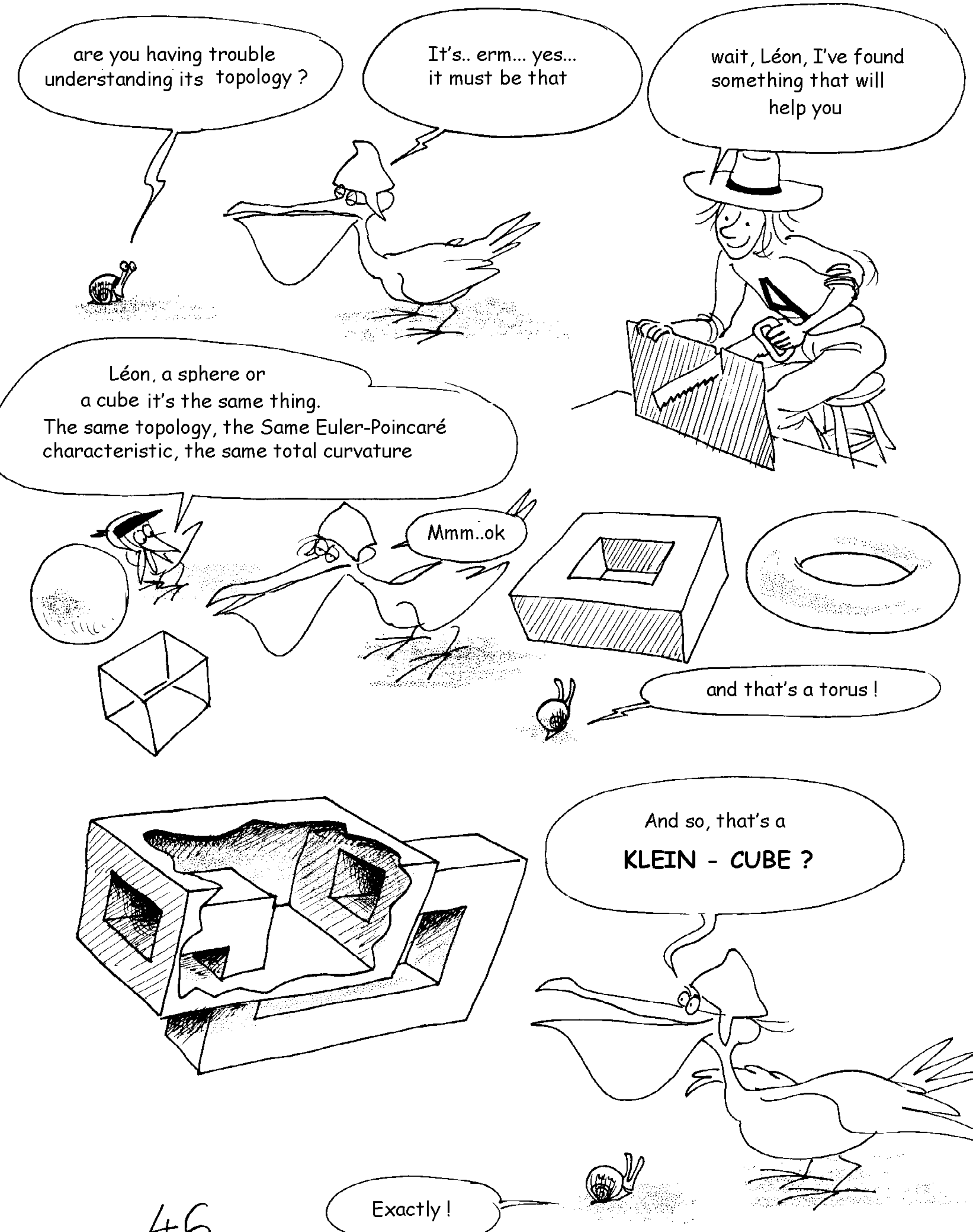


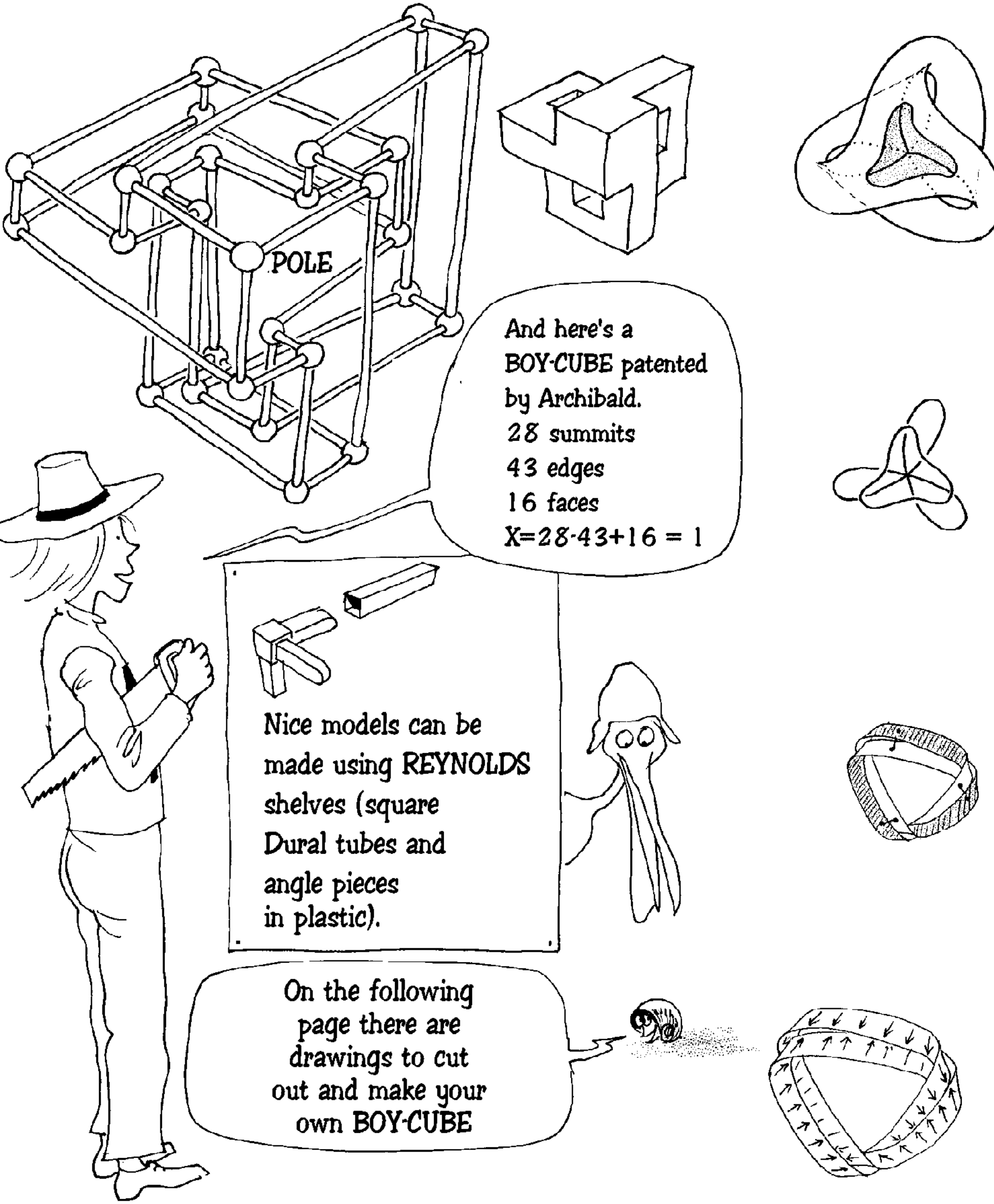
THE BOY CUBE



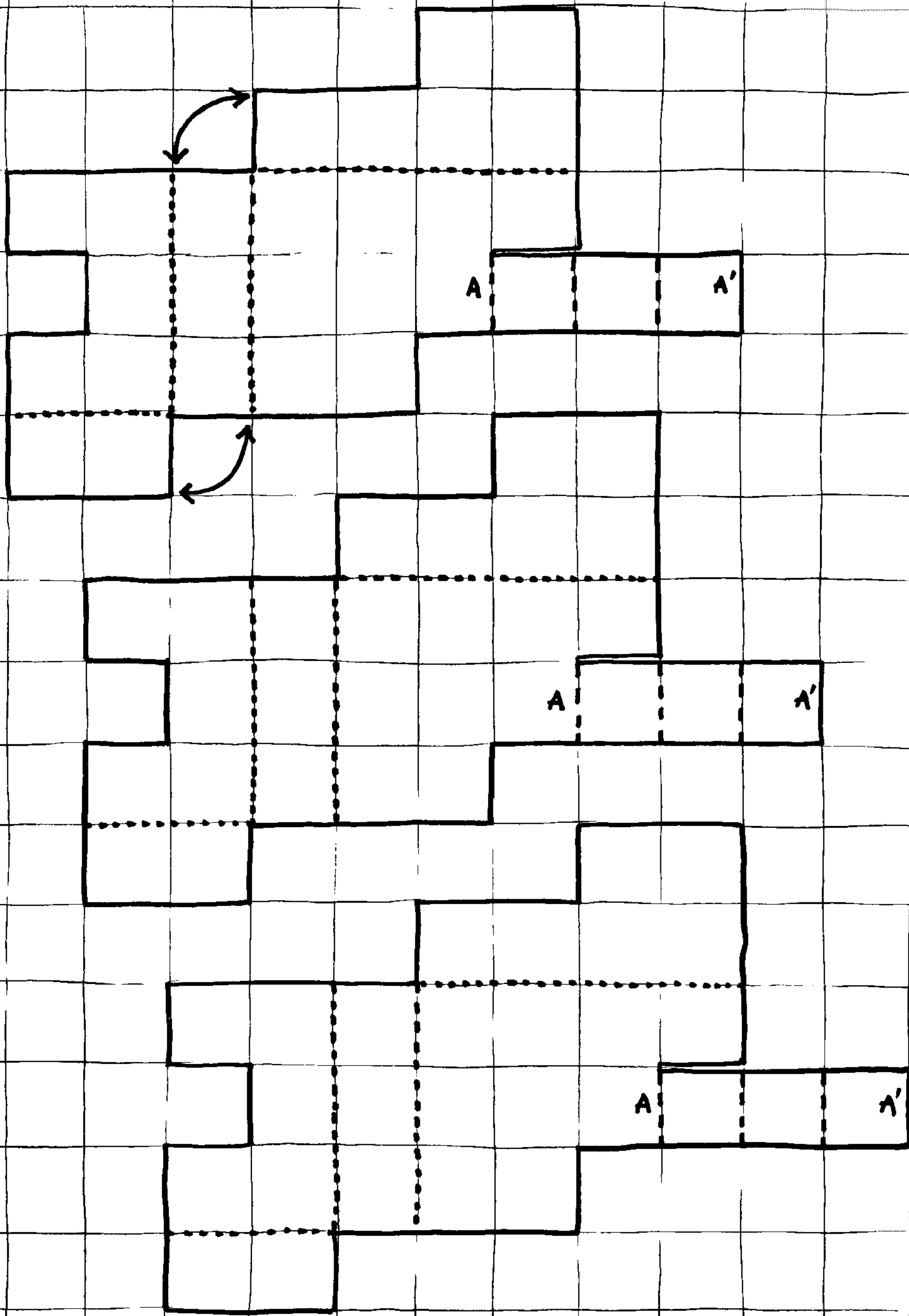


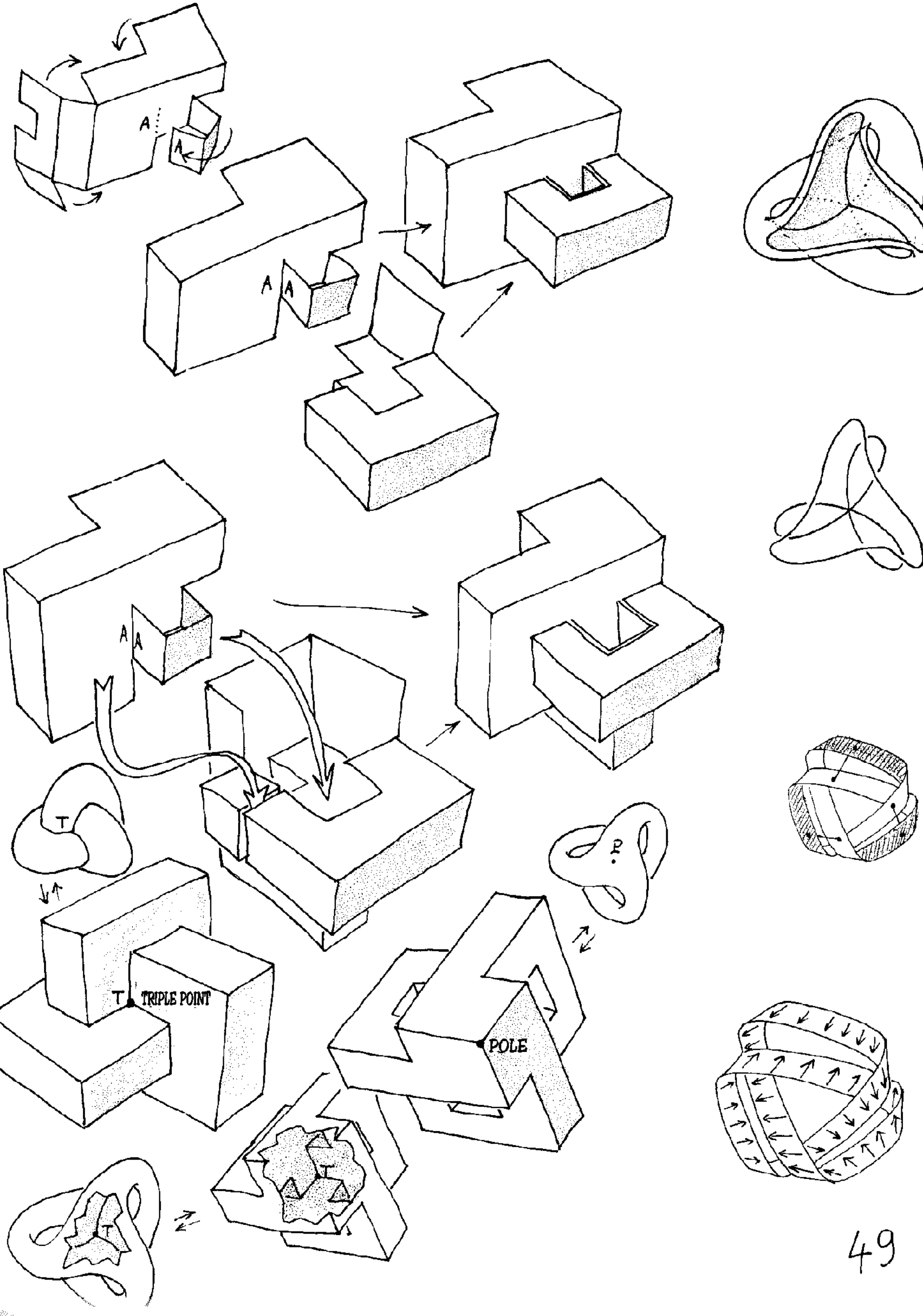



are you having trouble understanding its topology ?
It's.. erm... yes... it must be that
wait, Léon, I've found something that will help you
Léon, a sphere or a cube it's the same thing. The same topology, the Same Euler-Poincaré characteristic, the same total curvature
Mmm..ok
and that's a torus !
And so, that's a KLEIN - CUBE ?
Exactly !

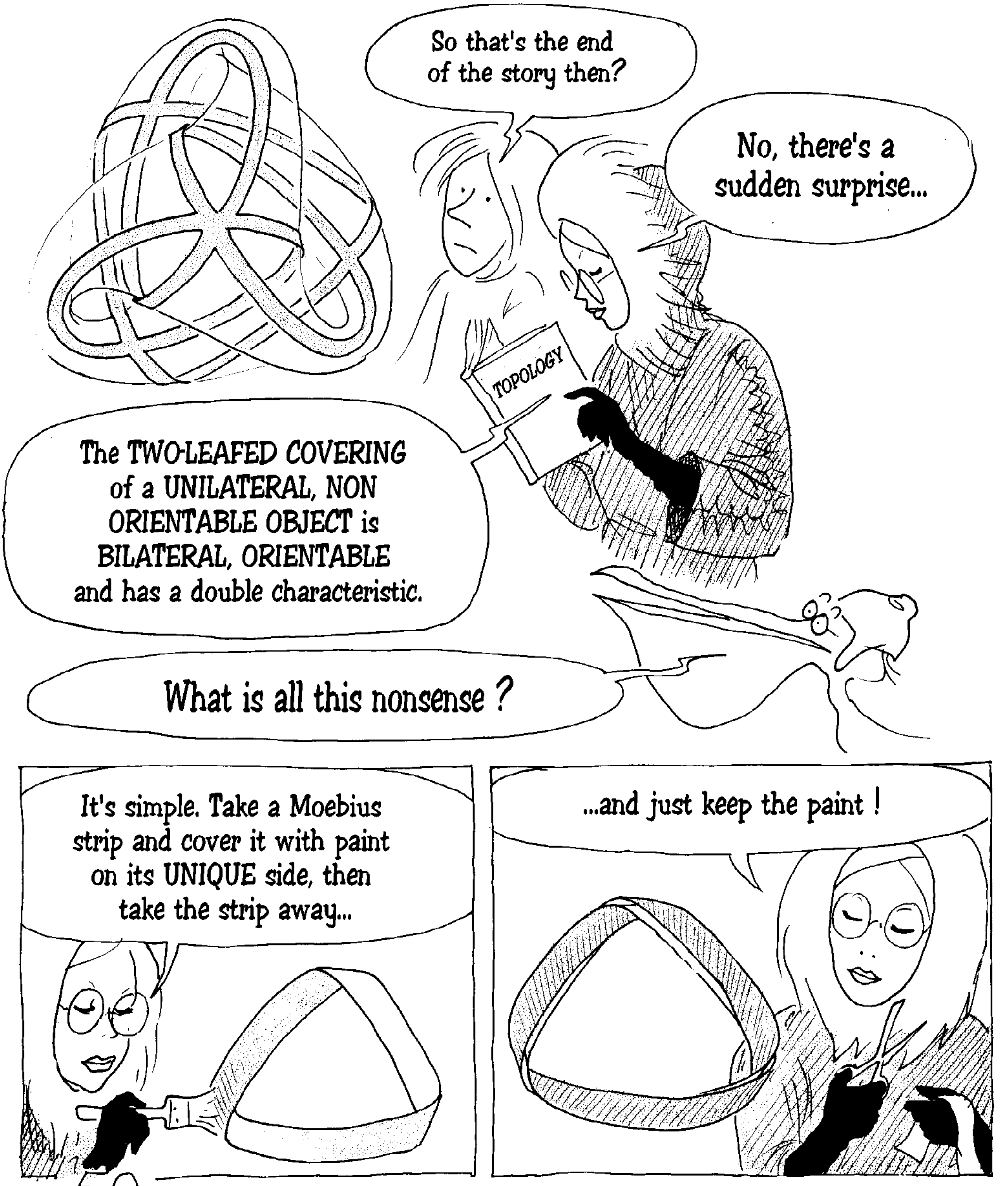


POLE
And here's a BOY-CUBE patented by Archibald.
28 summits
43 edges
16 faces
X=28-43+16 = 1
Nice models can be made using REYNOLDS shelves (square Dural tubes and angle pieces in plastic).
On the following page there are drawings to cut out and make your own BOY-CUBE

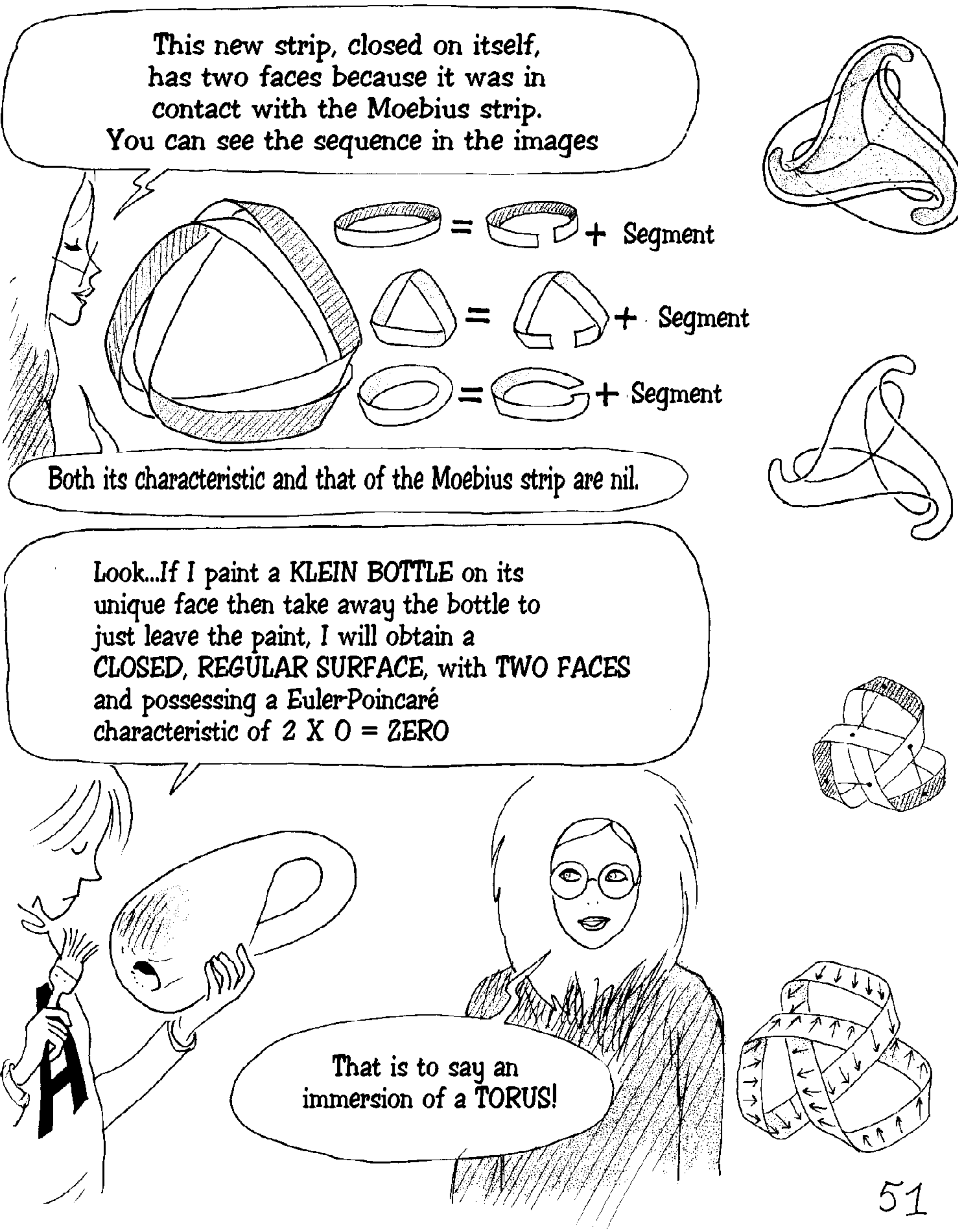

A
A'
A
A'
A
A'


A
A
A A
A A
T
TRIPLE POINT
POLE
T
T

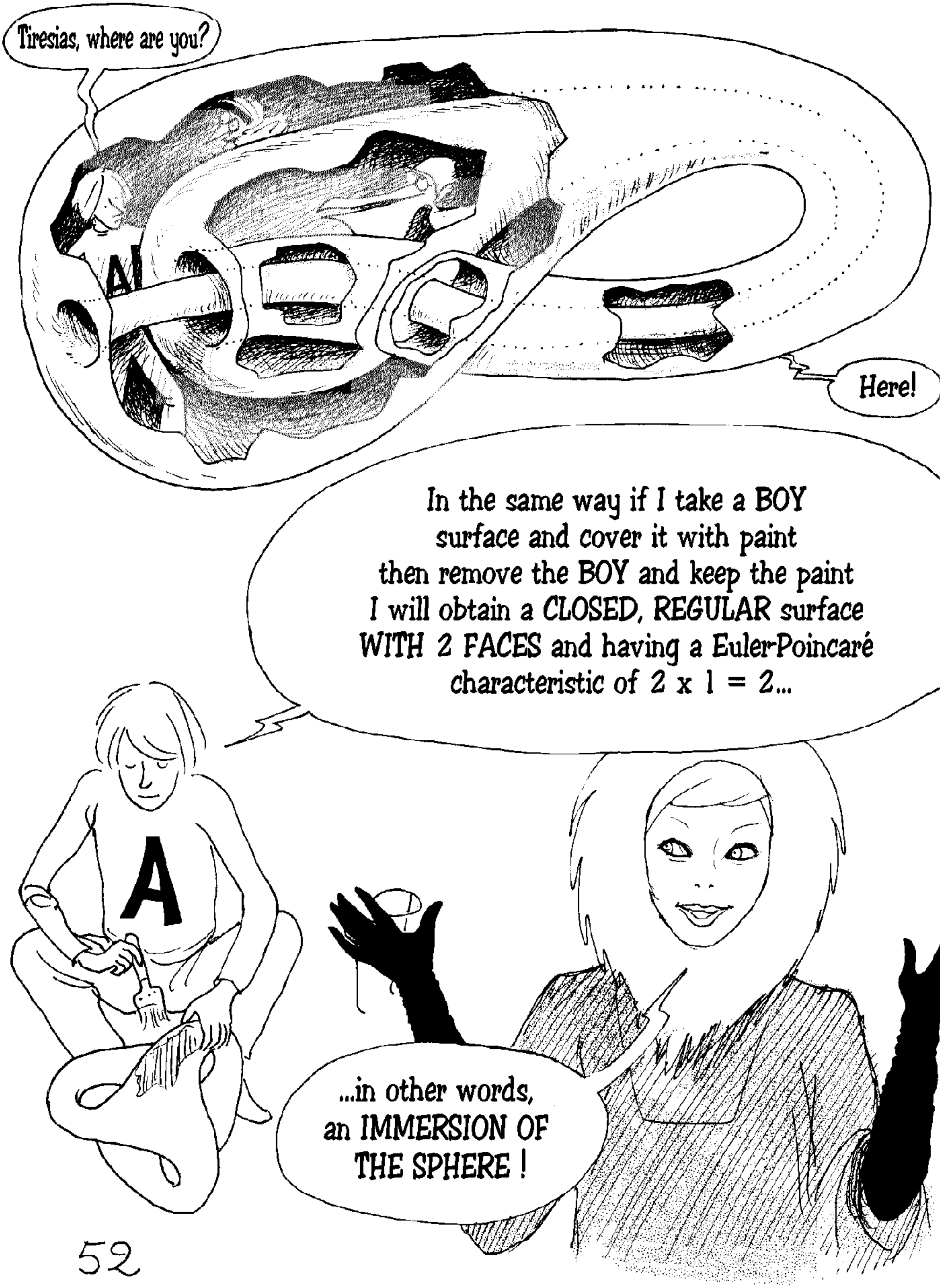
COVERINGS

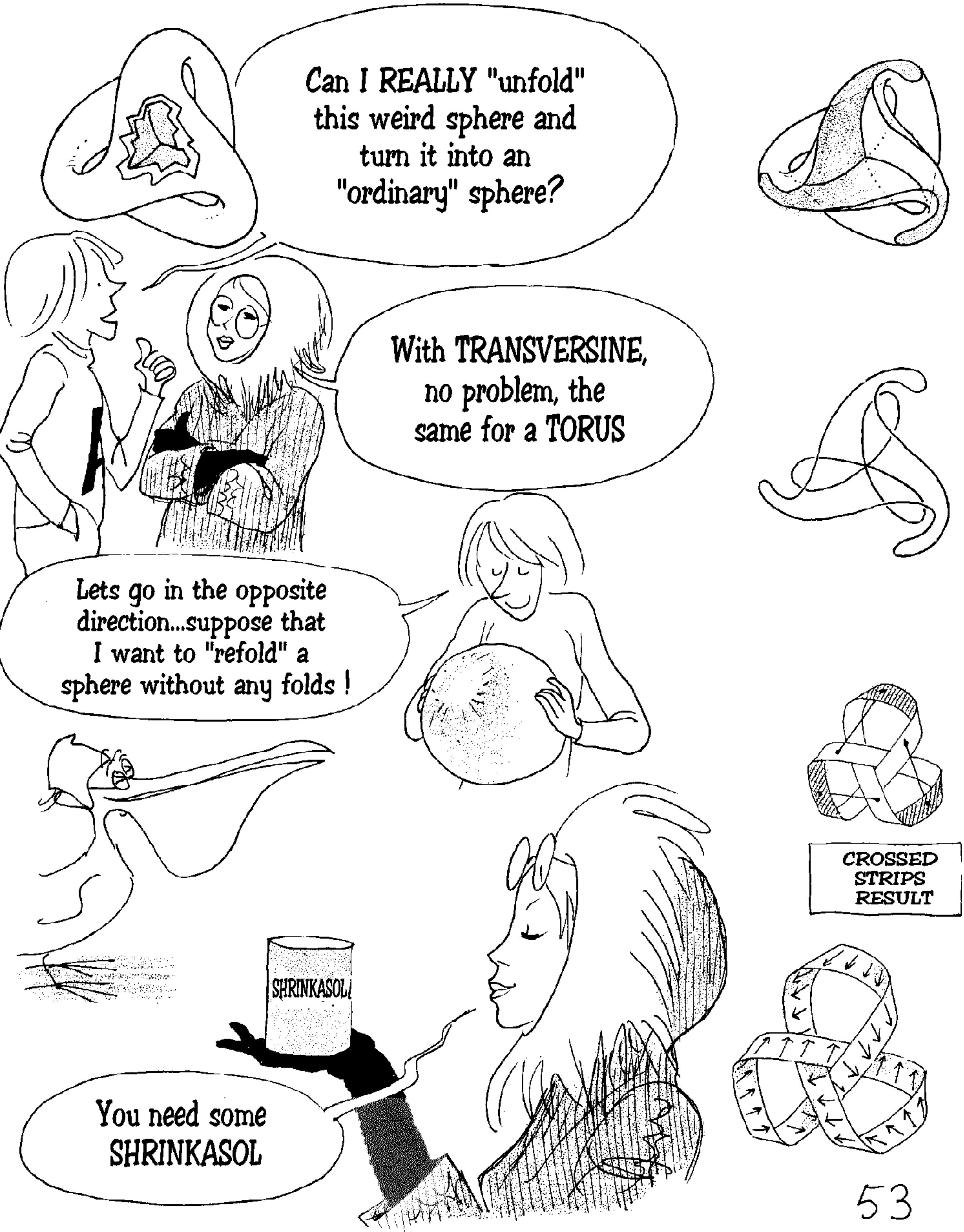


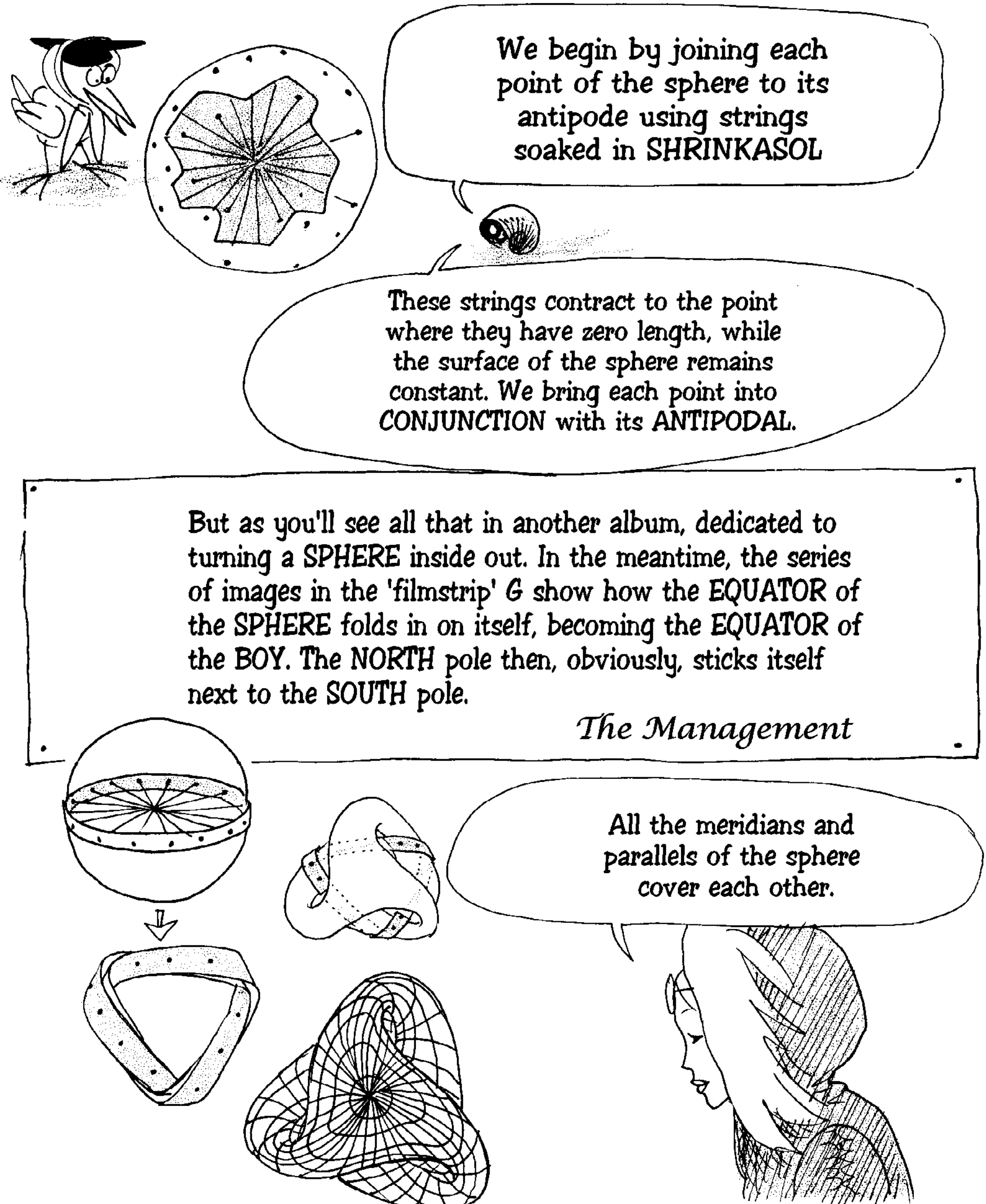
So that's the end of the story then?
No, there's a sudden surprise...
TOPOLOGY
The TWO-LEAFED COVERING of a UNILATERAL, NON ORIENTABLE OBJECT is BILATERAL, ORIENTABLE and has a double characteristic.
What is all this nonsense ?
It's simple. Take a Moebius strip and cover it with paint on its UNIQUE side, then take the strip away...
...and just keep the paint !

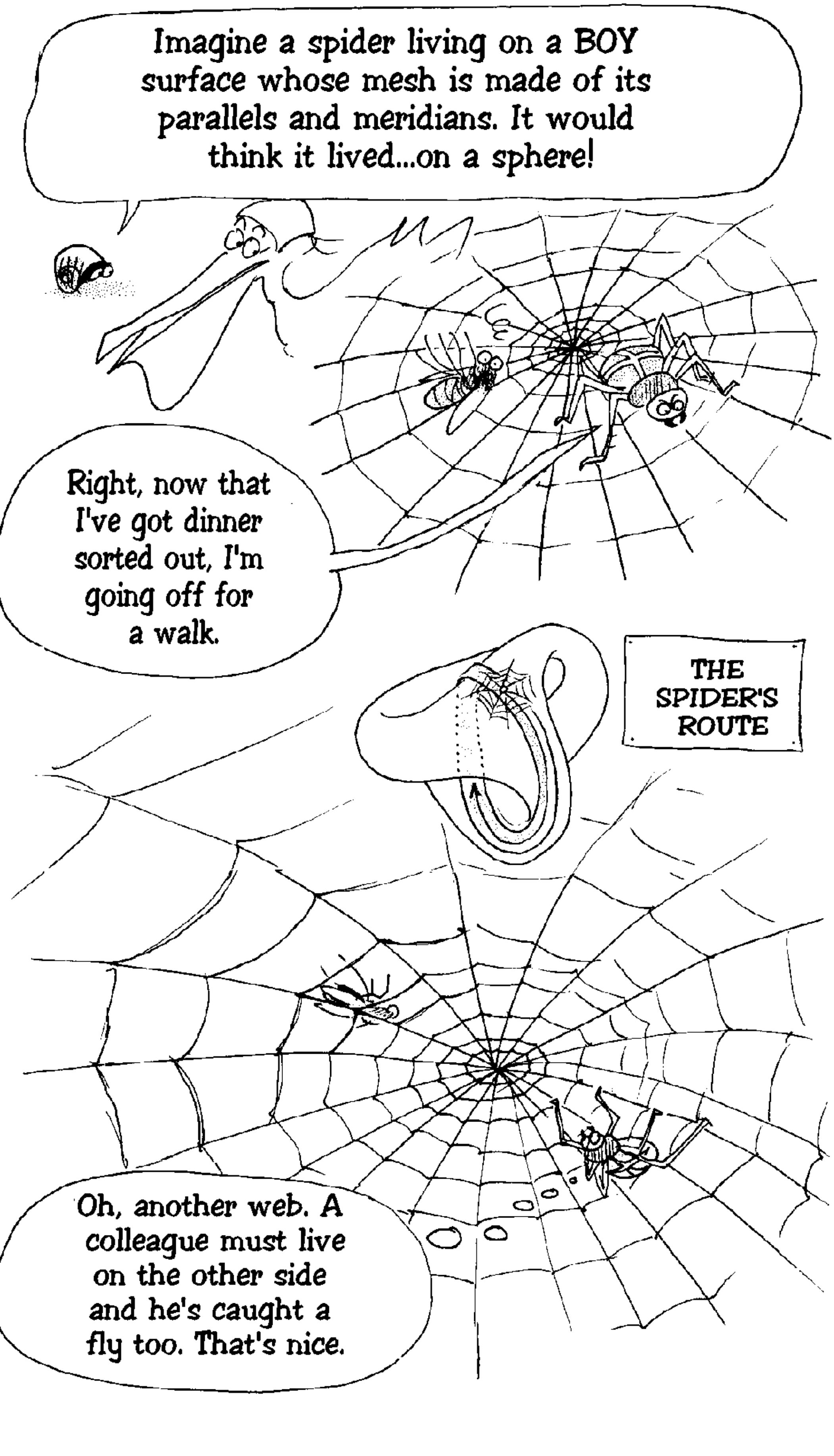


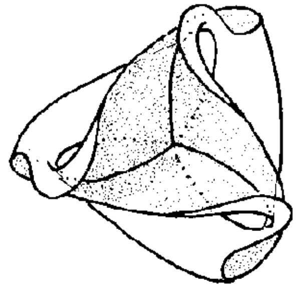
This new strip, closed on itself, has two faces because it was in contact with the Moebius strip. You can see the sequence in the images
= + Segment
= + Segment
= + Segment
Both its characteristic and that of the Moebius strip are nil.
Look...If I paint a KLEIN BOTTLE on its unique face then take away the bottle to just leave the paint, I will obtain a CLOSED, REGULAR SURFACE, with TWO FACES and possessing a Euler-Poincaré characteristic of 2 X 0 = ZERO
That is to say an immersion of a TORUS!


Tiresias, where are you?
Here!
In the same way if I take a BOY surface and cover it with paint then remove the BOY and keep the paint I will obtain a CLOSED, REGULAR surface WITH 2 FACES and having a Euler-Poincaré characteristic of 2 x 1 = 2...
...in other words, an IMMERSION OF THE SPHERE !

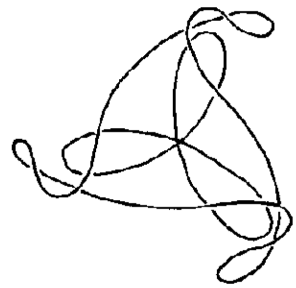

Can I REALLY "unfold" this weird sphere and turn it into an "ordinary" sphere?
With TRANSVERSINE, no problem, the same for a TORUS
Lets go in the opposite direction...suppose that I want to "refold" a sphere without any folds !
CROSSED STRIPS RESULT
SHRINKASOL
You need some SHRINKASOL

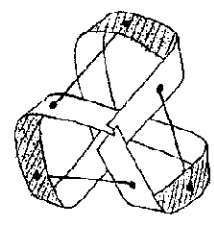

We begin by joining each point of the sphere to its antipode using strings soaked in SHRINKASOL
These strings contract to the point where they have zero length, while the surface of the sphere remains constant. We bring each point into CONJUNCTION with its ANTIPODAL.
But as you'll see all that in another album, dedicated to turning a SPHERE inside out. In the meantime, the series of images in the 'filmstrip' G show how the EQUATOR of the SPHERE folds in on itself, becoming the EQUATOR of the BOY. The NORTH pole then, obviously, sticks itself next to the SOUTH pole.
The Management
All the meridians and parallels of the sphere cover each other.

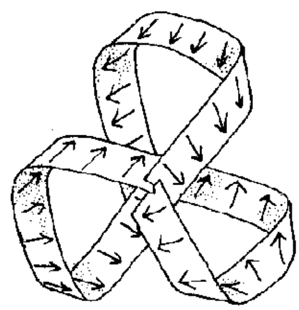


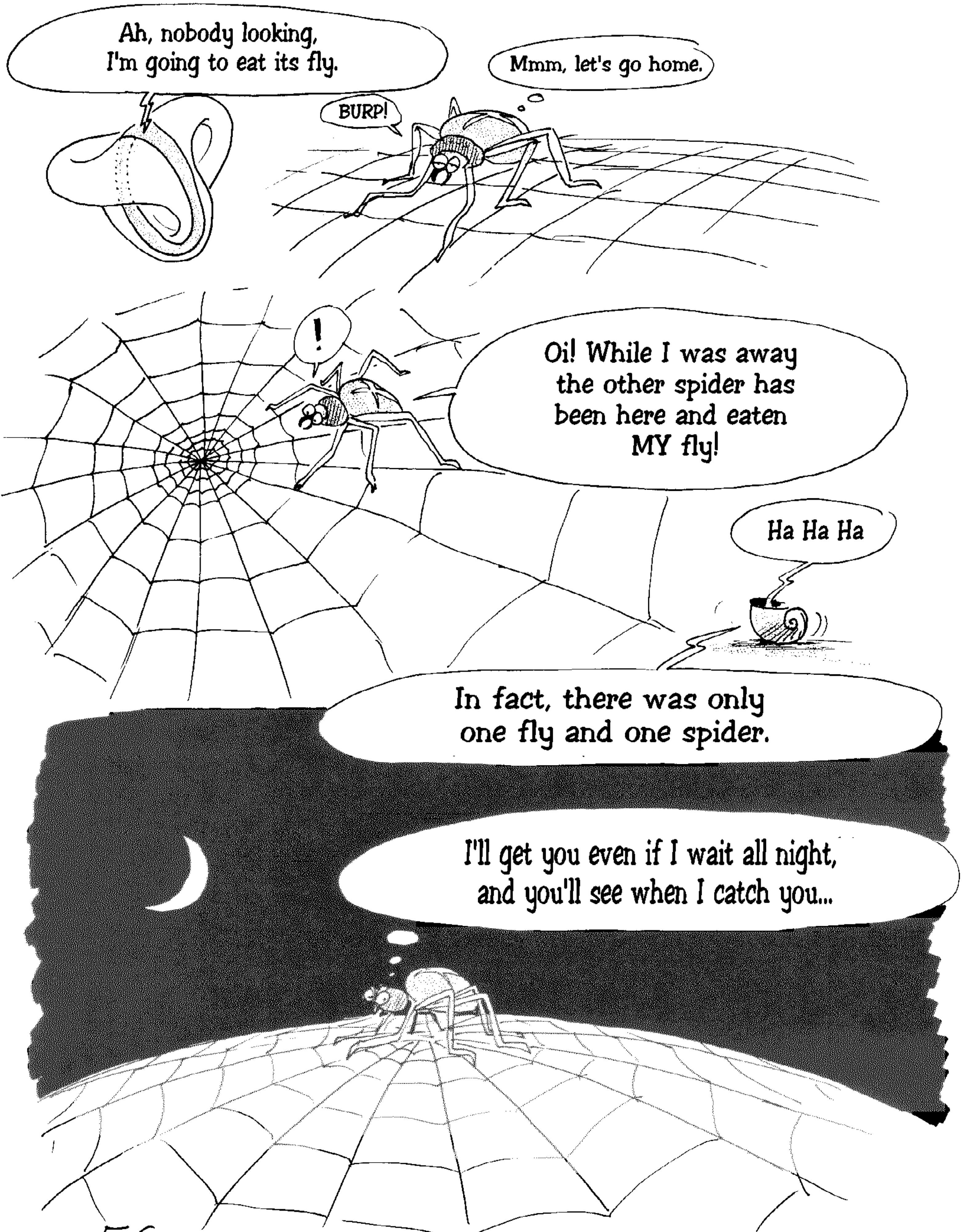


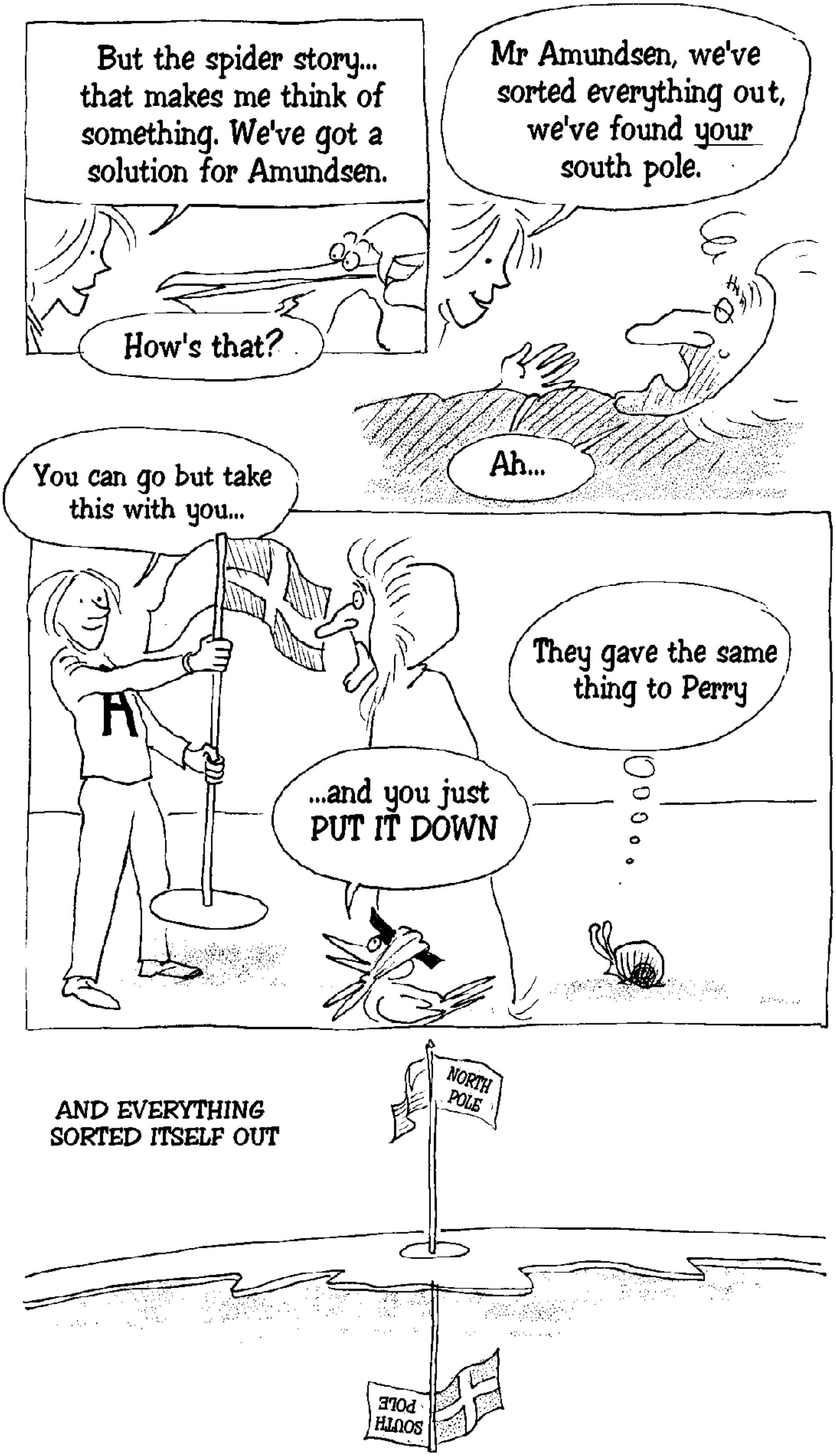
Closure of the three "tympani"

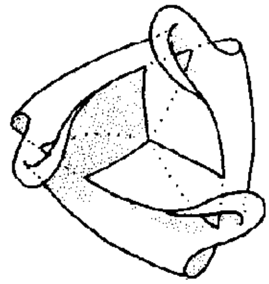




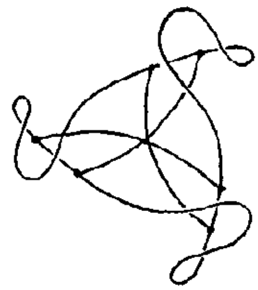


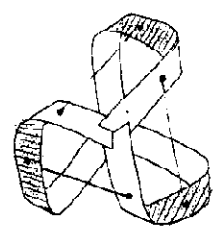

Ah, nobody looking,
I'm going to eat its fly.
Mmm, let's go home.
BURP!
!
Oi! While I was away the other spider has been here and eaten MY fly!
Ha Ha Ha
In fact, there was only one fly and one spider.
I'll get you even if I wait all night, and you'll see when I catch you...

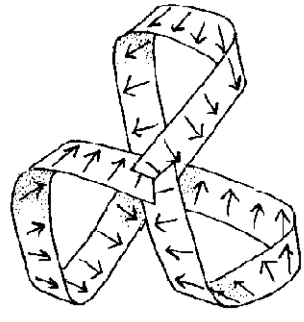




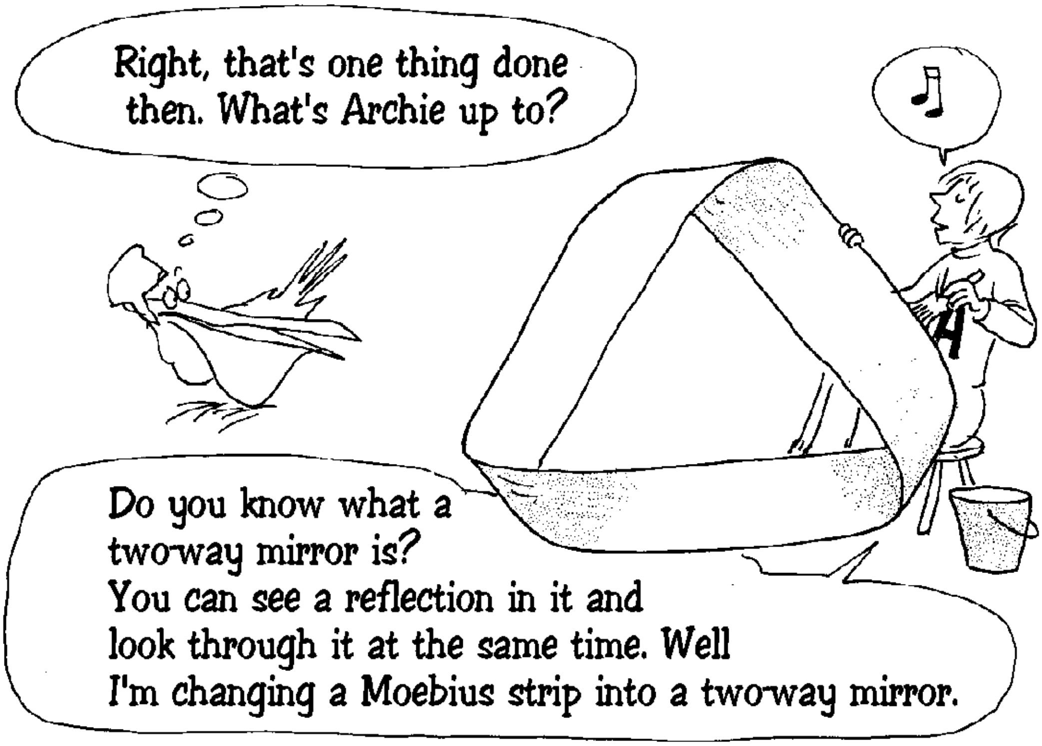
APPEARANCE OF "EARS"

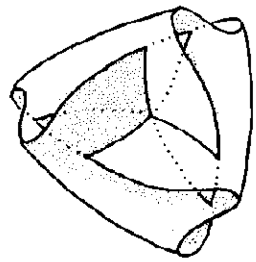


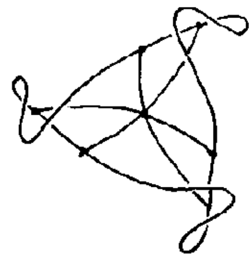




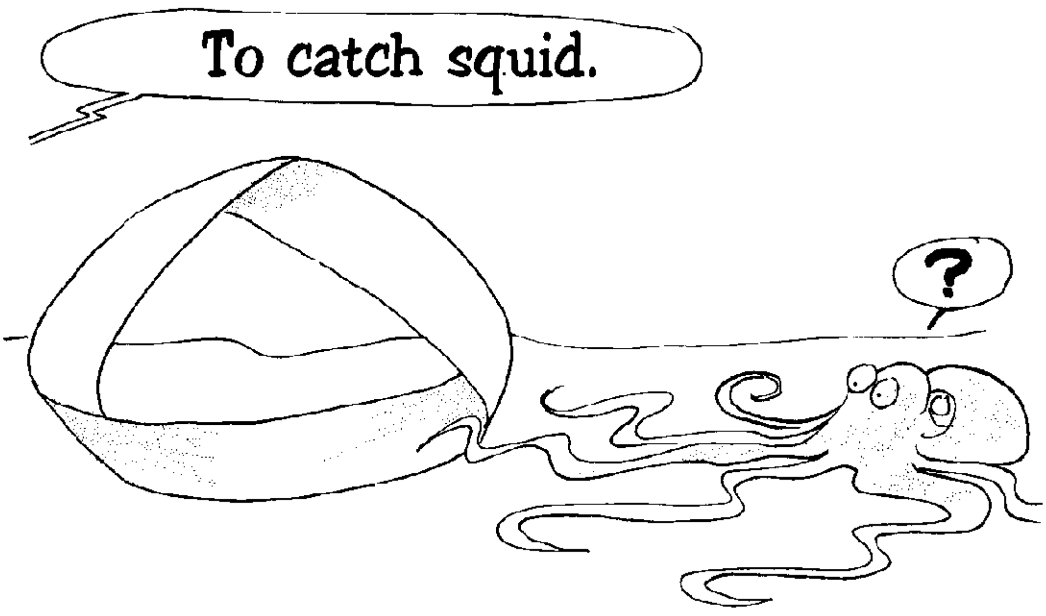

Ah, what a nice day!
Now that really looks like something
Monsieur Amundsen, the historic photo please...
Shoo, I want to be alone in my historic photo
South Pole
In science it's like in anything else, sometimes you shouldn't dig too far...
...each pole has its place and the stable doors are properly bolted.
Not only that but if we dug under the North pole we might get some nasty surprises.
And someone here might get very upset about that.

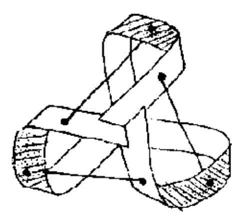


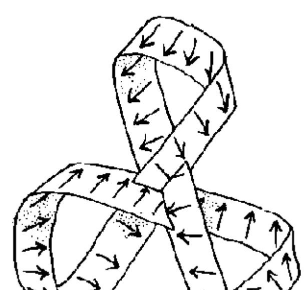




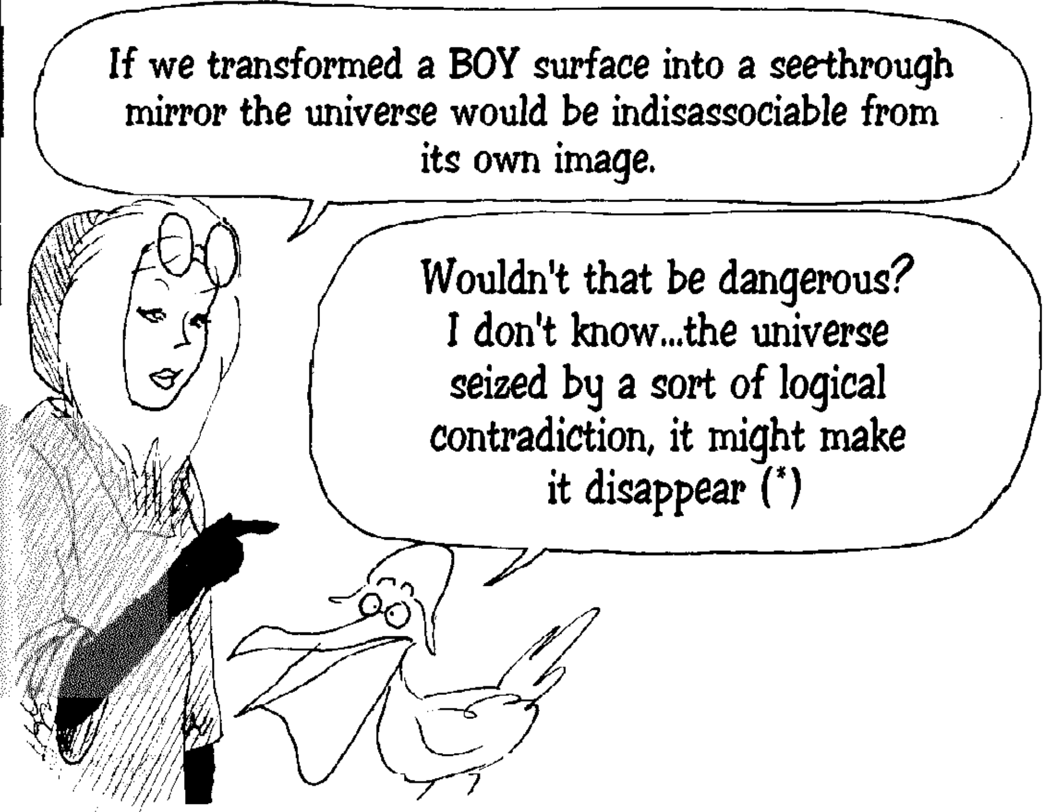
THE MIRROR STAGE

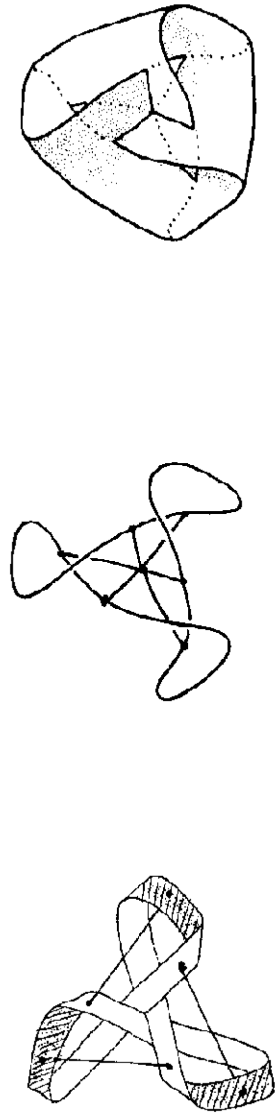






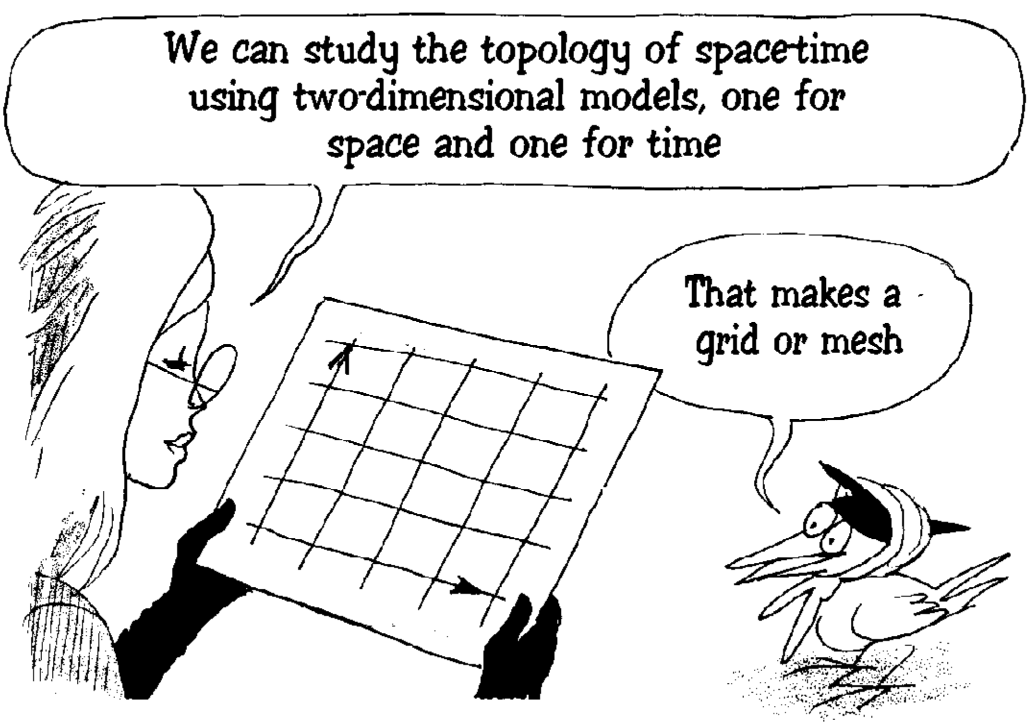
(*) YOU CAN MAKE MIRRORS LIKE THIS OUT OF ANY OLD KLEIN BOTTLES YOU FIND LYING AROUND

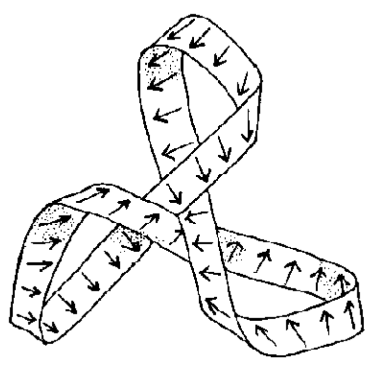




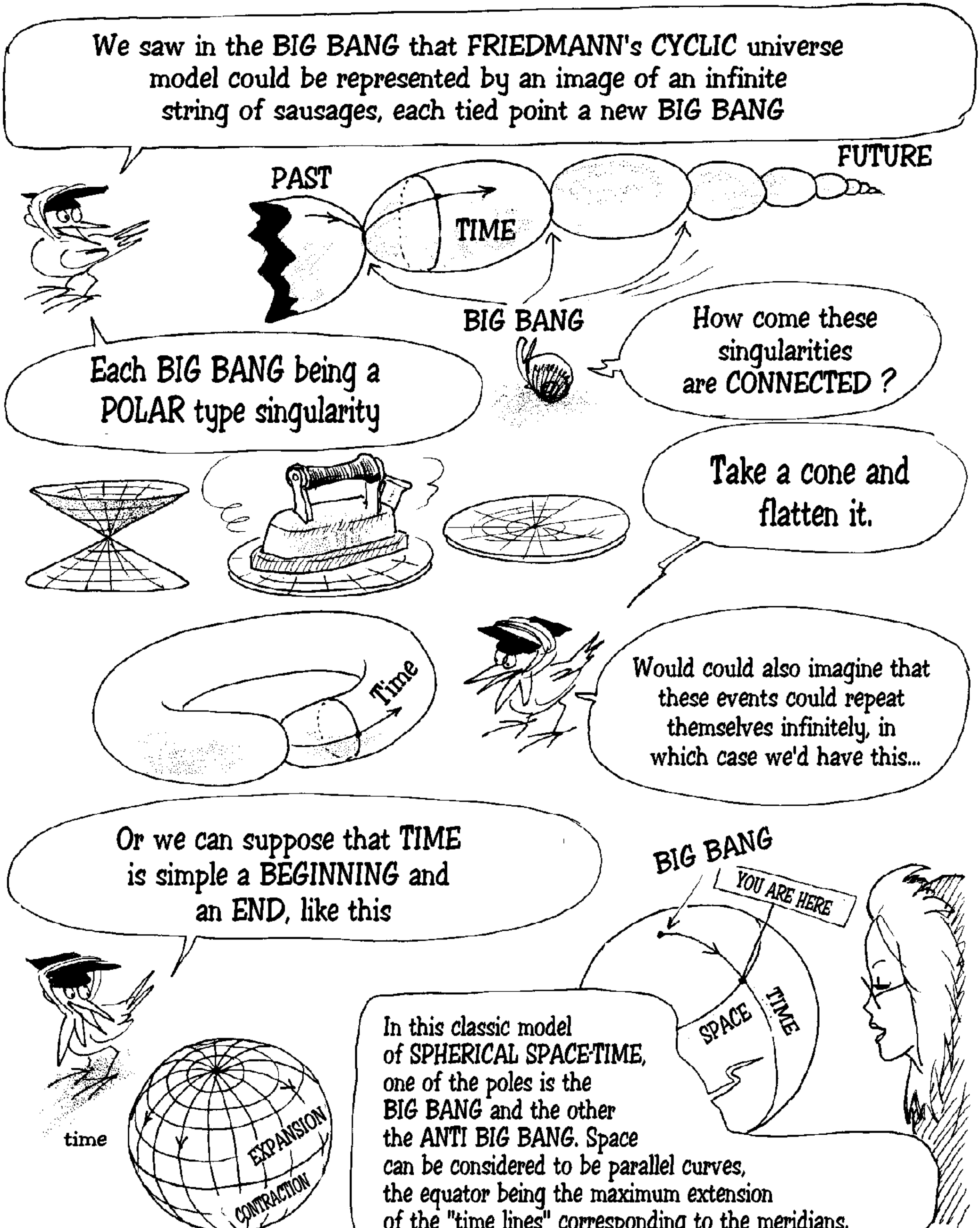
CREATION OF A TRIPLE POINT

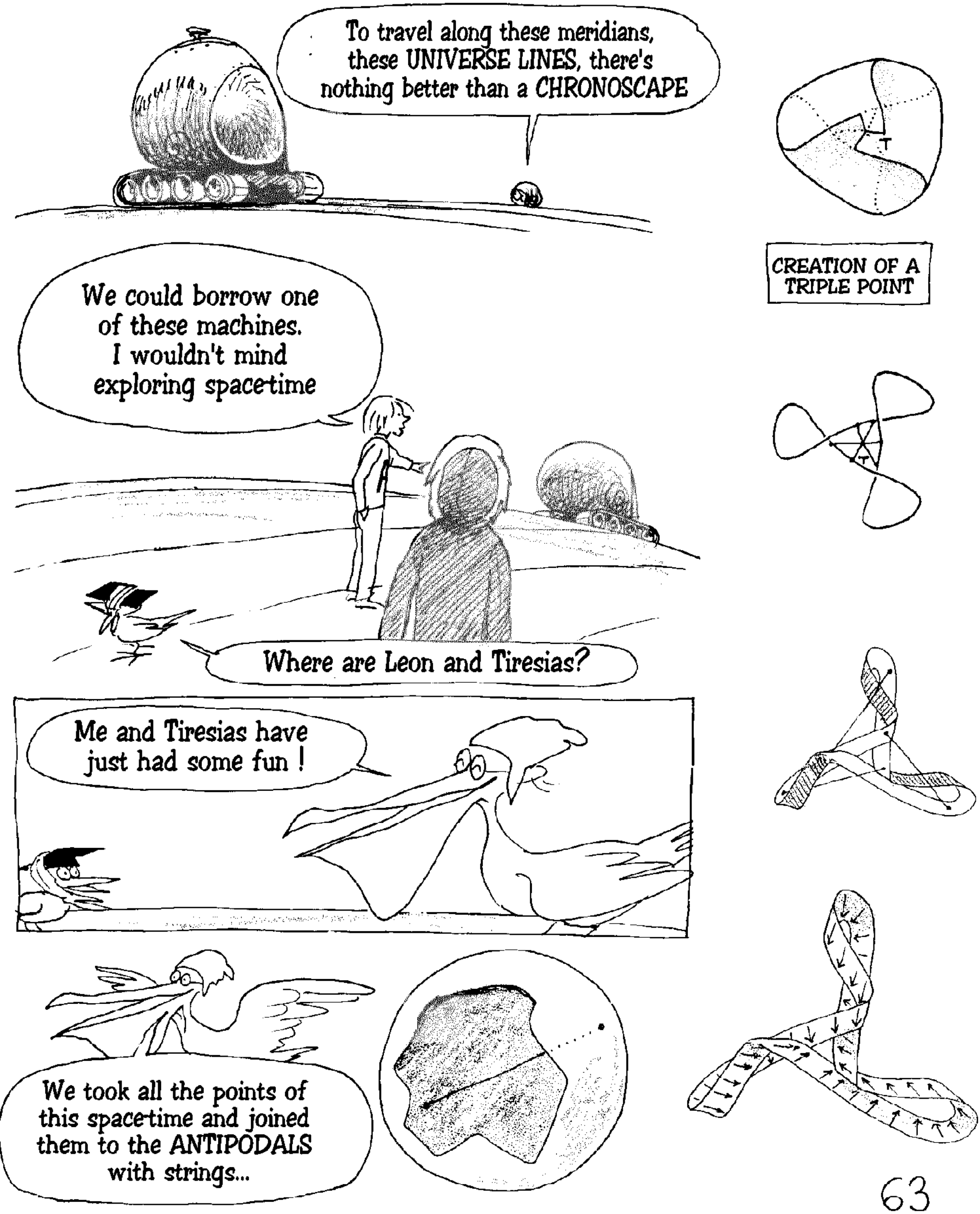
SPACE-TIME GONE MAD

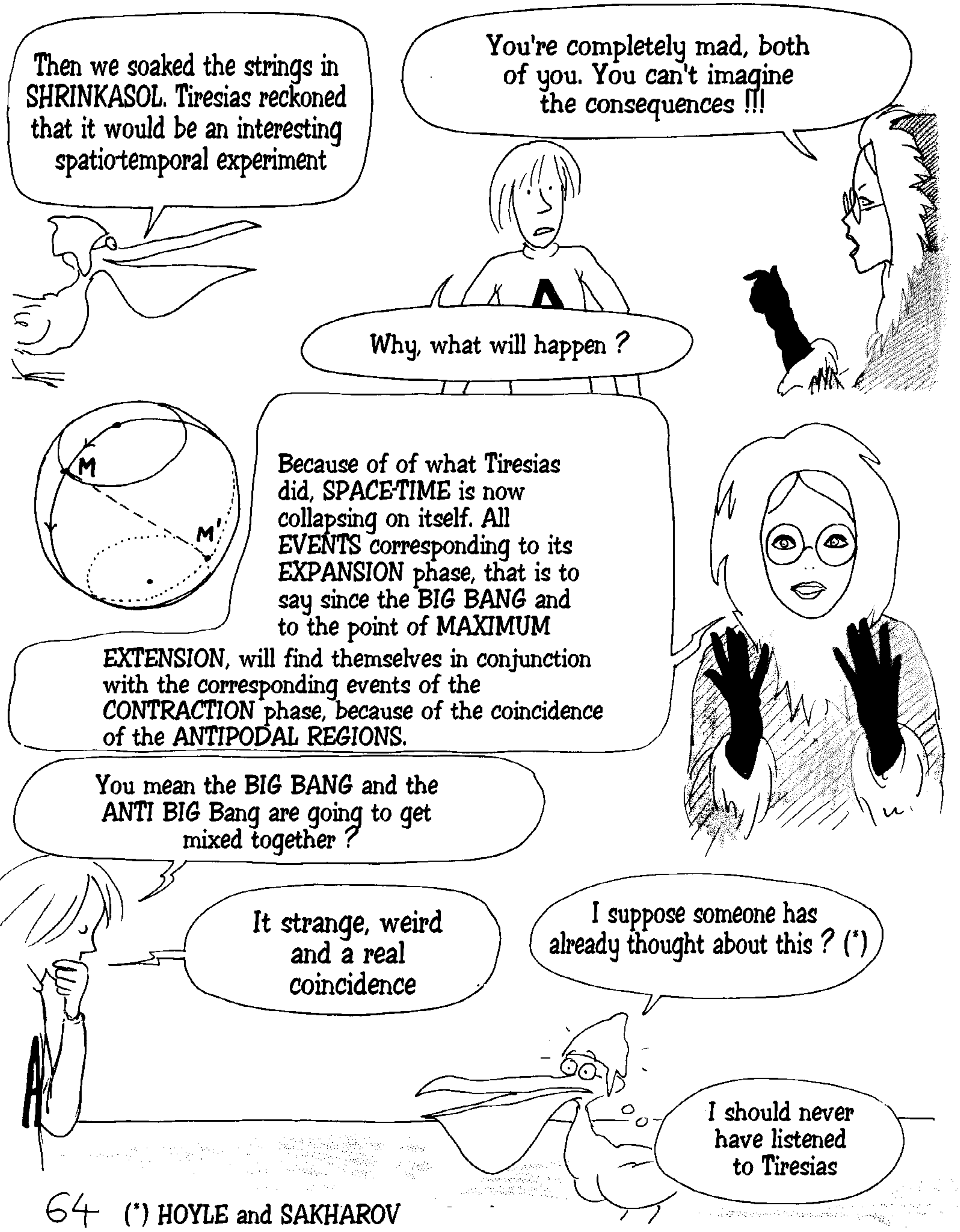




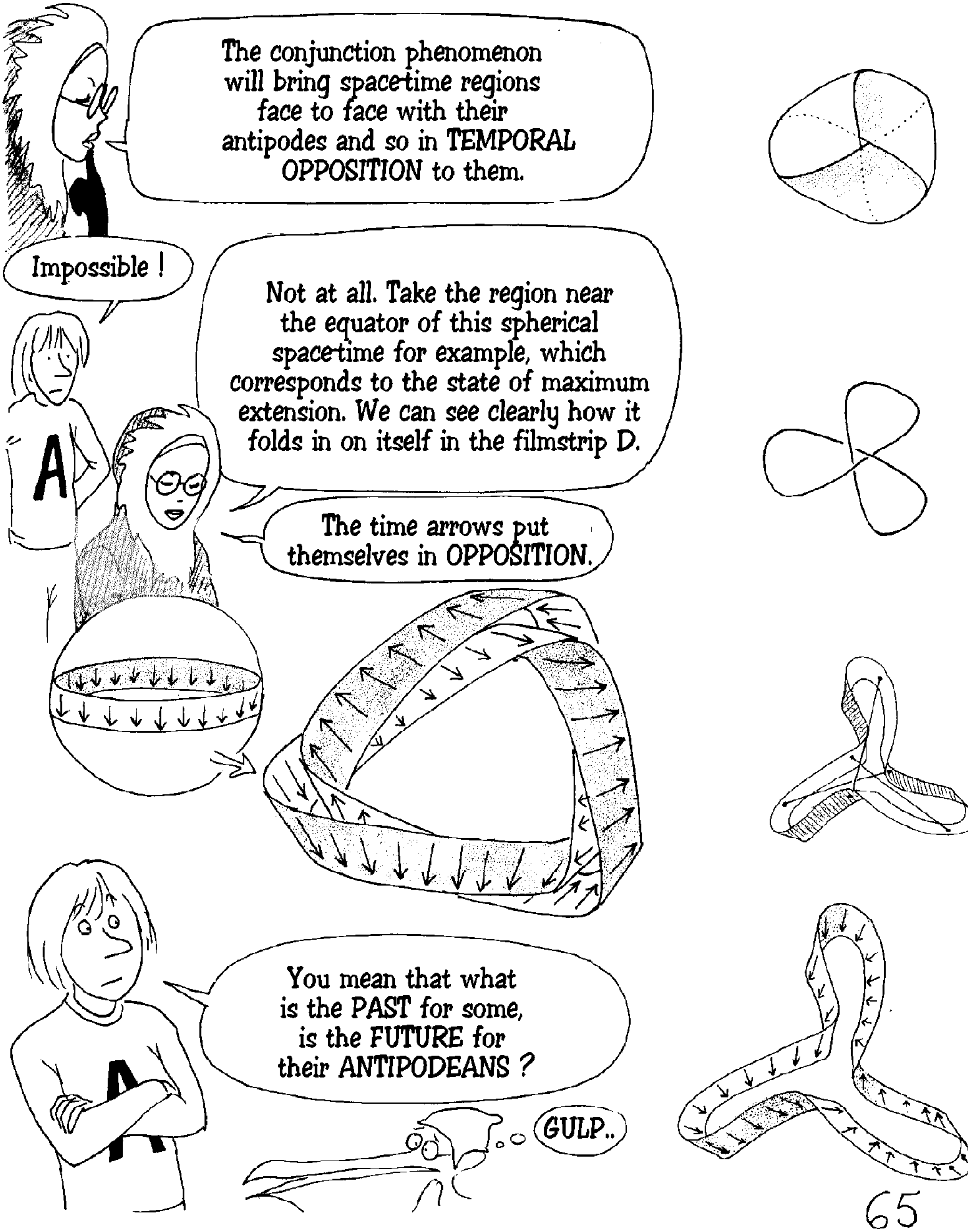
(*) NO ONE HAS EVER TRIED THIS


We saw in the BIG BANG that FRIEDMANN's CYCLIC universe model could be represented by an image of an infinite string of sausages, each tied point a new BIG BANG
PAST
TIME
FUTURE
BIG BANG
Each BIG BANG being a POLAR type singularity
How come these singularities are CONNECTED ?
Take a cone and flatten it.
Time
Would could also imagine that these events could repeat themselves infinitely, in which case we'd have this...
Or we can suppose that TIME is simple a BEGINNING and an END, like this
BIG BANG
YOU ARE HERE
SPACE
TIME
time
EXPANSION
CONTRACTION
In this classic model of SPHERICAL SPACE-TIME, one of the poles is the BIG BANG and the other the ANTI BIG BANG. Space can be considered to be parallel curves, the equator being the maximum extension of the "time lines" corresponding to the meridians.

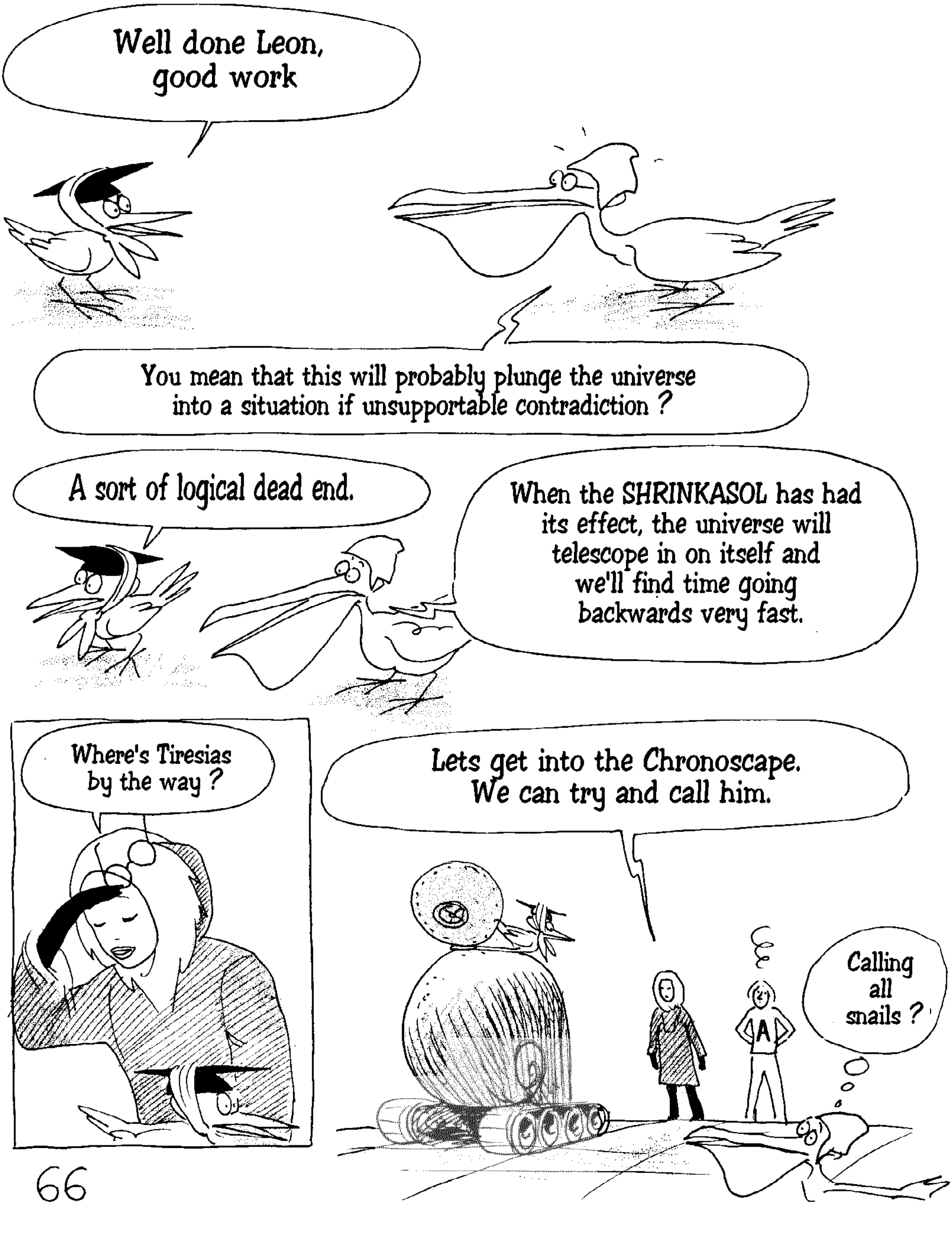

To travel along these meridians, these UNIVERSE LINES, there's nothing better than a CHRONOSCAPE
CREATION OF A TRIPLE POINT
T
We could borrow one of these machines. I wouldn't mind exploring spacetime
Where are Leon and Tiresias?
Me and Tiresias have just had some fun !
We took all the points of this spacetime and joined them to the ANTIPODALS with strings...



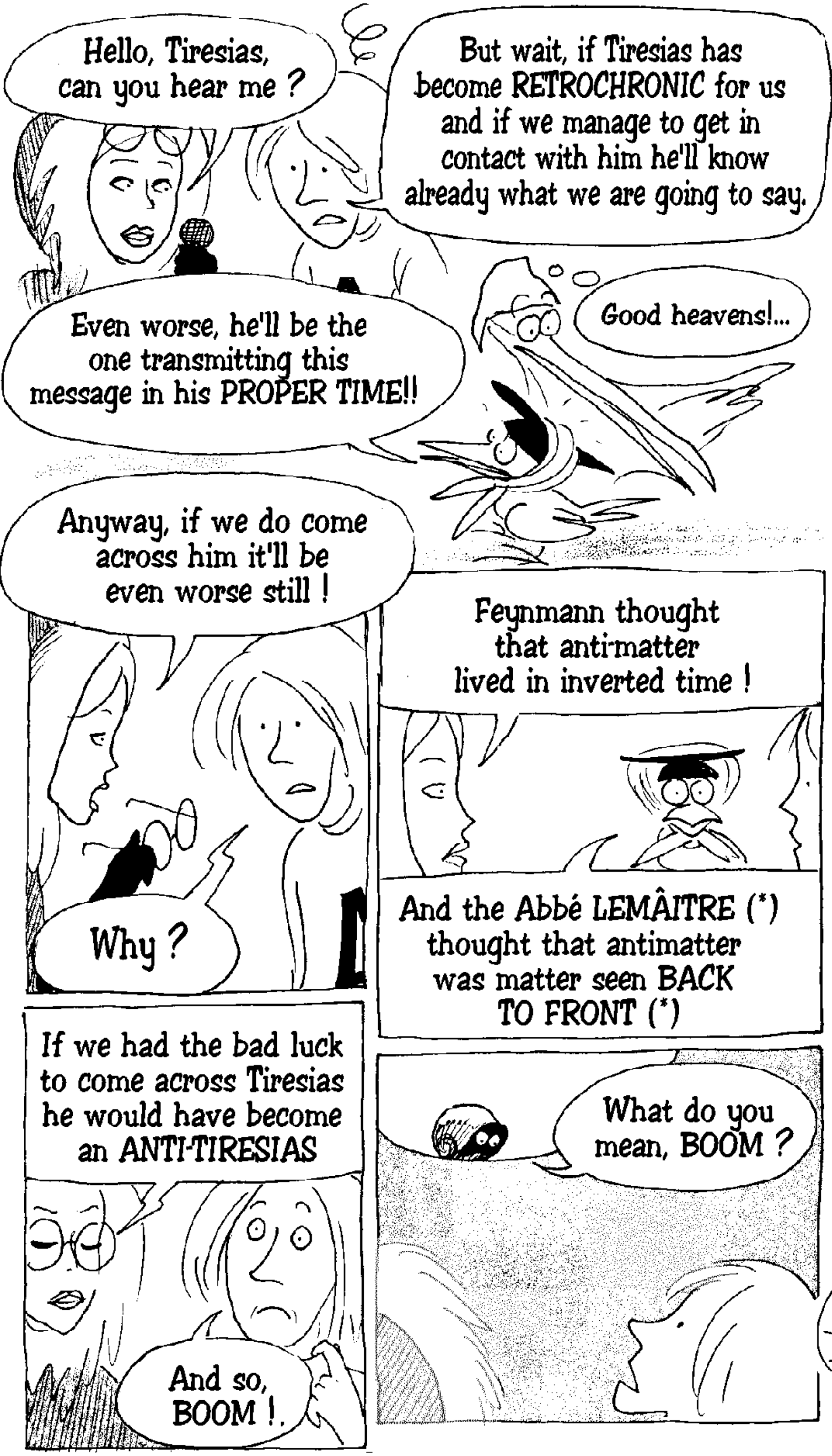
 (*) HOYLE and SAKHAROV

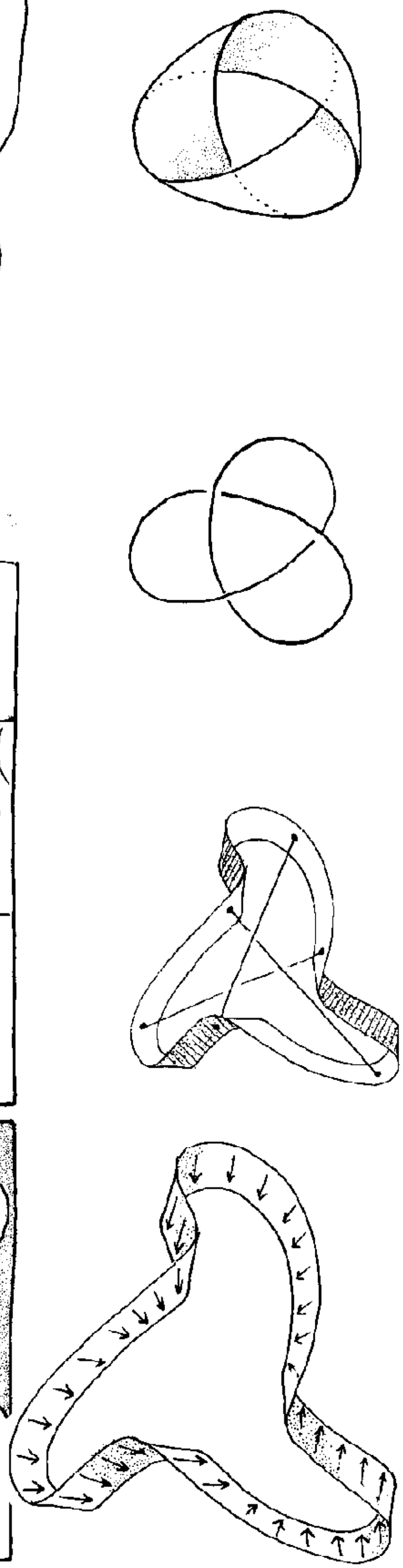


The conjunction phenomenon will bring space-time regions face to face with their antipodes and so in TEMPORAL OPPOSITION to them.
Impossible !
Not at all. Take the region near the equator of this spherical space-time for example, which corresponds to the state of maximum extension. We can see clearly how it folds in on itself in the filmstrip D.
The time arrows put themselves in OPPOSITION.
You mean that what is the PAST for some, is the FUTURE for their ANTIPODEANS ?
GULP..

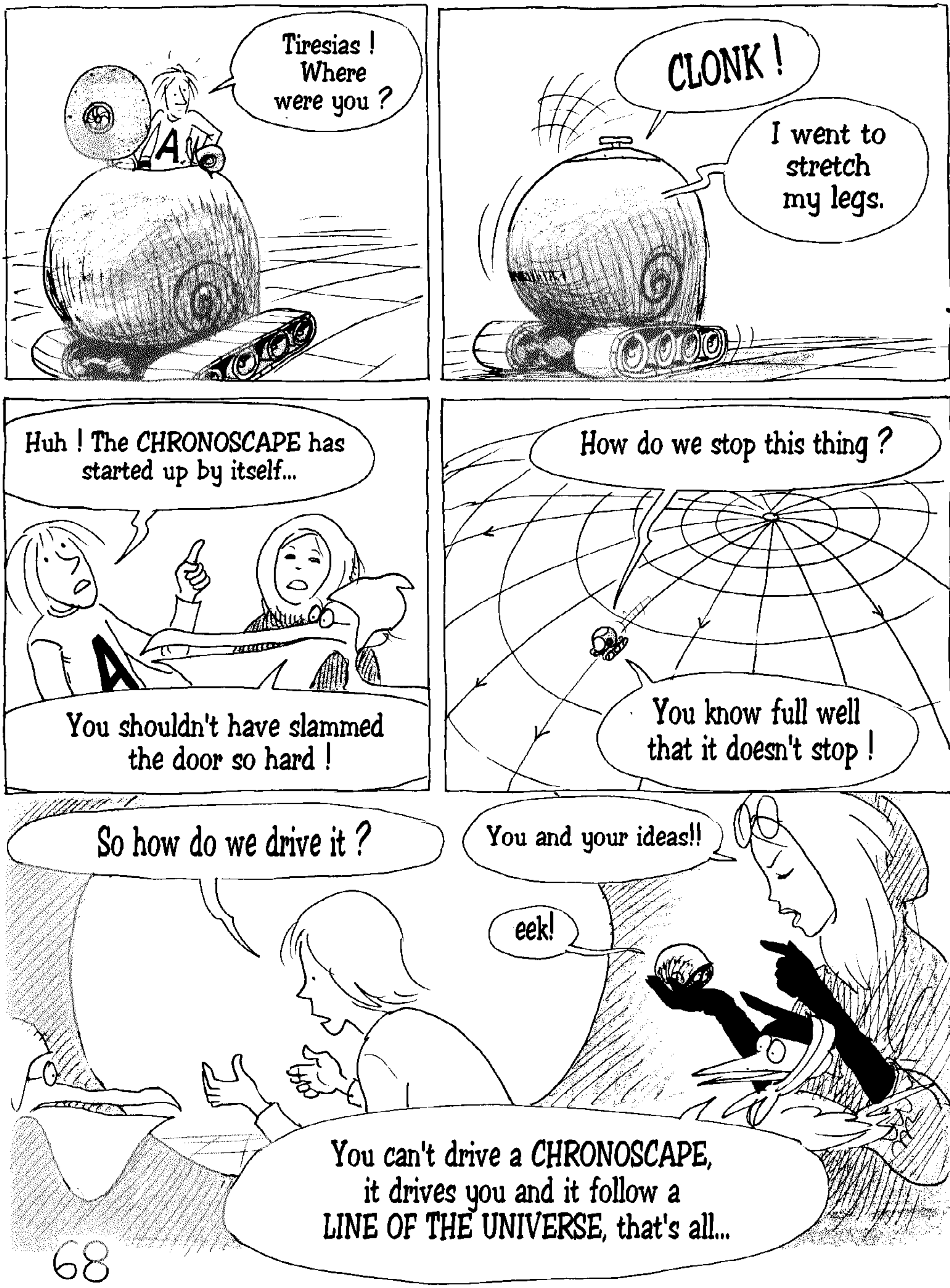


Well done Leon, good work
You mean that this will probably plunge the universe into a situation if unsupportable contradiction ?
A sort of logical dead end.
When the SHRINKASOL has had its effect, the universe will telescope in on itself and we'll find time going backwards very fast.
Where's Tiresias by the way ?
Lets get into the Chronoscape. We can try and call him.
A
Calling all snails ?

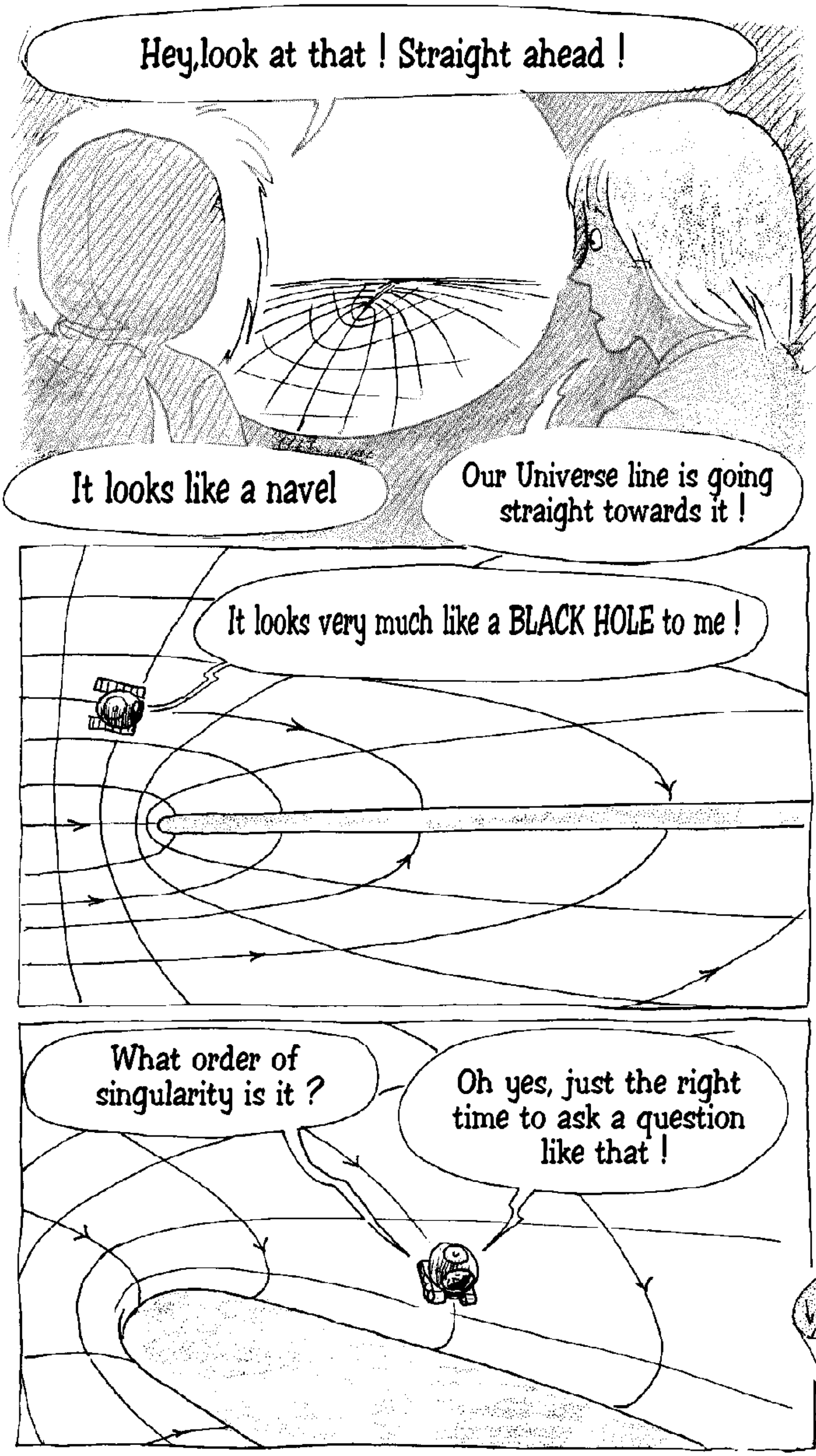


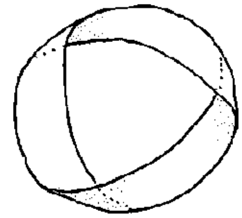


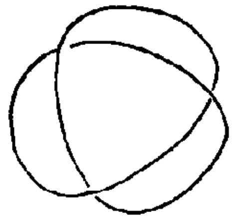
(*) See the BIG BANG

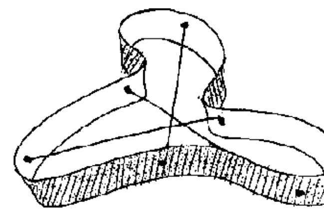


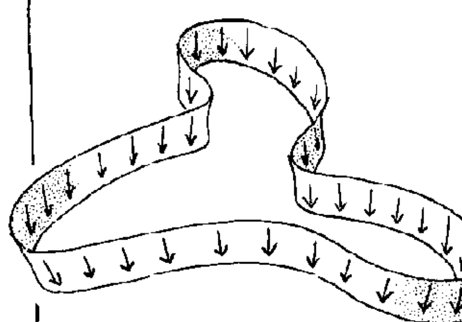
Tiresias ! Where were you ?
CLONK !
I went to stretch my legs.
Huh ! The CHRONOSCAPE has started up by itself...
You shouldn't have slammed the door so hard !
How do we stop this thing ?
You know full well that it doesn't stop !
So how do we drive it ?
You and your ideas!!
eek!
You can't drive a CHRONOSCAPE, it drives you and it follow a LINE OF THE UNIVERSE, that's all...

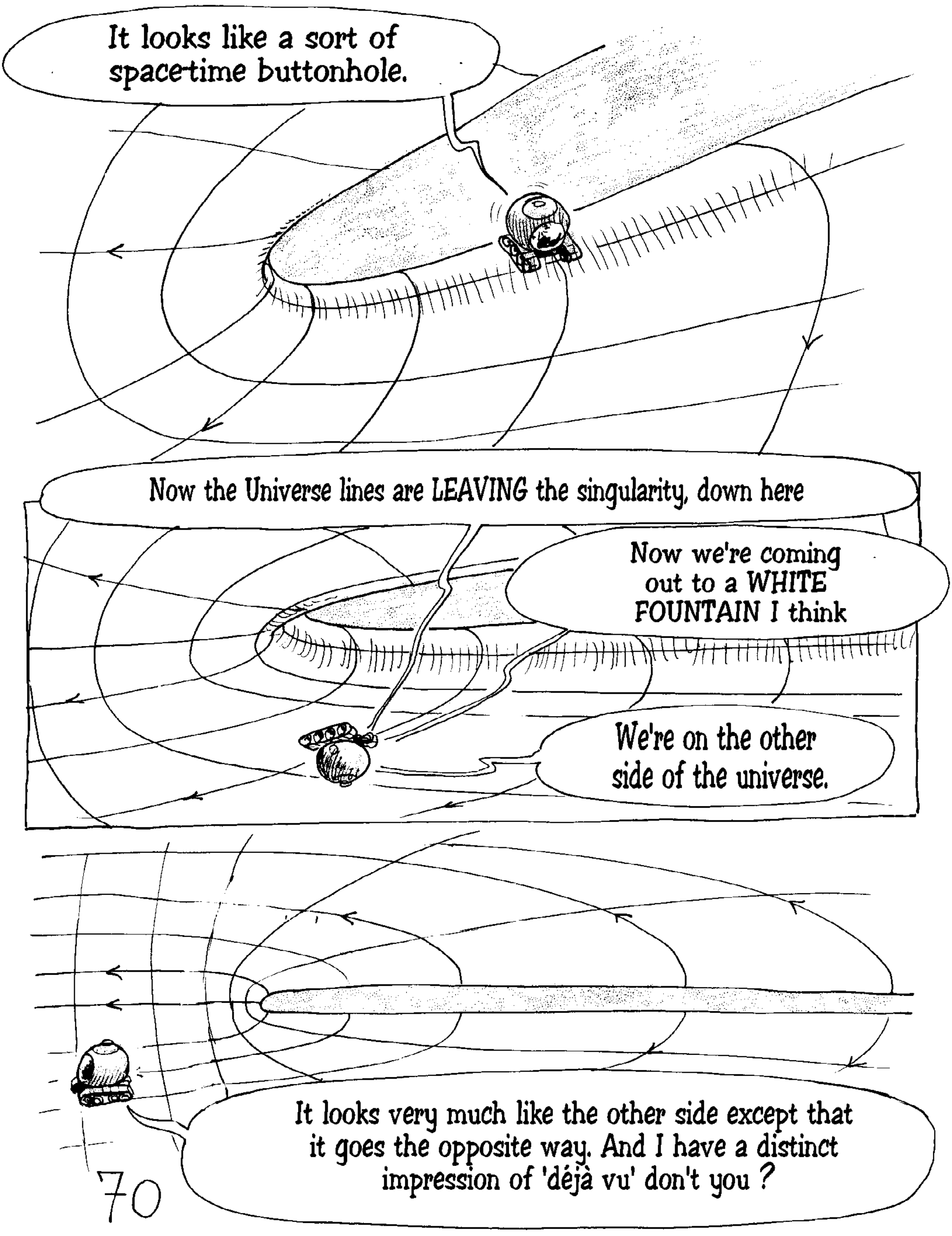

Hey,look at that ! Straight ahead !
It looks like a navel
Our Universe line is going straight towards it !
It looks very much like a BLACK HOLE to me !
What order of singularity is it ?
Oh yes, just the right time to ask a question like that !

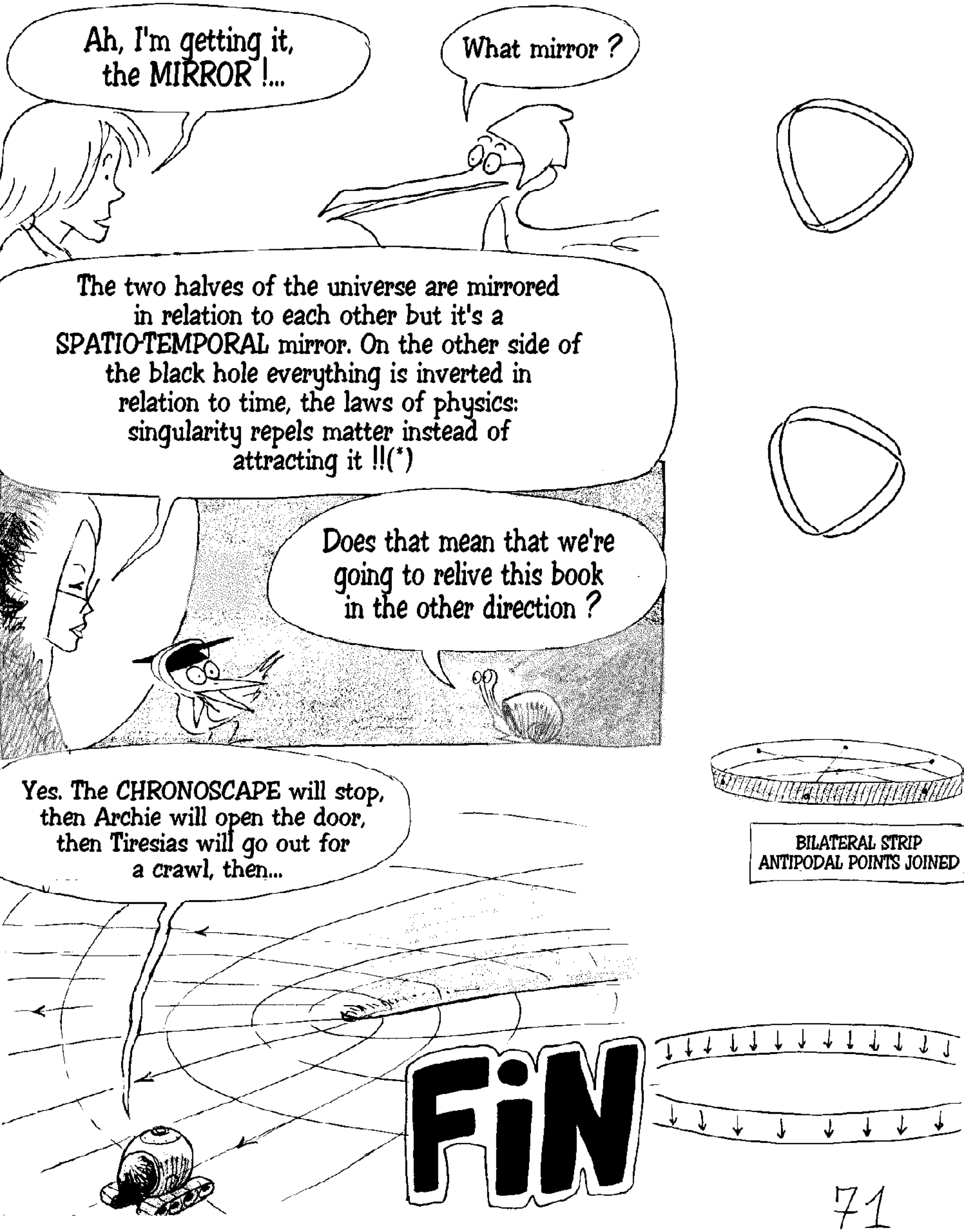









It looks like a sort of spacetime buttonhole.
Now the Universe lines are LEAVING the singularity, down here
Now we're coming out to a WHITE FOUNTAIN I think
We're on the other side of the universe.
It looks very much like the other side except that it goes the opposite way. And I have a distinct impression of 'déjà vu' don't you ?



(*) THE SAME STRUCTURE CAN EXIST IN 4 DIMENSIONS.

SCIENTIFIC ANNEX

BOY, a pupil of Hilbert, discovered his surface in 1902. The first analytical representation of it was given in 1981 by Jérôme Souriau, son of the mathematician J.M. SOURIAU, and the author of this book. The semi-empirical method used assimilates the meridians of the surface to ellipses which are then given parameters. The current point is given by :

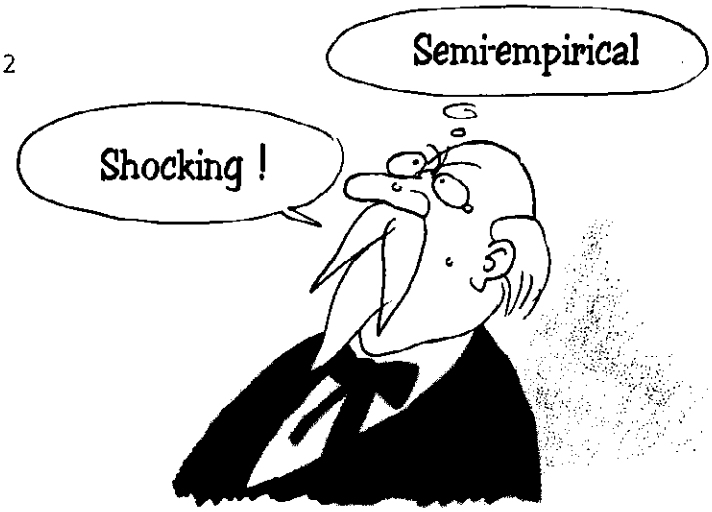
$$\begin{cases} x = X_1 \cos\mu - Z_1 \sin\alpha \sin\mu \\ y = X_1 \sin\mu + Z_1 \sin\alpha \cos\mu \\ z = Z_1 \cos\alpha \end{cases} \qquad \begin{cases} X_1 = \dfrac{A^2 - B^2}{\sqrt{A^2+B^2}} + A\cos\theta - B\sin\theta \\ Z_1 = \sqrt{A^2+B^2} + A\cos\theta + B\sin\theta \end{cases}$$

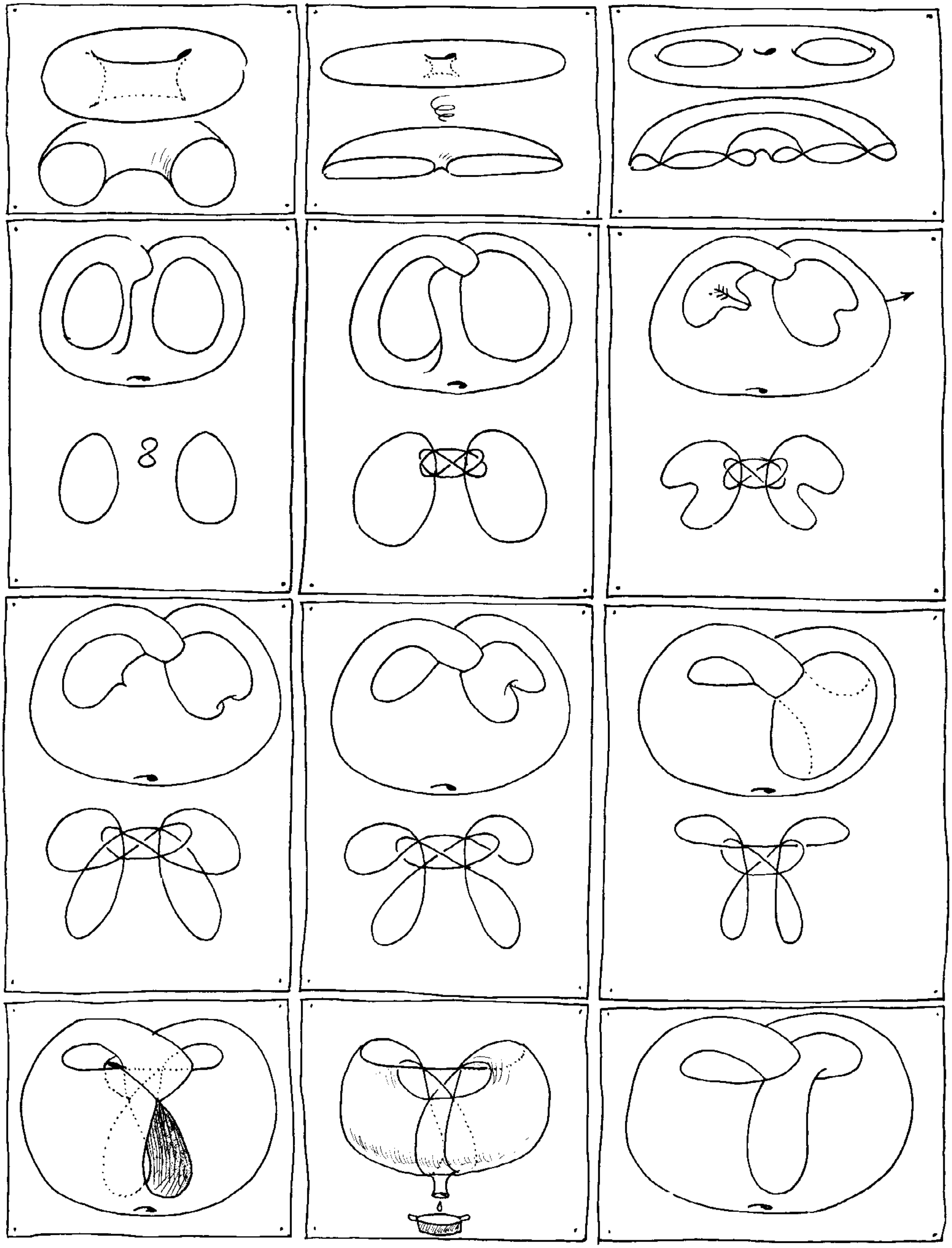
$$\alpha = \frac{\pi}{8}\sin 3\mu \qquad \begin{cases} A(\mu) = 10 + 1{,}41 \sin(6\mu - \pi/3) + 1{,}98 \sin(3\mu - \pi/6) \\ B(\mu) = 10 + 1{,}41 \sin(6\mu - \pi/3) - 1{,}98 \sin(3\mu - \pi/6) \end{cases}$$

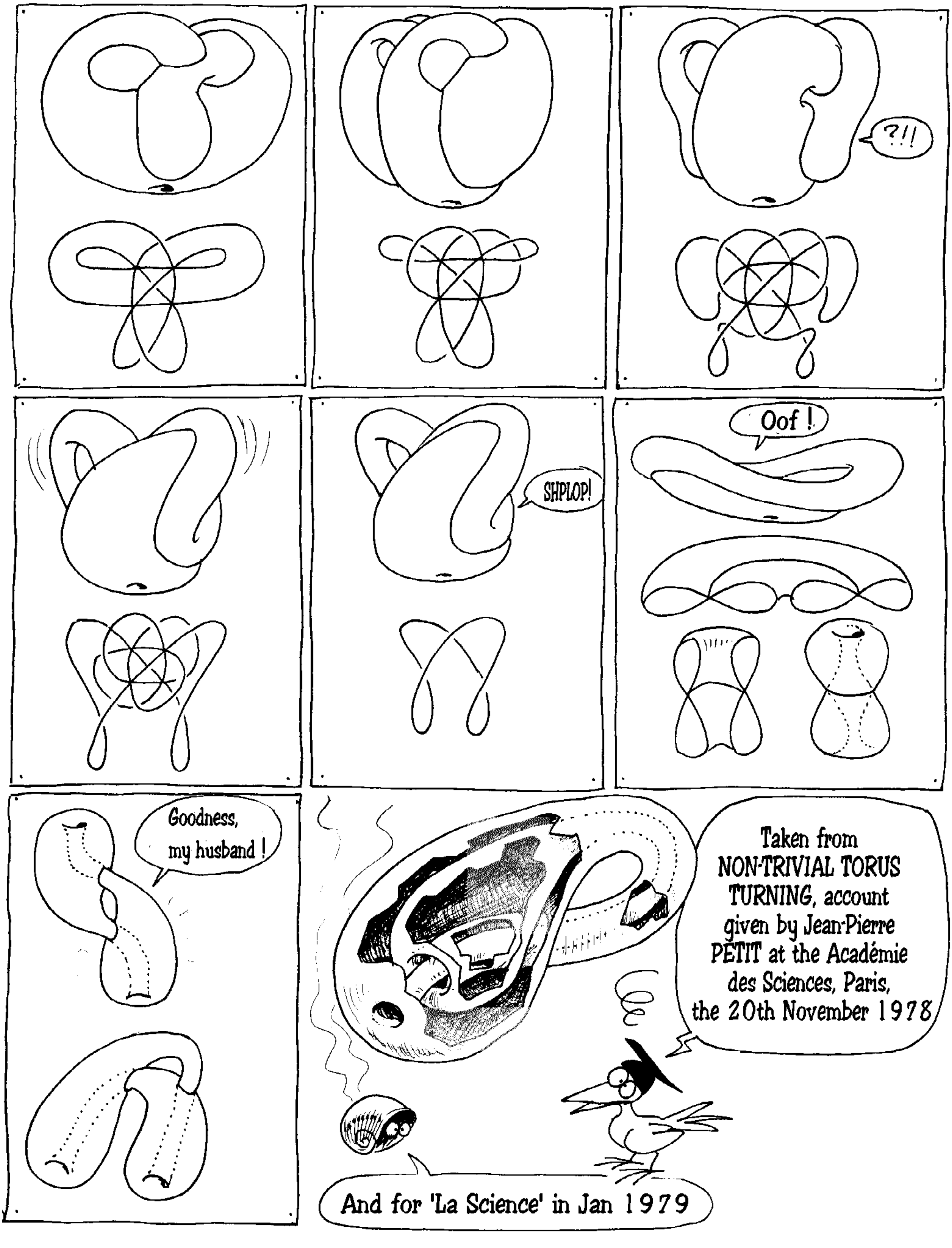
Meridians: curves $\mu = cte$, θ variant of 0 to 2π, μ variant of 0 to π.

The following programme in BASIC traces the drawing on the cover pages

```
1  REM  TRACE MERIDIENS DE LA SURFACE DE BOY
3  HOME : TEXT
50 PI = 3.141592:P3 = PI / 3:P6 = PI / 8:P8 = PI / 8
60  HGR : HCOLOR= 3
90  FOR MU = 0 TO PI STEP 0.1
95 P = P + 1
100 D = 34 + 4.794 *  SIN (6 * MU - P3)
110 E = 6.732 *  SIN (3 * MU - P6)
120 A = D + E:B = D - E
130 SA =  SIN (P8 *  SIN (3 * MU))
140 C2 =  SQR (A * A + B * B):C3 = (4 * D * E) / C2
160 CM =  COS (MU):SM =  SIN (MU)
180  FOR TE = 0 TO 6.288 STEP .06
190 TC = A *  COS (TE):TS = B *  SIN (TE)
200 X1 = C3 + TC - TS
210 Z1 = C2 + TC + TS
250  REM  VOICI LES 3 COORDONNEES
300 X = X1 * CM - Z1 * SA * SM
310 Y = X1 * SM + Z1 * SA * CM
350  REM  PROGRAMME DE DESSIN
360  HPLOT 130 + X,80 + Y
400  NEXT TE: NEXT MU
```






?!!
SHPLOP!
Oof !
Goodness,
my husband !
Taken from
NON-TRIVIAL TORUS
TURNING, account
given by Jean-Pierre
PETIT at the Académie
des Sciences, Paris,
the 20th November 1978
And for 'La Science' in Jan 1979