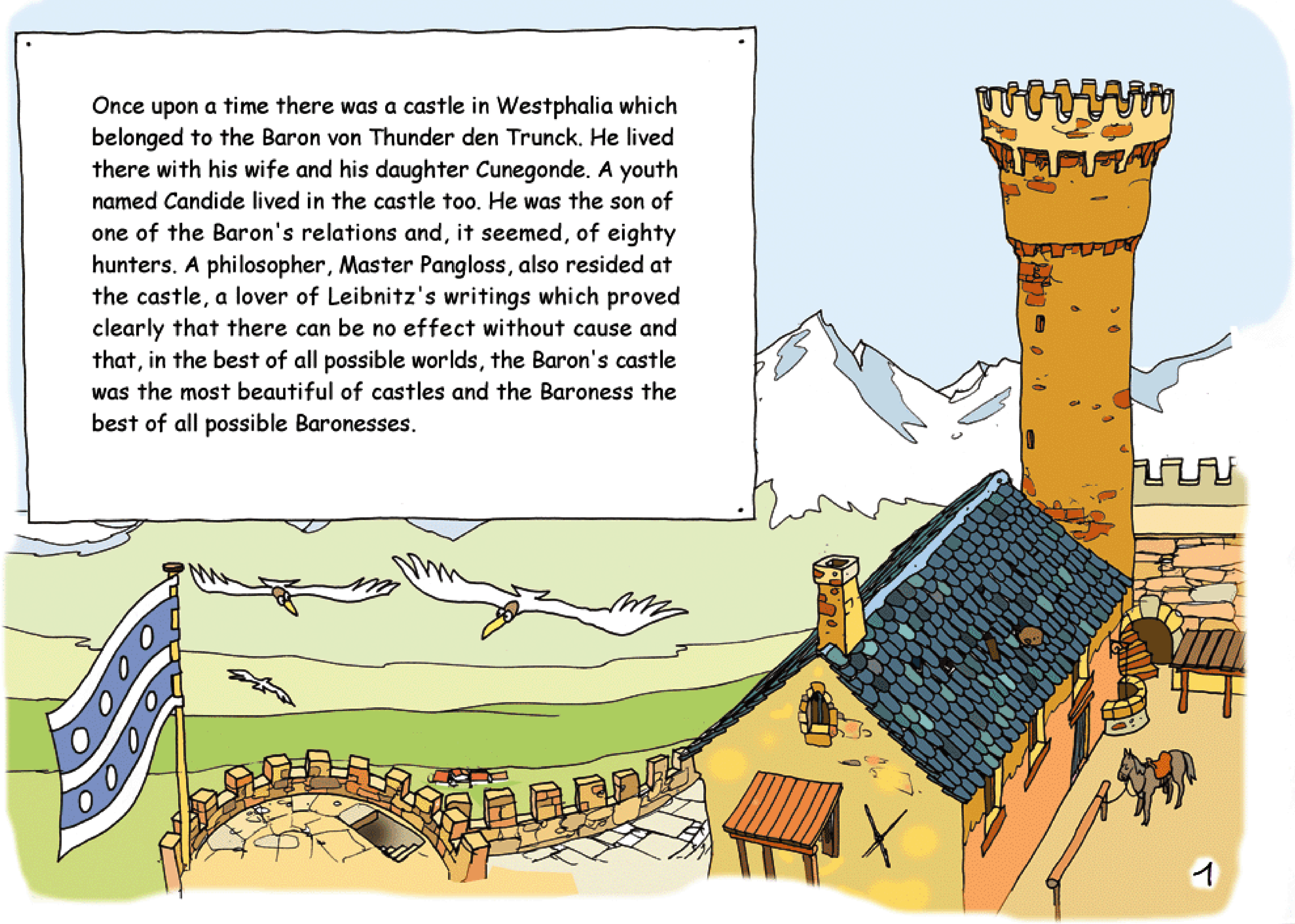
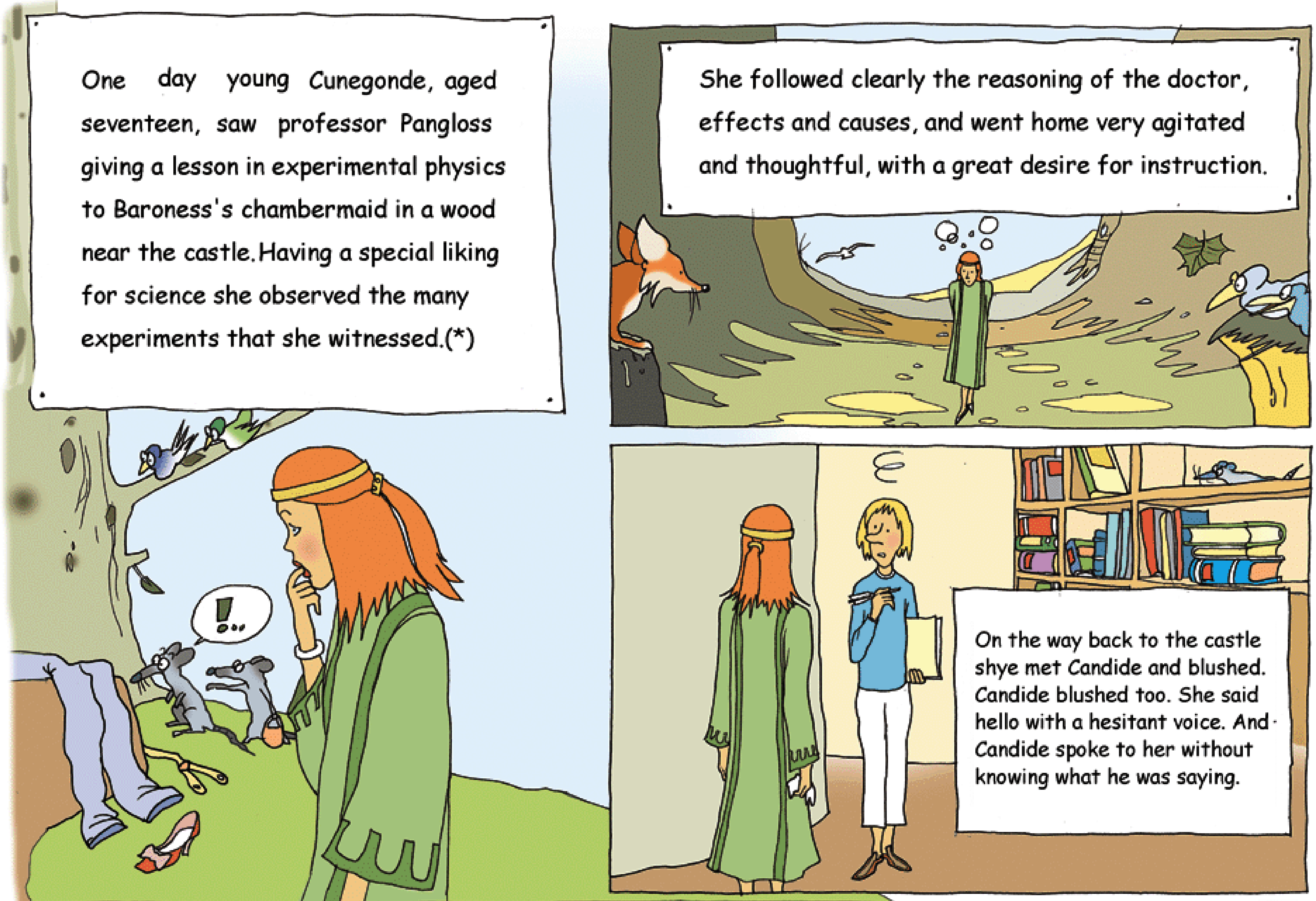
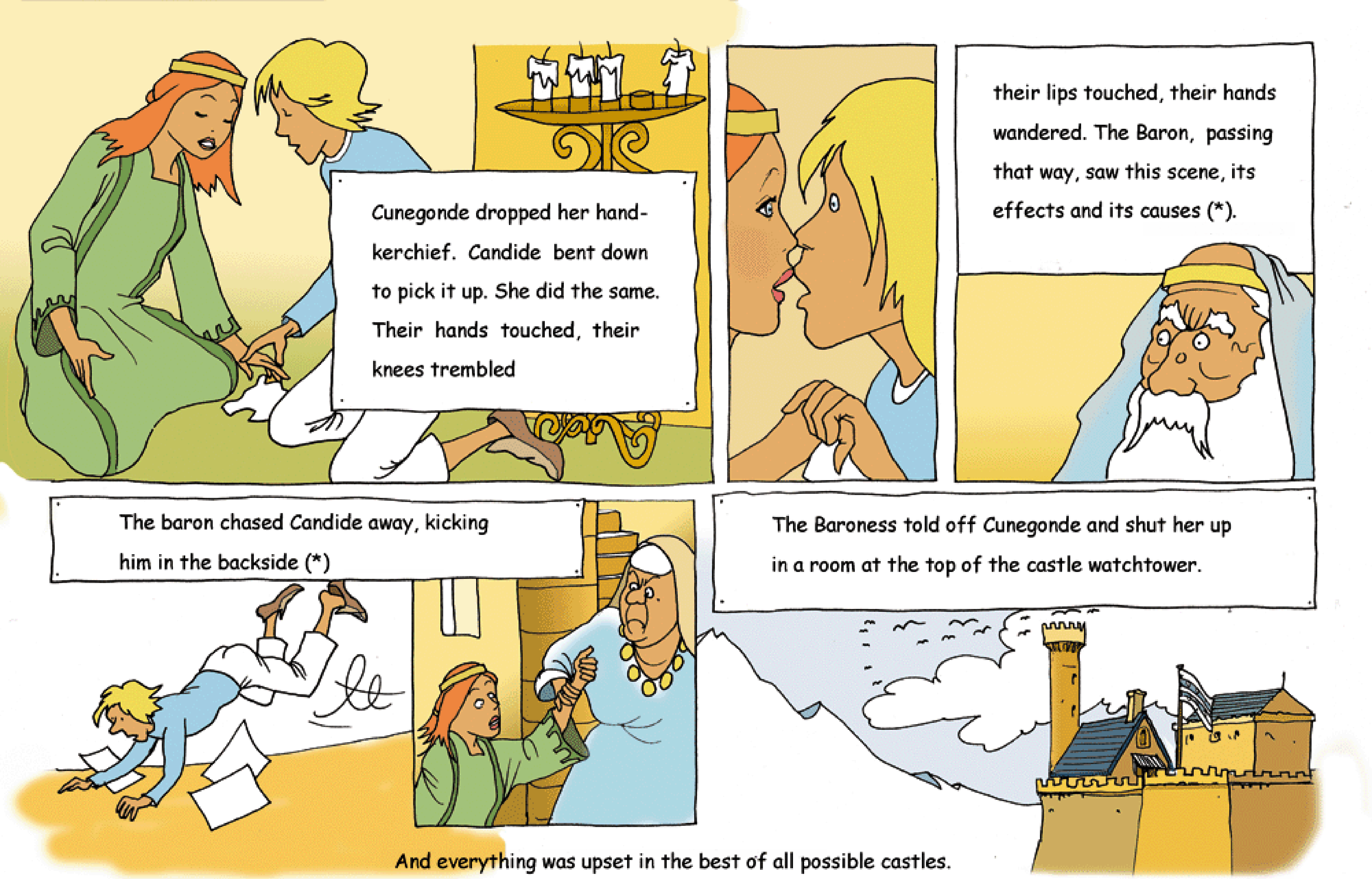
VERTICAL PASSION

Jean-Pierre Petit


Once upon a time there was a castle in Westphalia which belonged to the Baron von Thunder den Trunck. He lived there with his wife and his daughter Cunegonde. A youth named Candide lived in the castle too. He was the son of one of the Baron's relations and, it seemed, of eighty hunters. A philosopher, Master Pangloss, also resided at the castle, a lover of Leibnitz's writings which proved clearly that there can be no effect without cause and that, in the best of all possible worlds, the Baron's castle was the most beautiful of castles and the Baroness the best of all possible Baronesses.



(*) Extracts for the book "Candide" by Voltaire (1694 - 1778)



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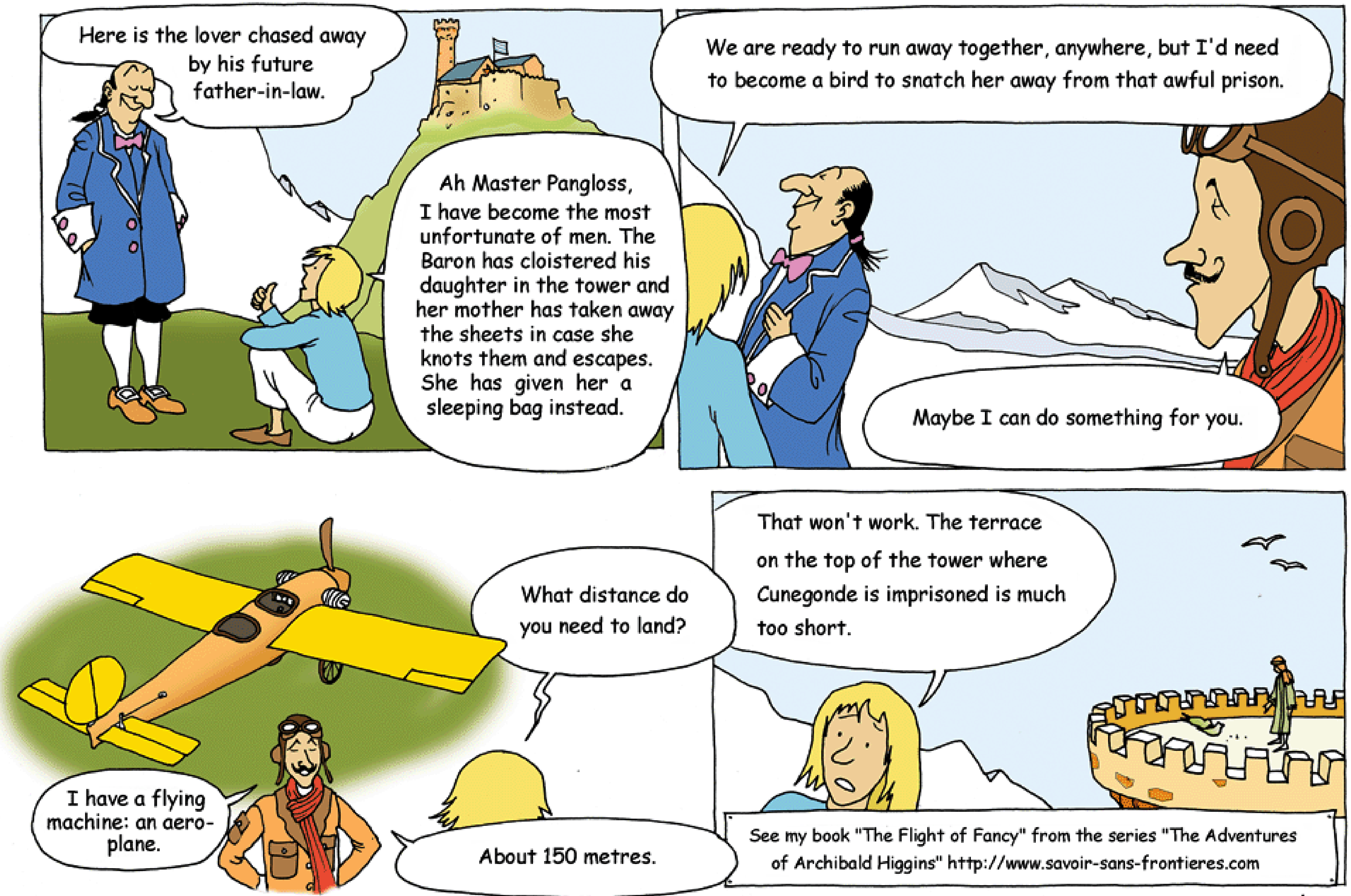
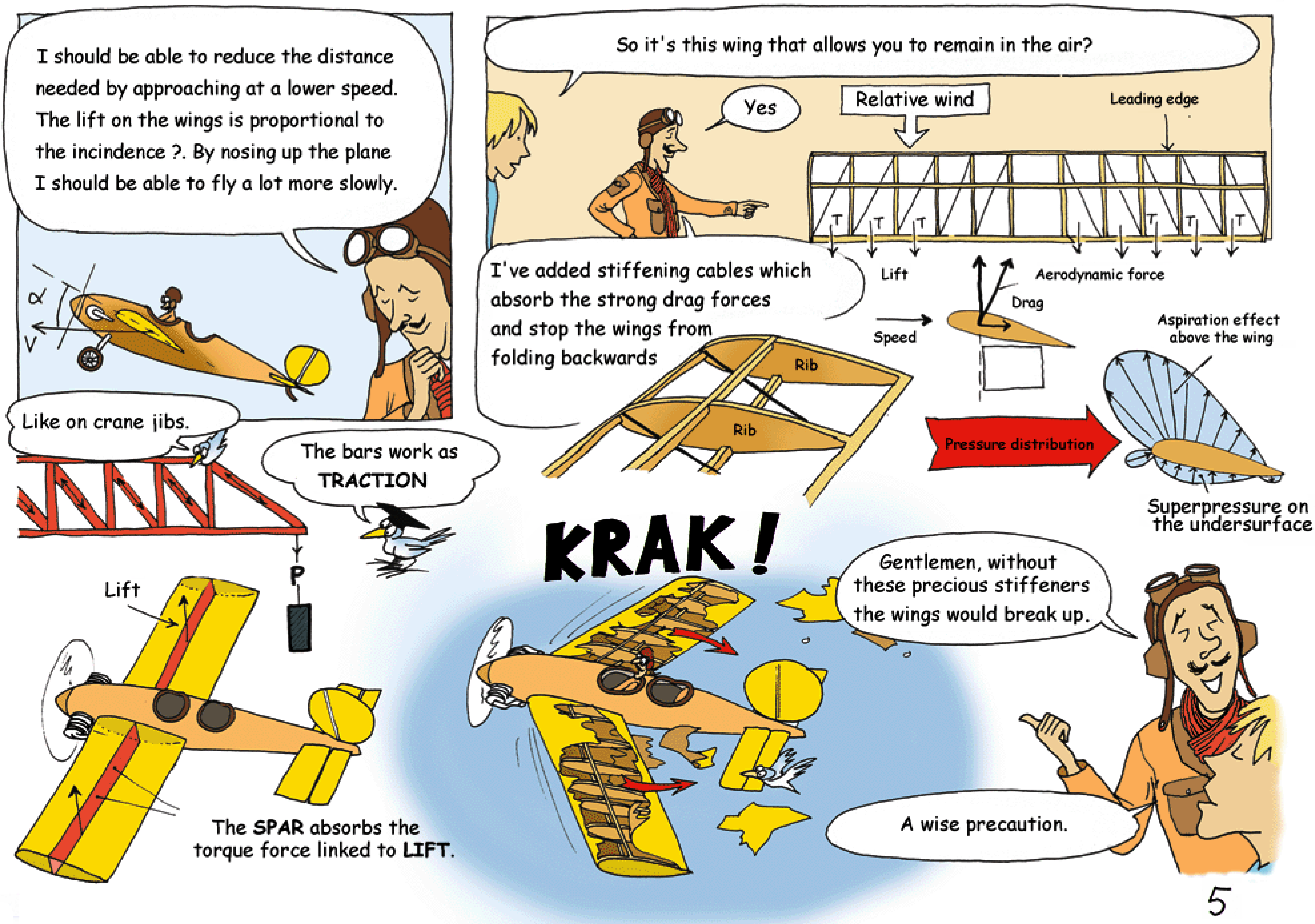
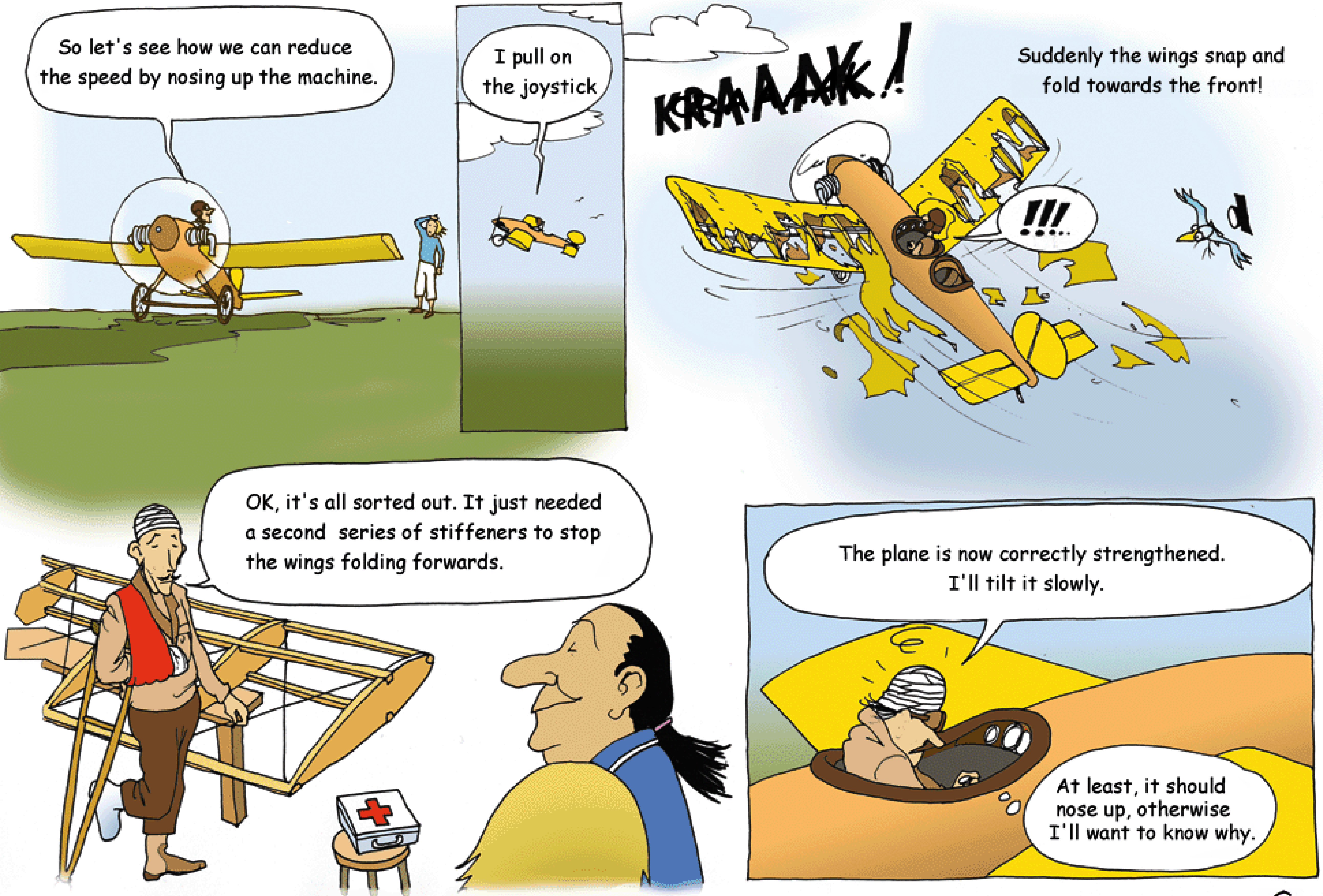
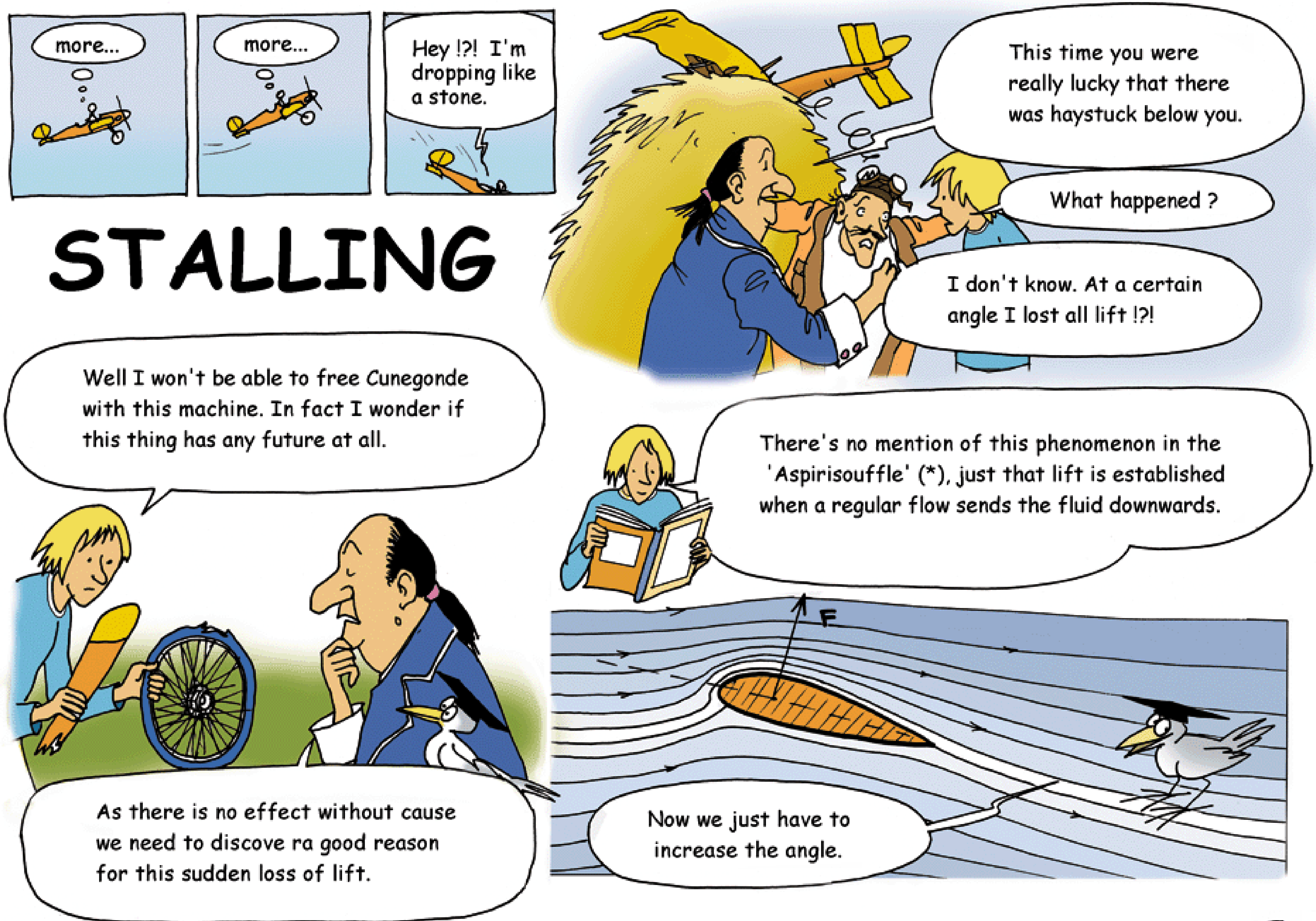

Here is the lover chased away by his future father-in-law.
Ah Master Pangloss, I have become the most unfortunate of men. The Baron has cloistered his daughter in the tower and her mother has taken away the sheets in case she knots them and escapes. She has given her a sleeping bag instead.
We are ready to run away together, anywhere, but I'd need to become a bird to snatch her away from that awful prison.
Maybe I can do something for you.
I have a flying machine: an aero-plane.
What distance do you need to land?
About 150 metres.
That won't work. The terrace on the top of the tower where Cunegonde is imprisoned is much too short.
See my book "The Flight of Fancy" from the series "The Adventures of Archibald Higgins" http://www.savoir-sans-frontieres.com

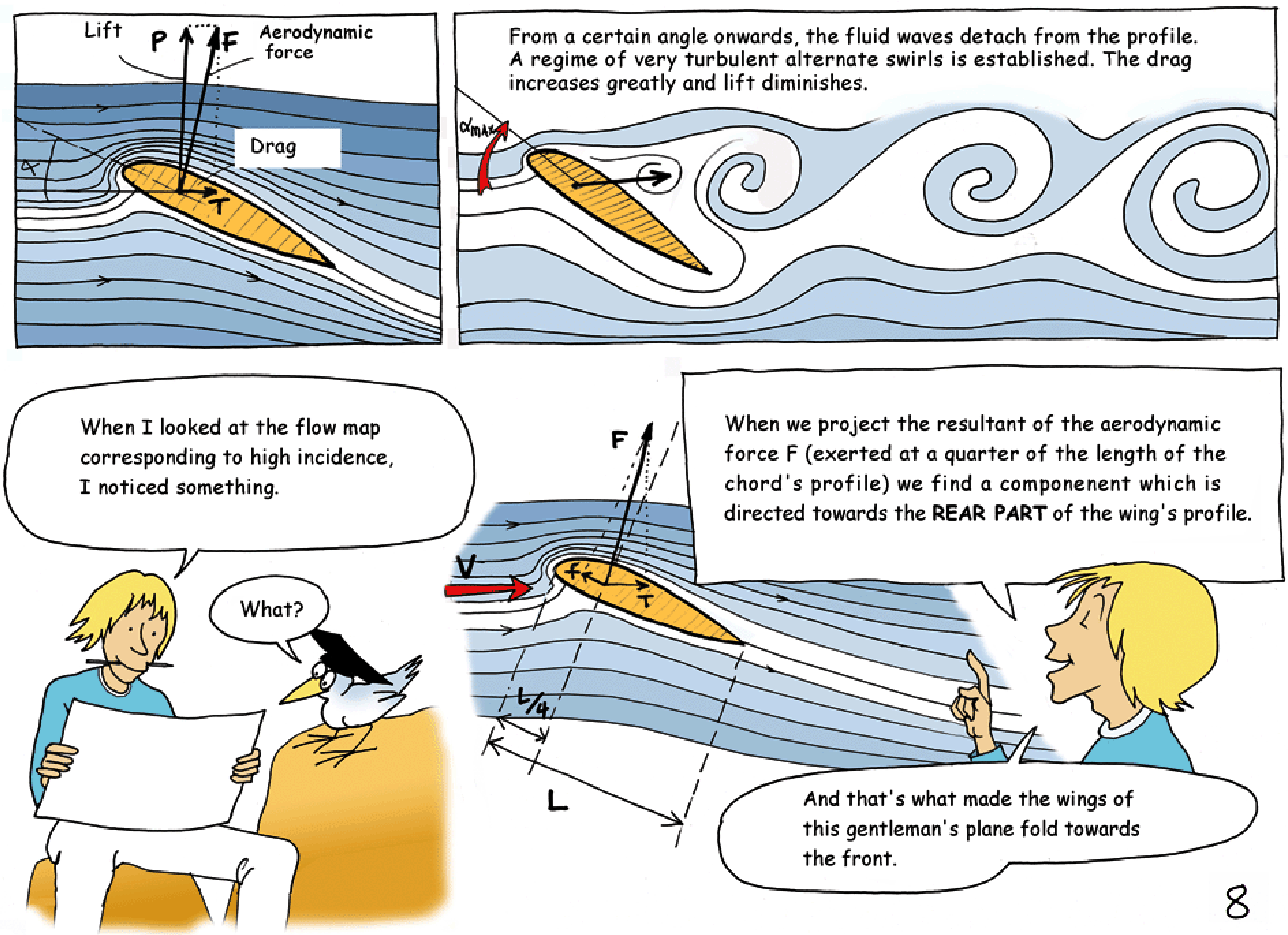


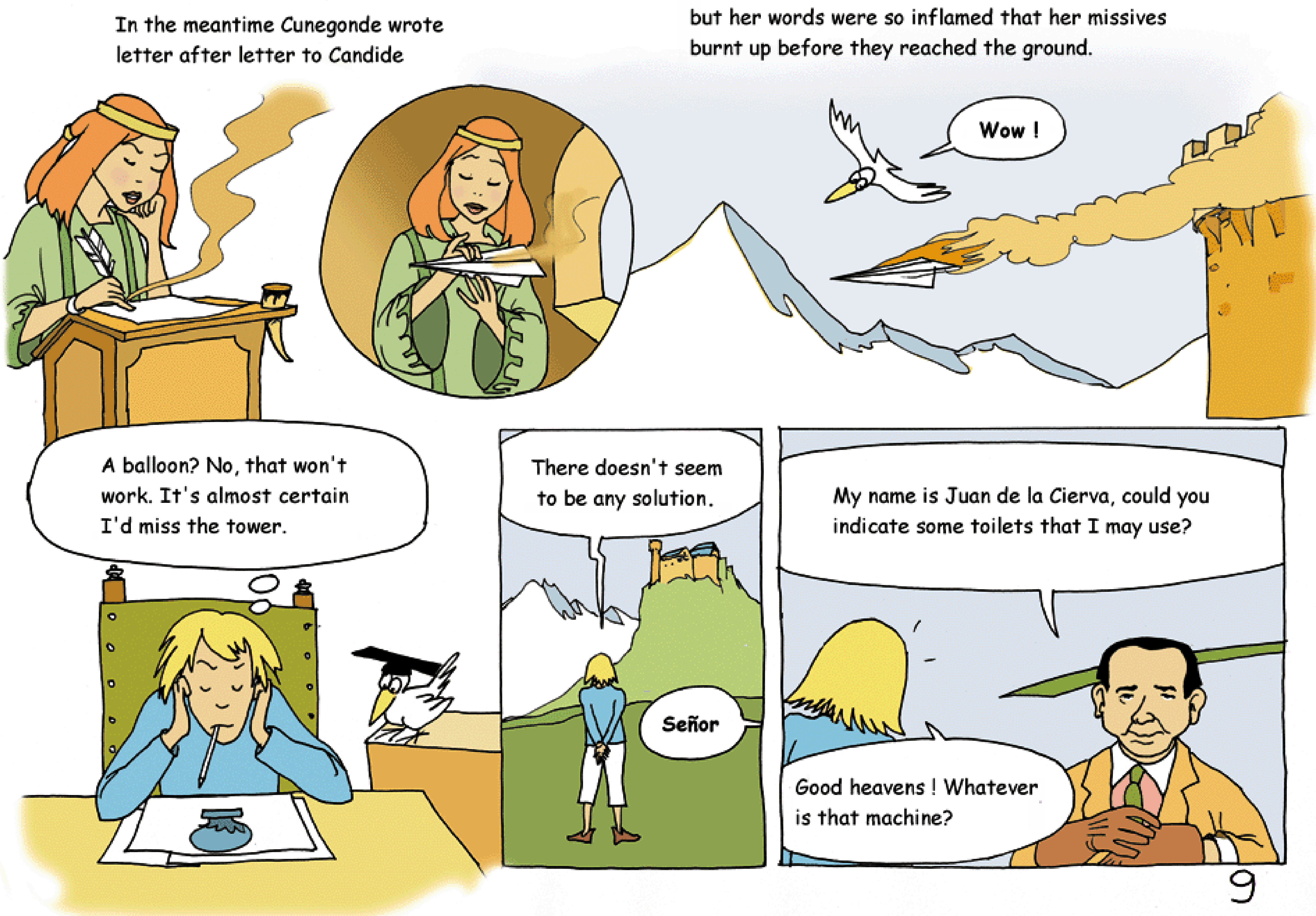
I should be able to reduce the distance needed by approaching at a lower speed. The lift on the wings is proportional to the incidence ?. By nosing up the plane I should be able to fly a lot more slowly.
α
V
So it's this wing that allows you to remain in the air?
Yes
Relative wind
Leading edge
T
Lift
Aerodynamic force
Drag
Speed
I've added stiffening cables which absorb the strong drag forces and stop the wings from folding backwards
Rib
Rib
Aspiration effect above the wing
Pressure distribution
Superpressure on the undersurface
Like on crane jibs.
The bars work as TRACTION
P
Lift
The SPAR absorbs the torque force linked to LIFT.
KRAK !
Gentlemen, without these precious stiffeners the wings would break up.
A wise precaution.

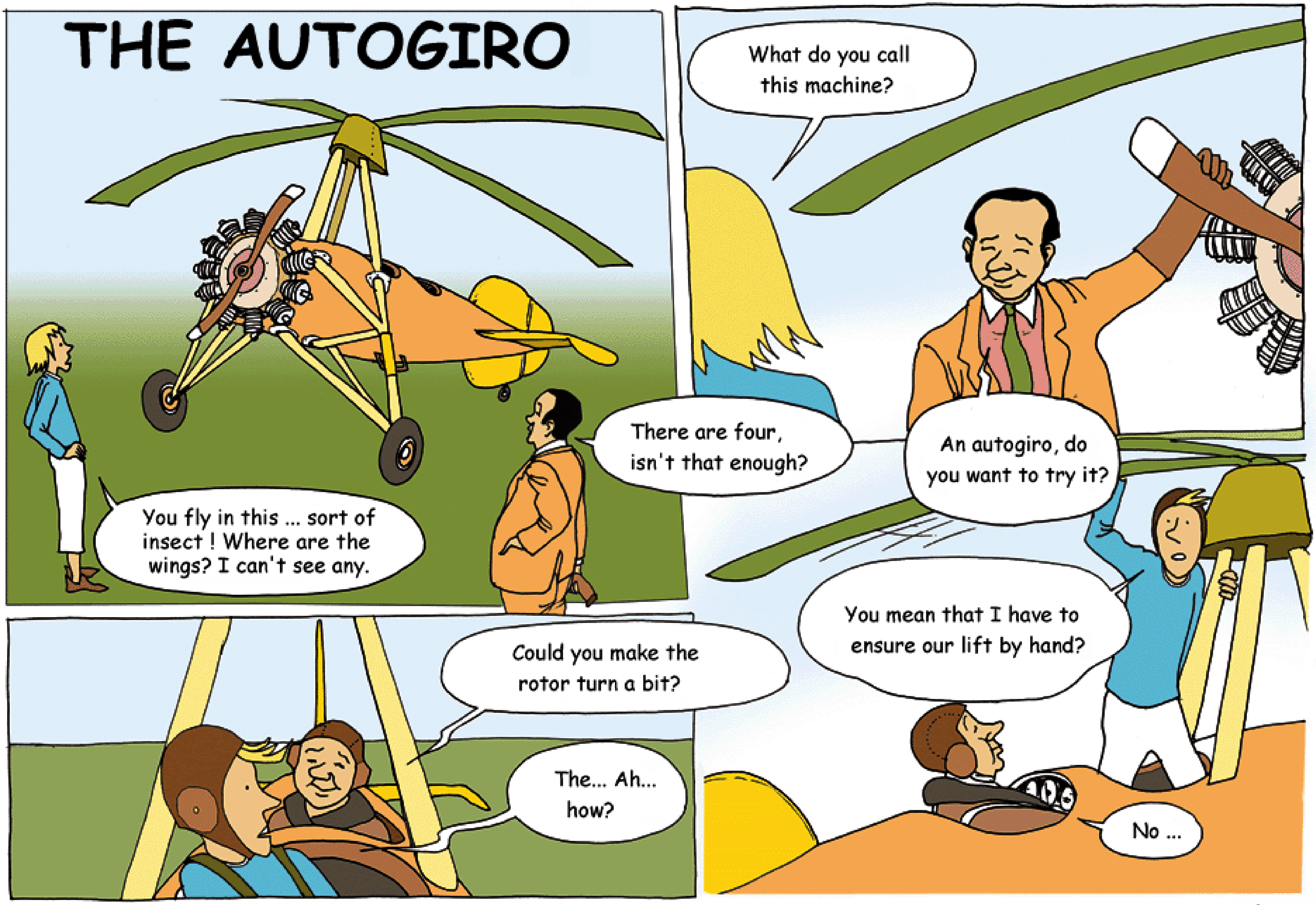

So let's see how we can reduce the speed by nosing up the machine.
I pull on the joystick
KRRAAAAAK!
Suddenly the wings snap and fold towards the front!
!!!...
OK, it's all sorted out. It just needed a second series of stiffeners to stop the wings folding forwards.
The plane is now correctly strengthened. I'll tilt it slowly.
At least, it should nose up, otherwise I'll want to know why.

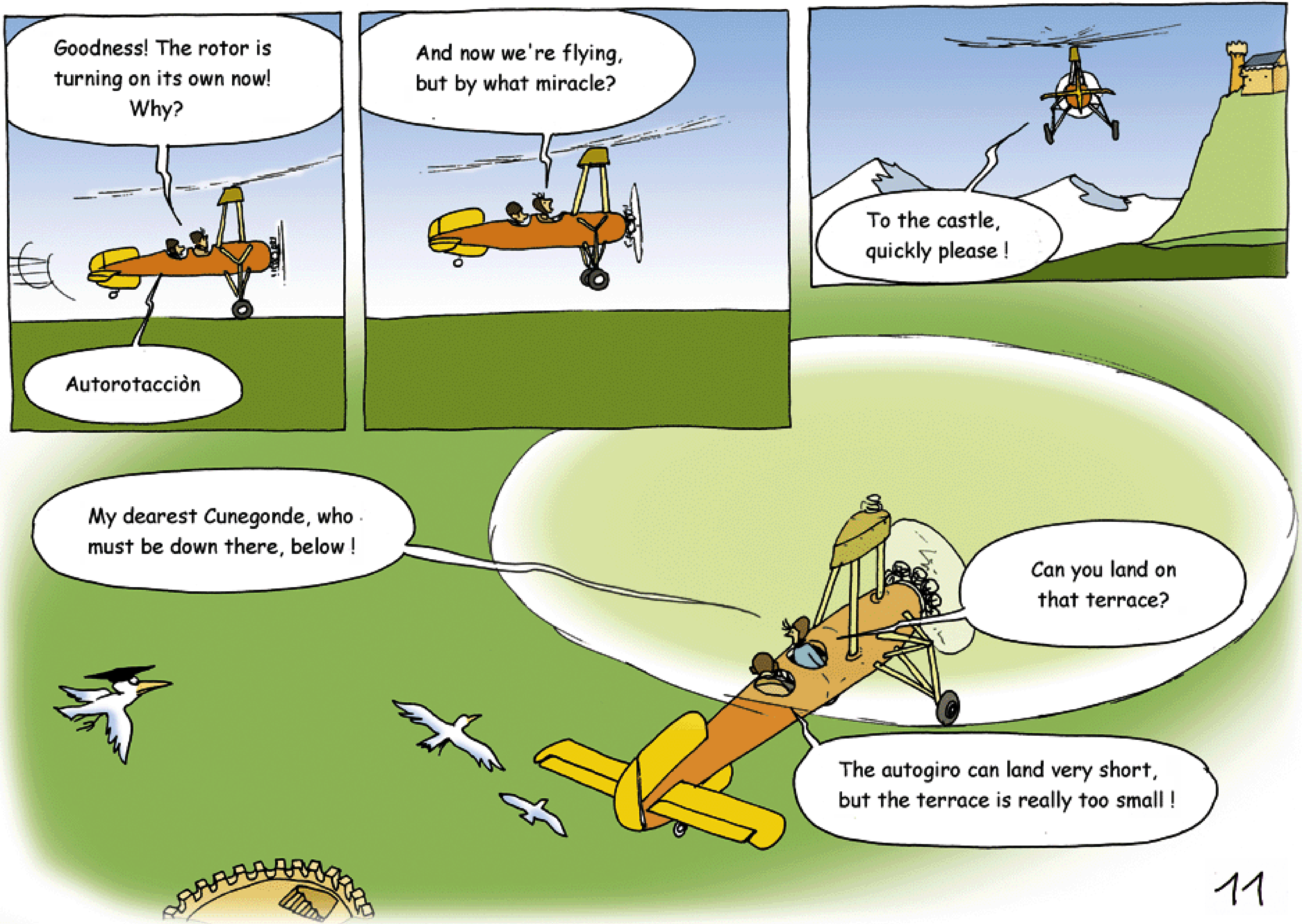


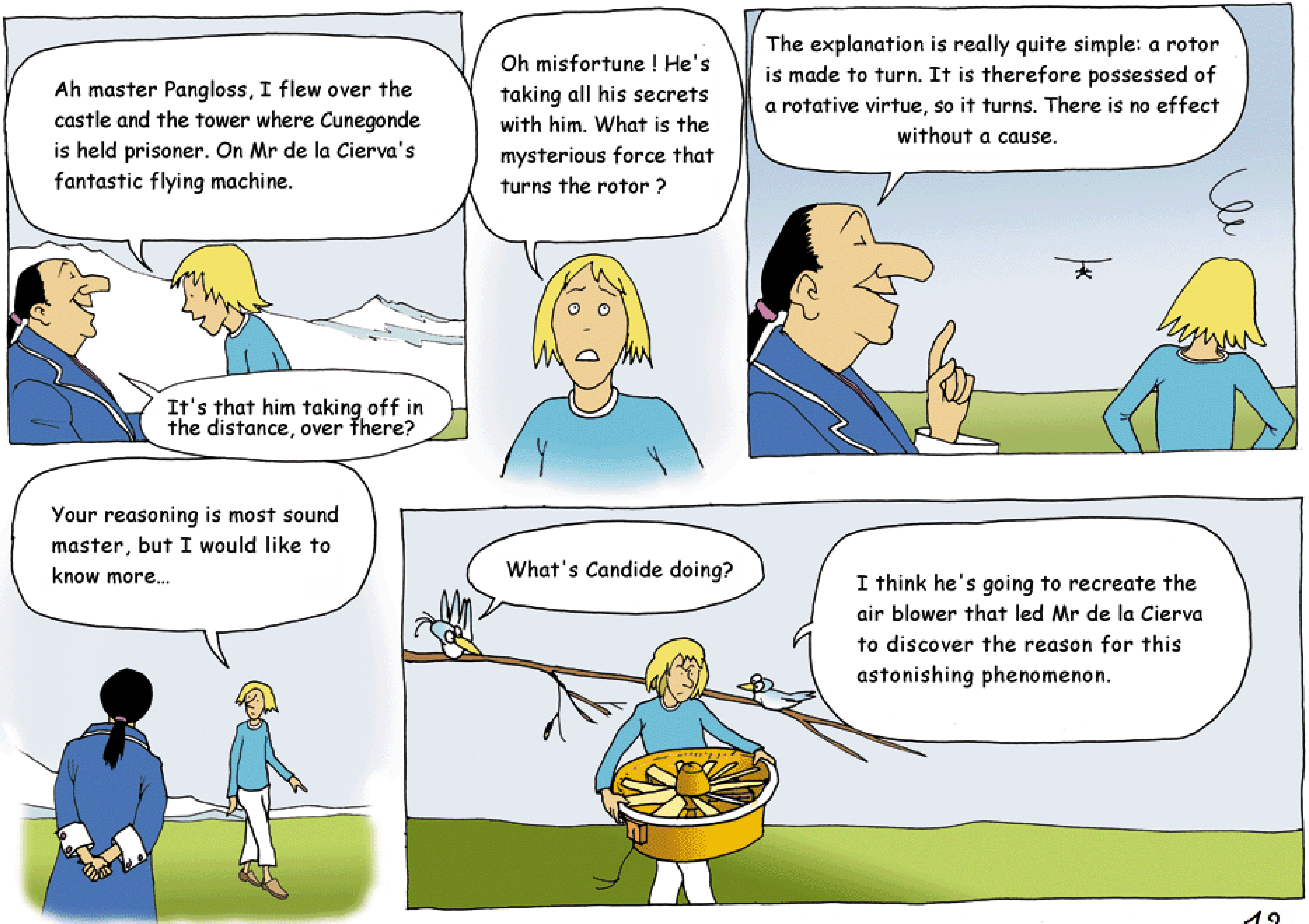
(*) http://www.savoir-sans-frontieres.com


Lift
P
F
Aerodynamic force
Drag
From a certain angle onwards, the fluid waves detach from the profile. A regime of very turbulent alternate swirls is established. The drag increases greatly and lift diminishes.
When I looked at the flow map corresponding to high incidence, I noticed something.
What?
When we project the resultant of the aerodynamic force F (exerted at a quarter of the length of the chord's profile) we find a componenent which is directed towards the REAR PART of the wing's profile.
F
V
L/4
L
And that's what made the wings of this gentleman's plane fold towards the front.

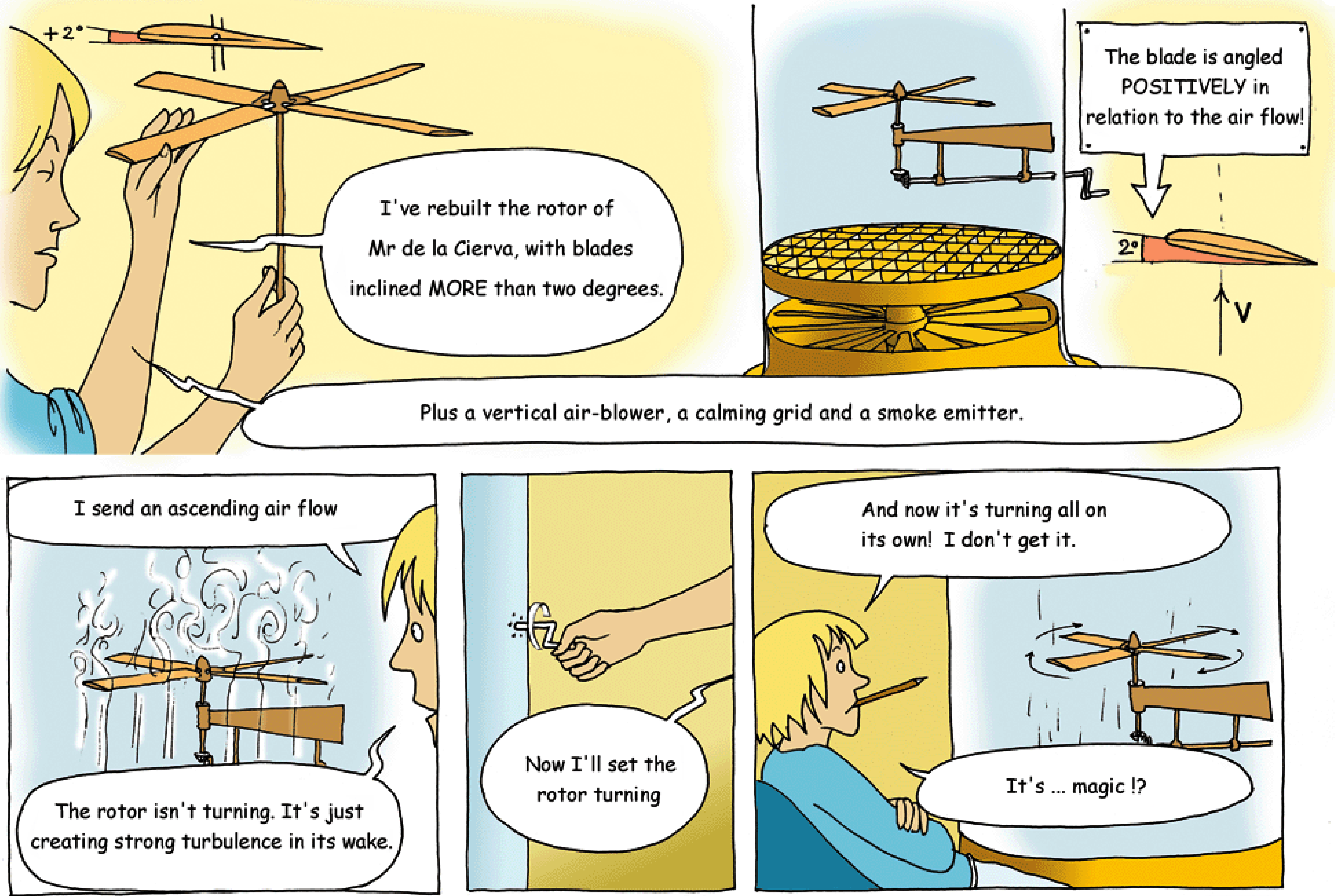

In the meantime Cunegonde wrote letter after letter to Candide
but her words were so inflamed that her missives burnt up before they reached the ground.
Wow !
A balloon? No, that won't work. It's almost certain I'd miss the tower.
There doesn't seem to be any solution.
Señor
My name is Juan de la Cierva, could you indicate some toilets that I may use?
Good heavens ! Whatever is that machine?


THE AUTOGIRO
You fly in this ... sort of insect ! Where are the wings? I can't see any.
There are four, isn't that enough?
What do you call this machine?
An autogiro, do you want to try it?
Could you make the rotor turn a bit?
The... Ah... how?
You mean that I have to ensure our lift by hand?
No ...

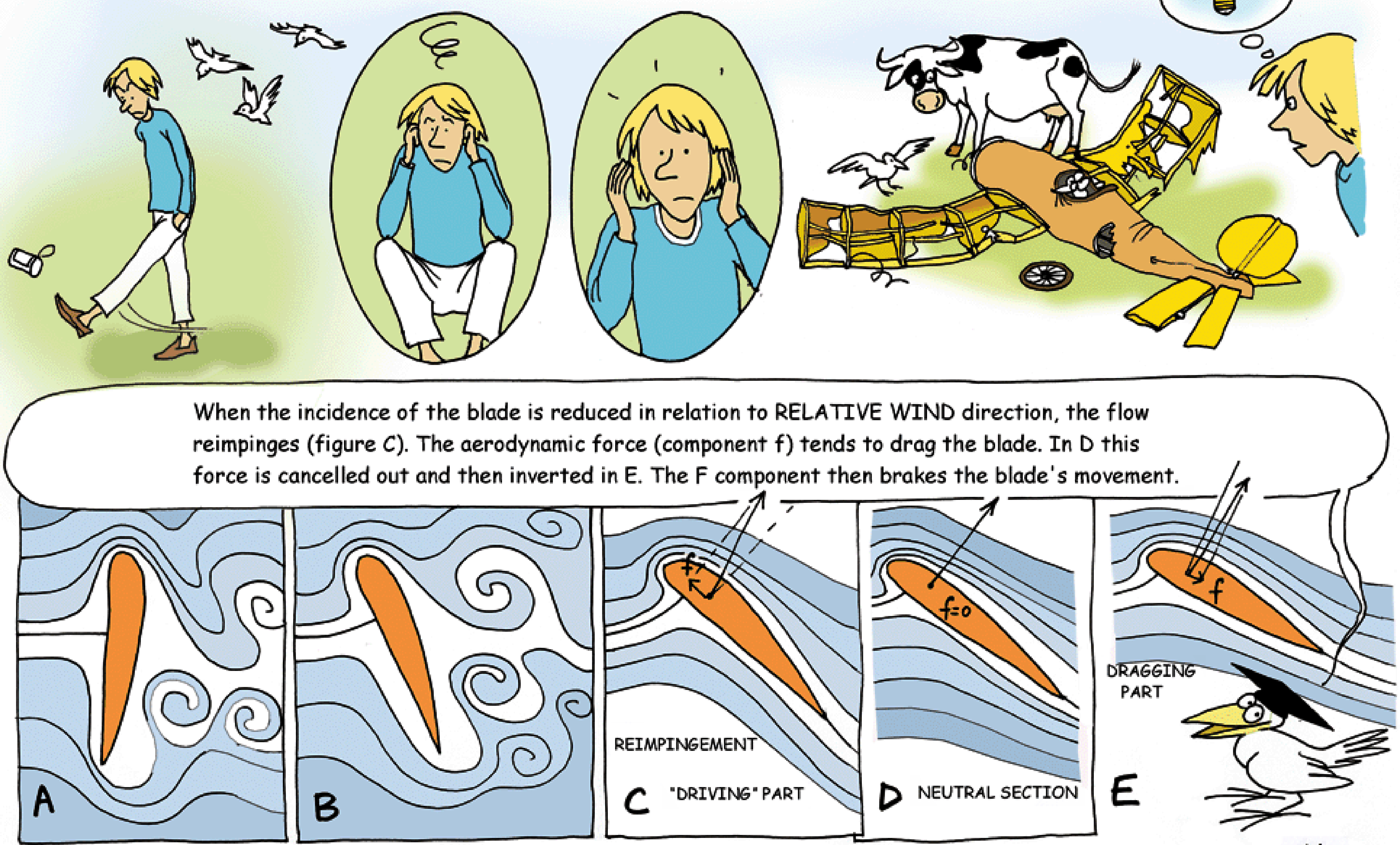

Goodness! The rotor is turning on its own now! Why?
Autorotacciòn
And now we're flying, but by what miracle?
To the castle, quickly please !
My dearest Cunegonde, who must be down there, below !
Can you land on that terrace?
The autogiro can land very short, but the terrace is really too small !

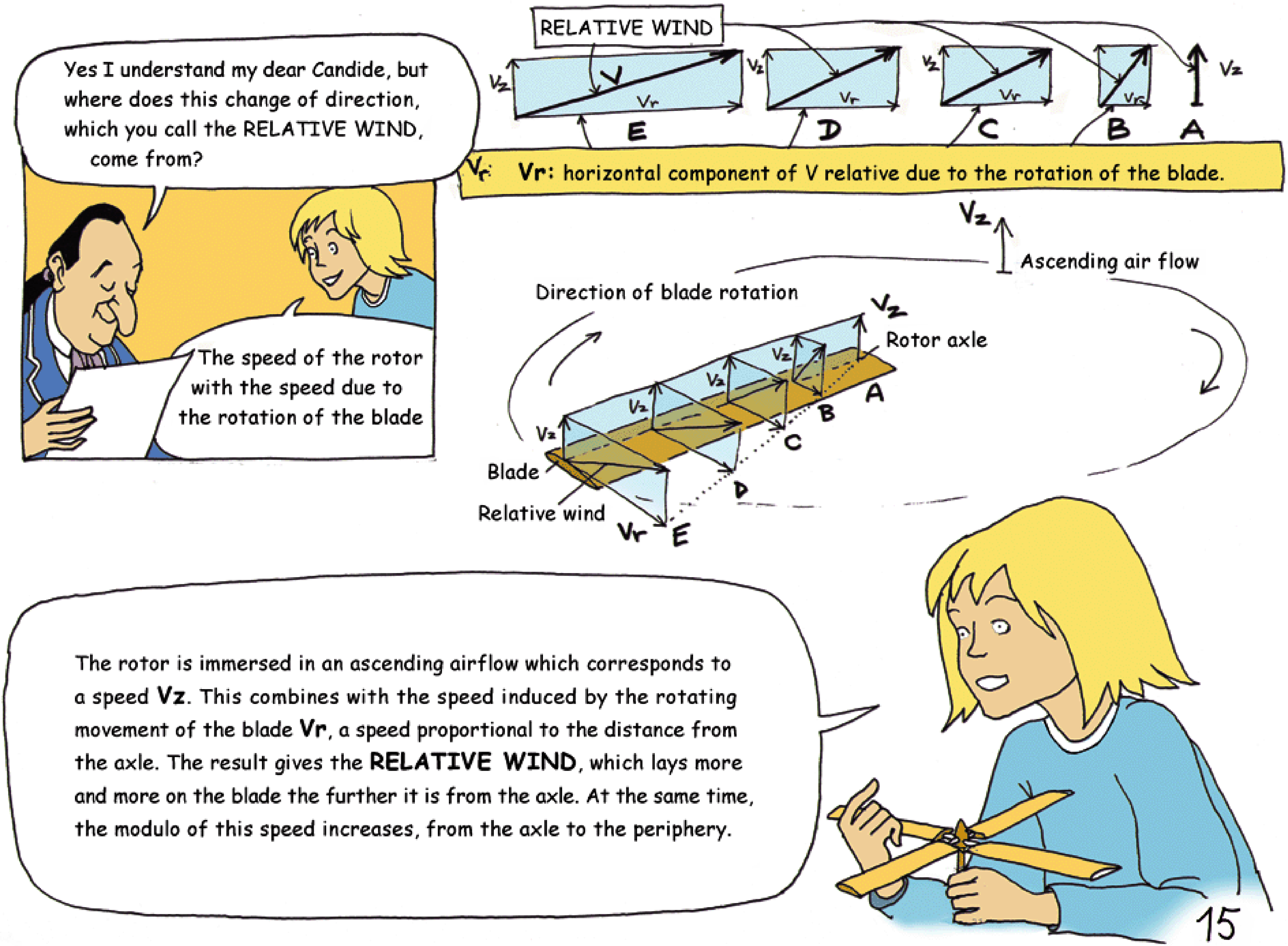


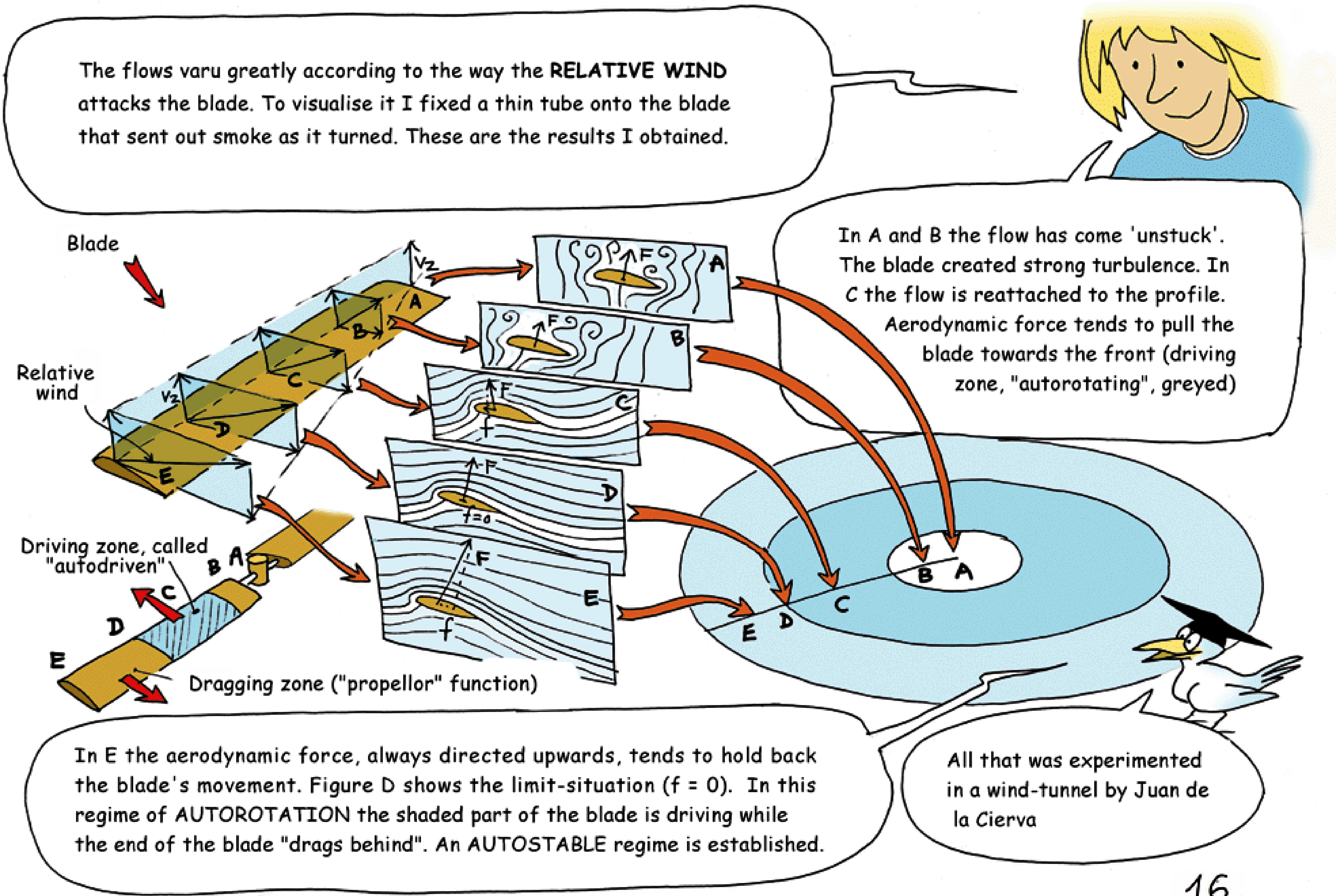
Ah master Pangloss, I flew over the castle and the tower where Cunegonde is held prisoner. On Mr de la Cierva's fantastic flying machine.
It's that him taking off in the distance, over there?
Oh misfortune ! He's taking all his secrets with him. What is the mysterious force that turns the rotor ?
The explanation is really quite simple: a rotor is made to turn. It is therefore possessed of a rotative virtue, so it turns. There is no effect without a cause.
Your reasoning is most sound master, but I would like to know more...
What's Candide doing?
I think he's going to recreate the air blower that led Mr de la Cierva to discover the reason for this astonishing phenomenon.


+2°
I've rebuilt the rotor of Mr de la Cierva, with blades inclined MORE than two degrees.
The blade is angled POSITIVELY in relation to the air flow!
2°
V
Plus a vertical air-blower, a calming grid and a smoke emitter.
I send an ascending air flow
The rotor isn't turning. It's just creating strong turbulence in its wake.
Now I'll set the rotor turning
And now it's turning all on its own! I don't get it.
It's ... magic !?

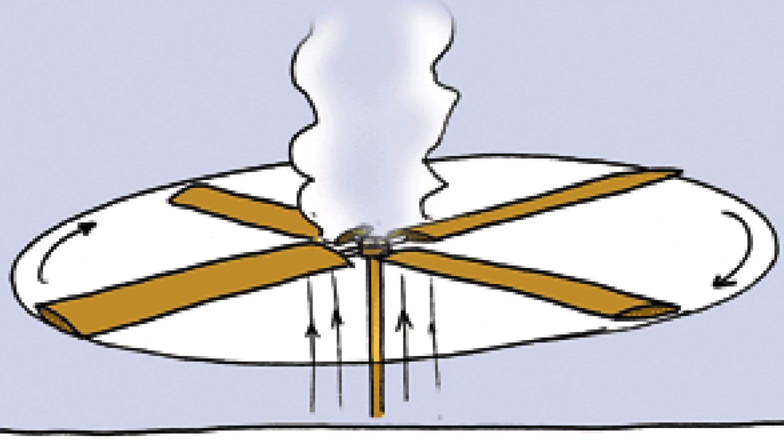
AUTOROTATION



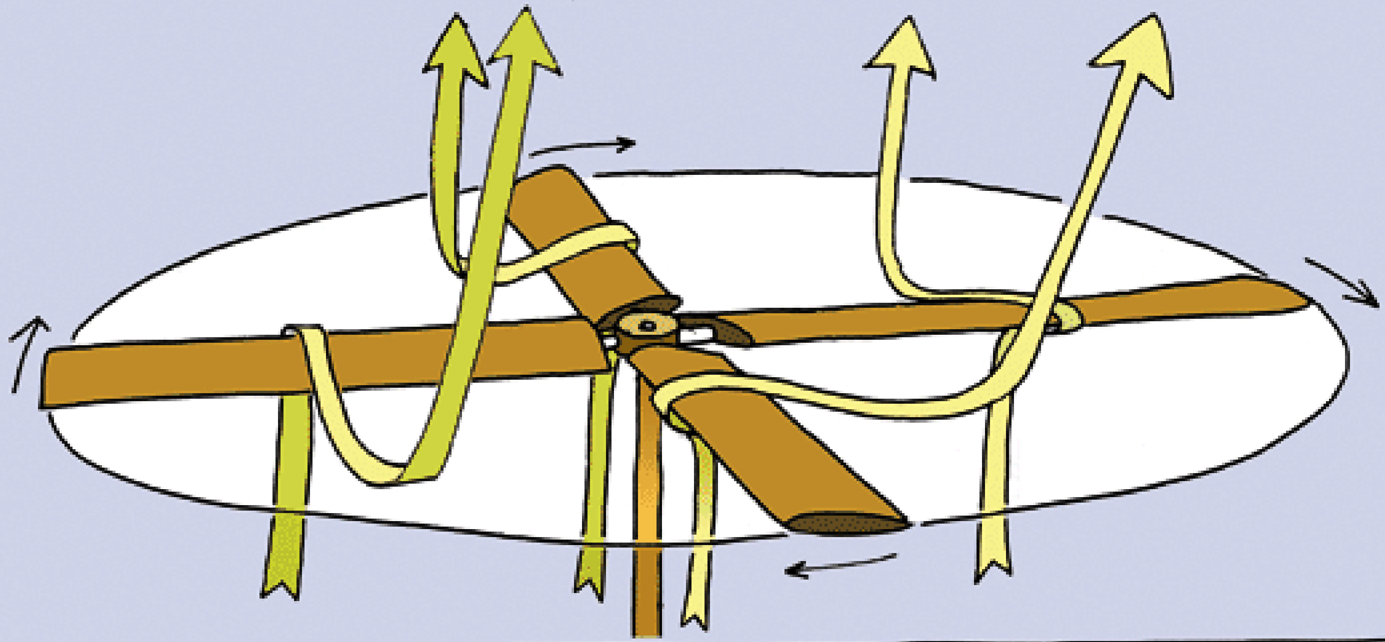

Yes I understand my dear Candide, but where does this change of direction, which you call the RELATIVE WIND, come from?
The speed of the rotor with the speed due to the rotation of the blade
RELATIVE WIND
V
Vz
Vr
E
D
C
B
A
Vr: horizontal component of V relative due to the rotation of the blade.
Vz
Ascending air flow
Direction of blade rotation
Rotor axle
Blade
Relative wind
The rotor is immersed in an ascending airflow which corresponds to a speed Vz. This combines with the speed induced by the rotating movement of the blade Vr, a speed proportional to the distance from the axle. The result gives the RELATIVE WIND, which lays more and more on the blade the further it is from the axle. At the same time, the modulo of this speed increases, from the axle to the periphery.



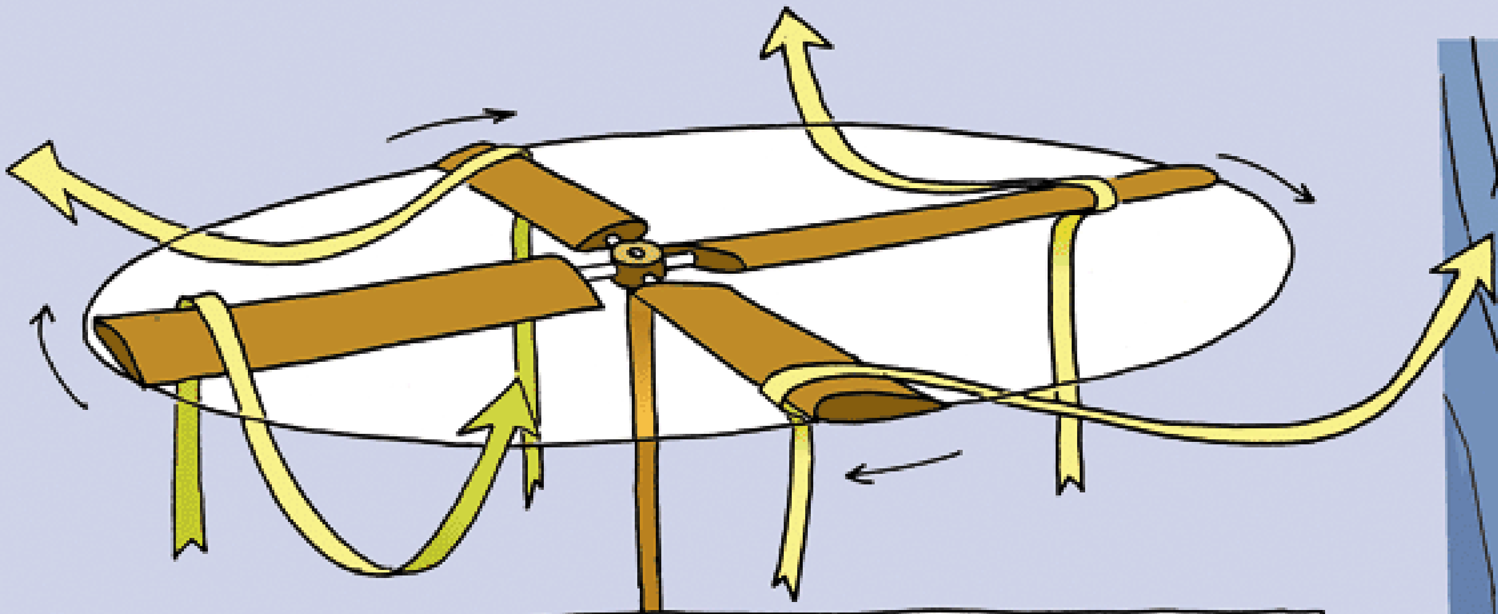
The flows varu greatly according to the way the **RELATIVE WIND** attacks the blade. To visualise it I fixed a thin tube onto the blade that sent out smoke as it turned. These are the results I obtained.
Blade
Relative wind
In A and B the flow has come 'unstuck'. The blade created strong turbulence. In C the flow is reattached to the profile. Aerodynamic force tends to pull the blade towards the front (driving zone, "autorotating", greyed)
Driving zone, called "autodriven"
Dragging zone ("propellor" function)
A
B
C
D
E
F
f
f=0
In E the aerodynamic force, always directed upwards, tends to hold back the blade's movement. Figure D shows the limit-situation (f = 0). In this regime of AUTOROTATION the shaded part of the blade is driving while the end of the blade "drags behind". An AUTOSTABLE regime is established.
All that was experimented in a wind-tunnel by Juan de la Cierva



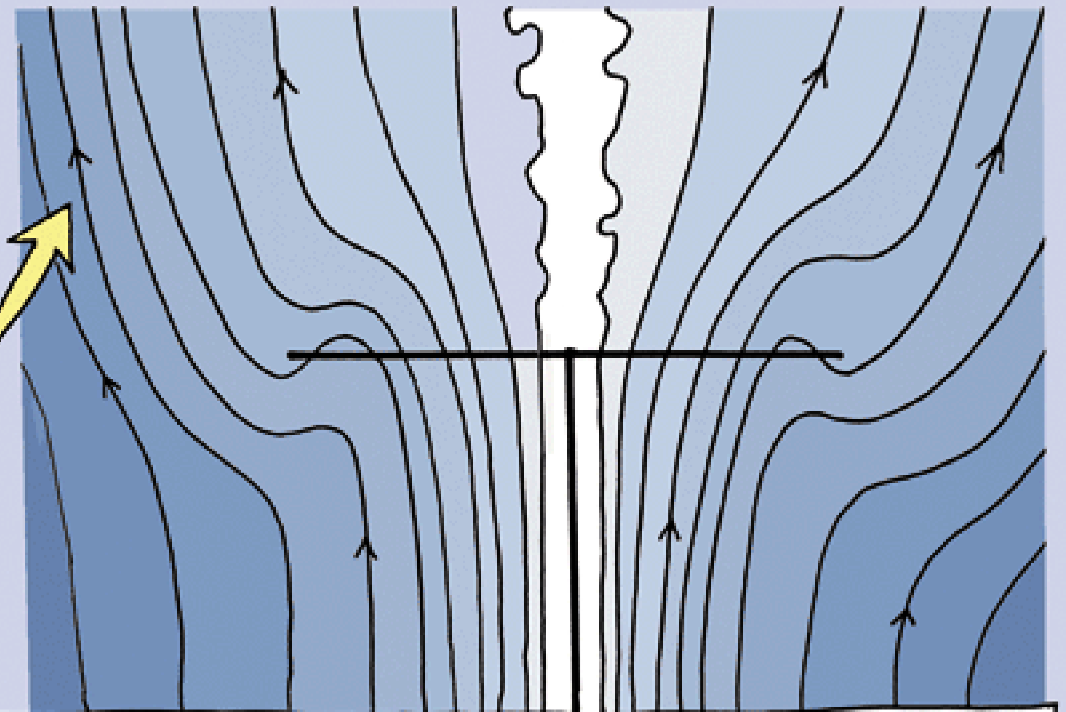
Above the central part ("detached" flow), there is a strong turbulent wake



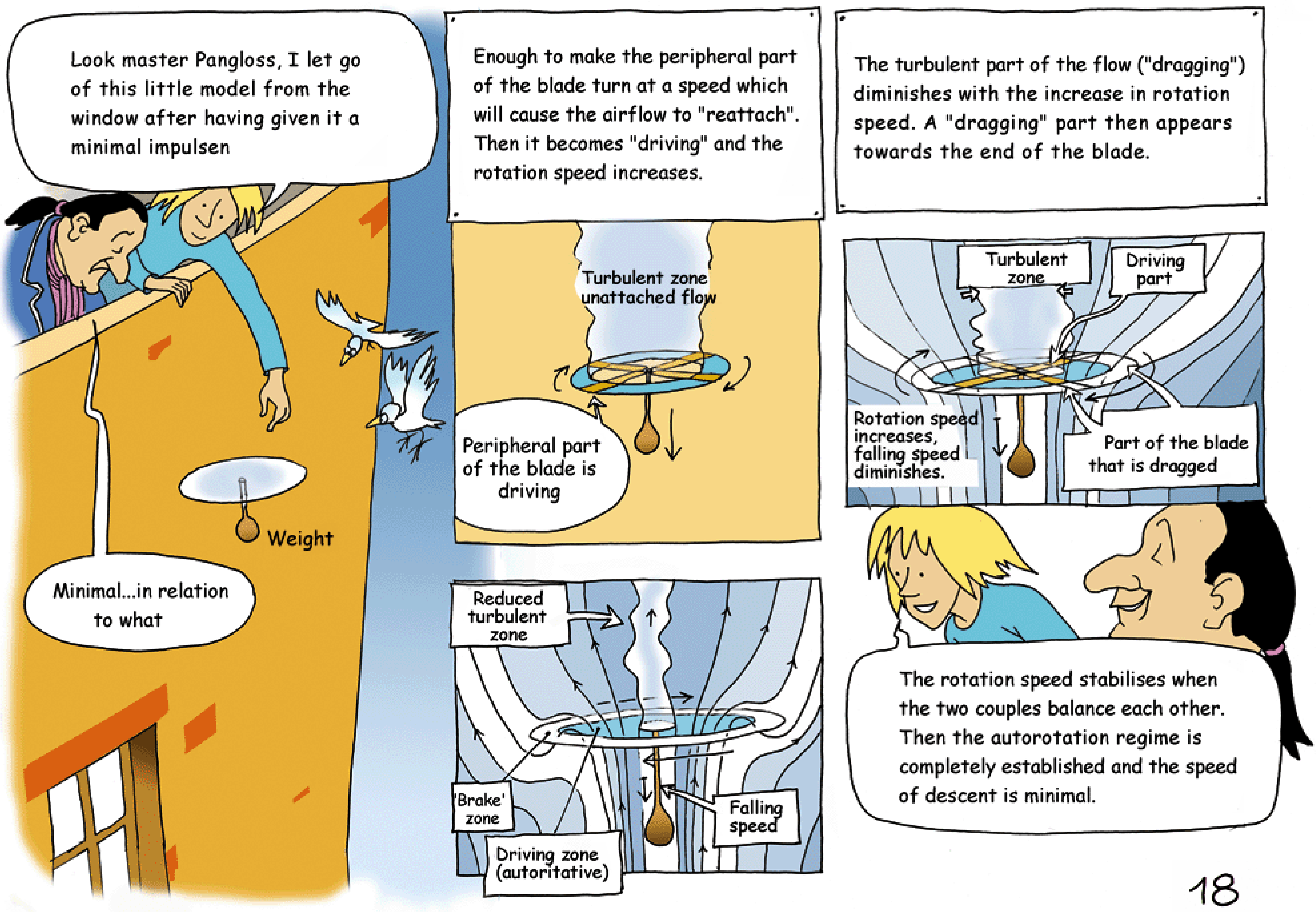
Here the flow is reattached to the blade's edge



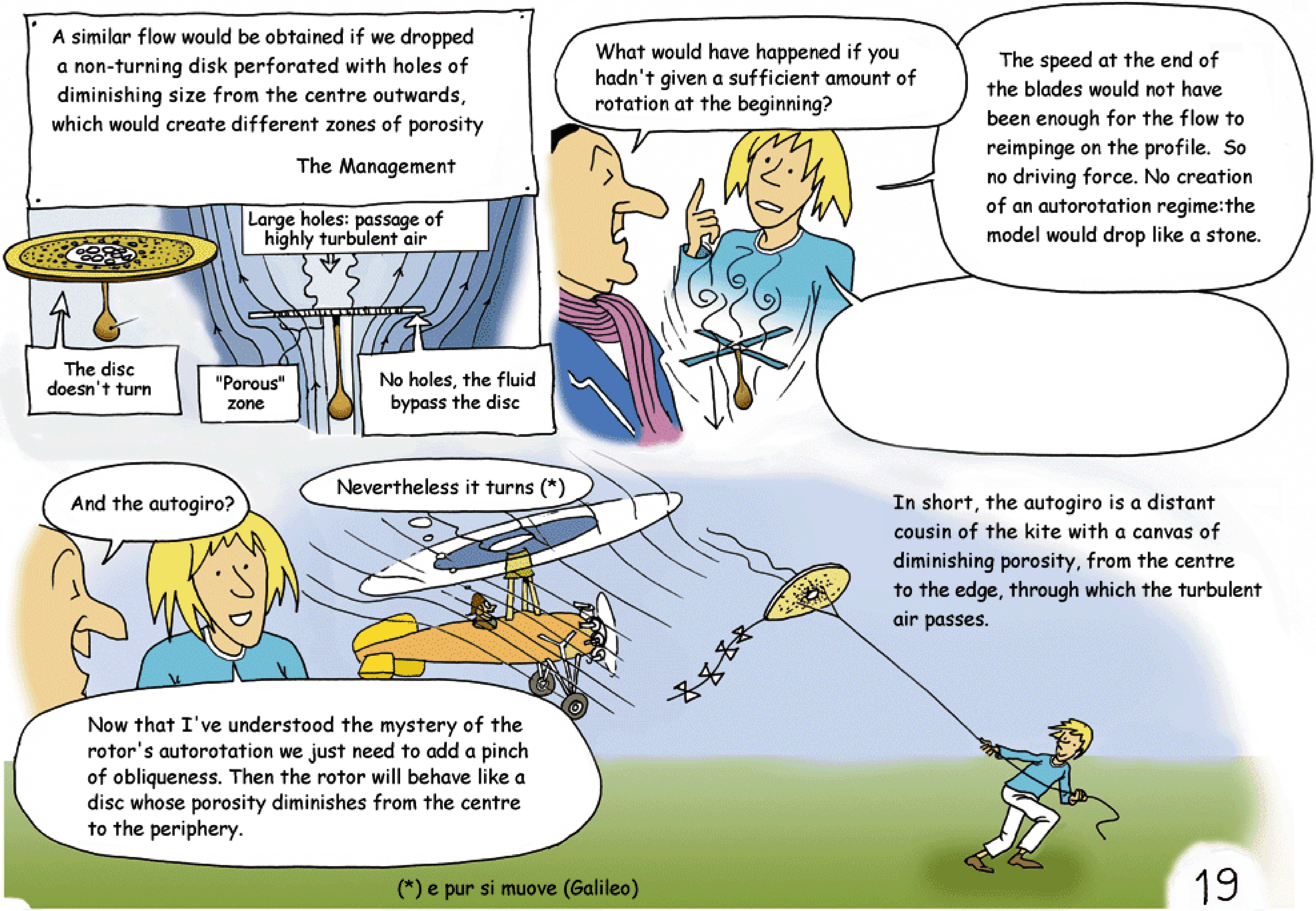
On the periphery, the impulse communicated to the air mass, directed downwards (**INDUCED SPEED**) is sufficient to push the air out beyond the disc area formed by the sweep of the blades.

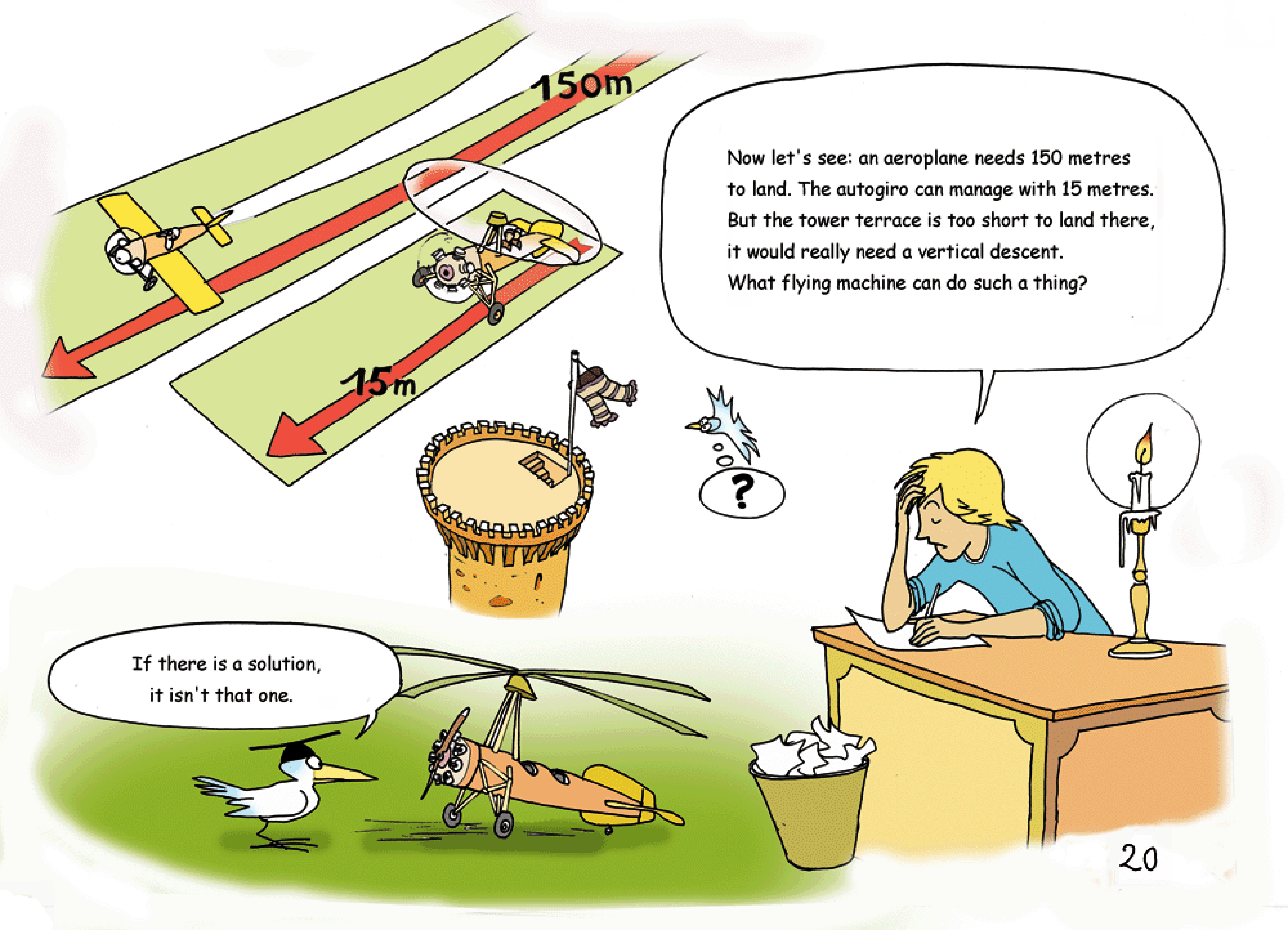


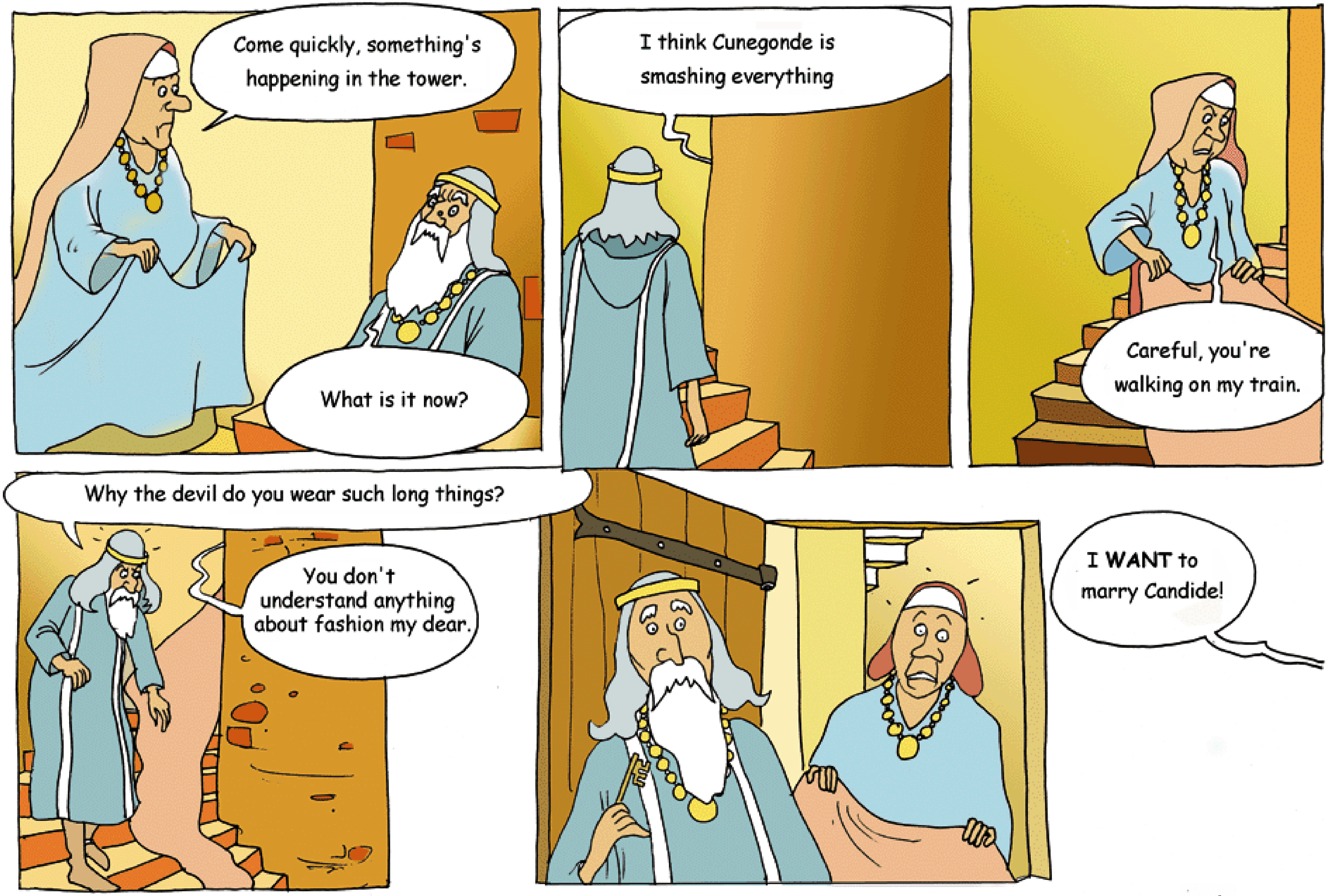
This gives the rather strange airflow shown above.

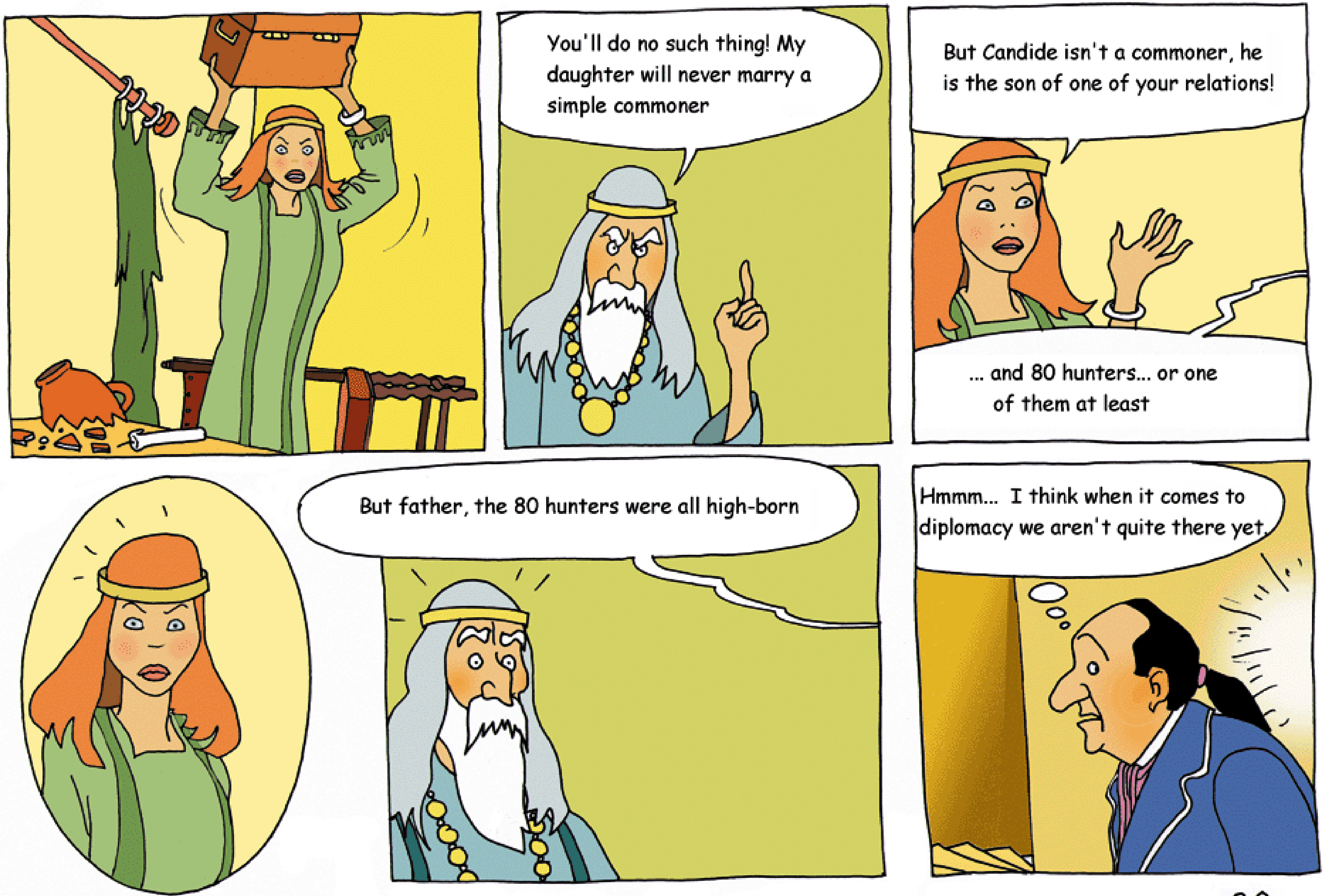


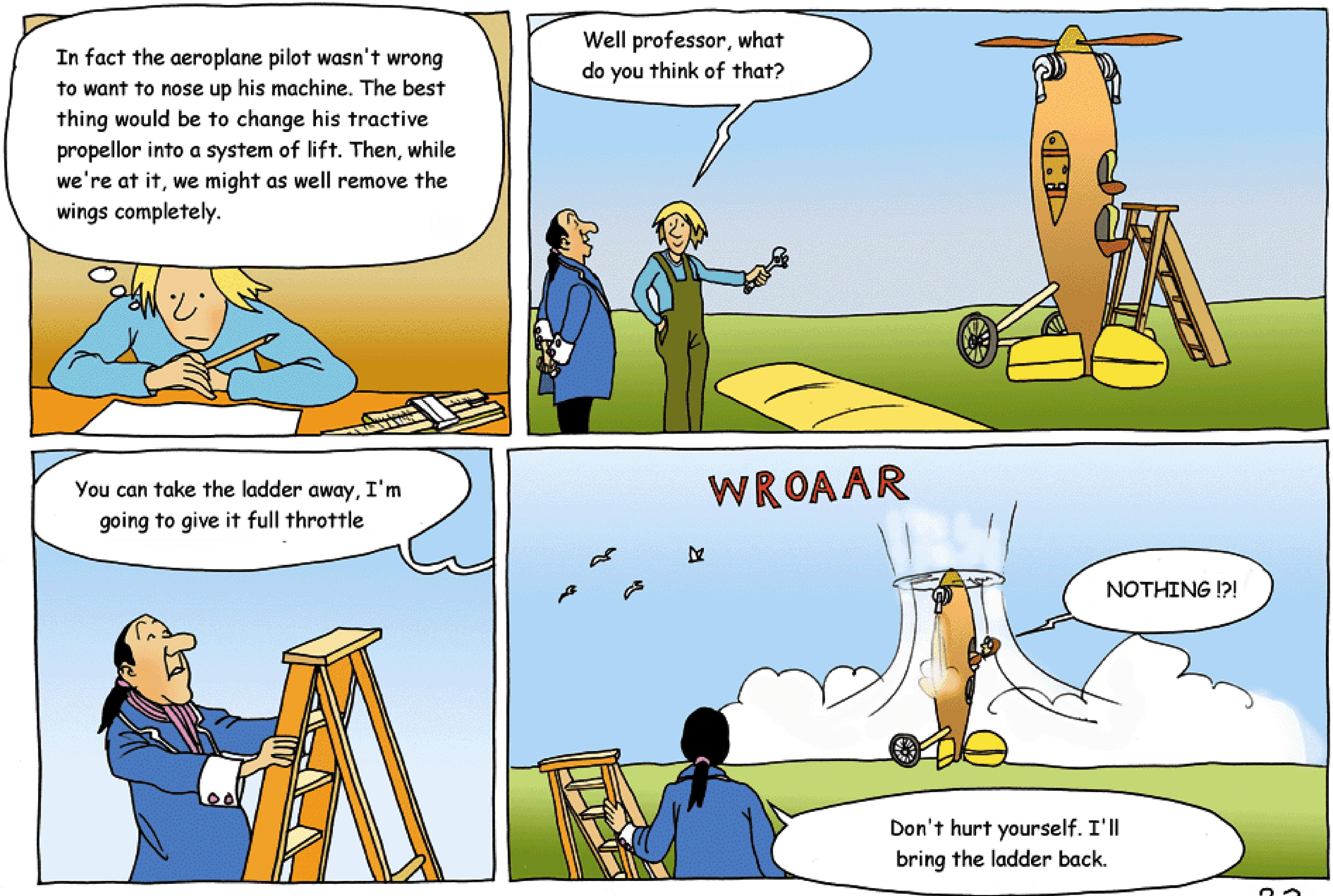
Look master Pangloss, I let go of this little model from the window after having given it a minimal impulsen
Minimal...in relation to what
Weight
Enough to make the peripheral part of the blade turn at a speed which will cause the airflow to "reattach". Then it becomes "driving" and the rotation speed increases.
Turbulent zone unattached flow
Peripheral part of the blade is driving
Reduced turbulent zone
'Brake' zone
Driving zone (autoritative)
Falling speed
The turbulent part of the flow ("dragging") diminishes with the increase in rotation speed. A "dragging" part then appears towards the end of the blade.
Turbulent zone
Driving part
Rotation speed increases, falling speed diminishes.
Part of the blade that is dragged
The rotation speed stabilises when the two couples balance each other. Then the autorotation regime is completely established and the speed of descent is minimal.

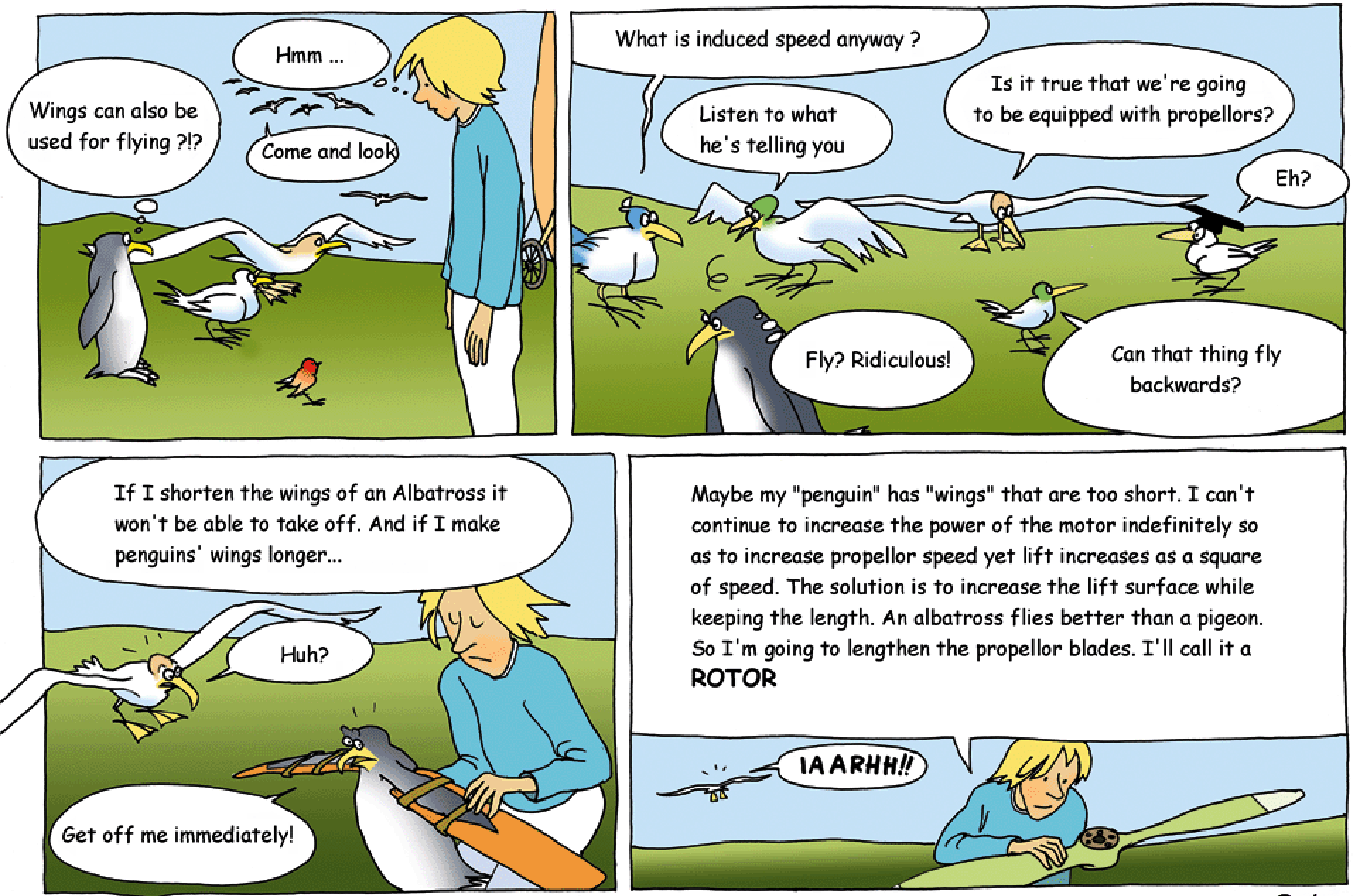

A similar flow would be obtained if we dropped a non-turning disk perforated with holes of diminishing size from the centre outwards, which would create different zones of porosity
The Management
Large holes: passage of highly turbulent air
The disc doesn't turn
"Porous" zone
No holes, the fluid bypass the disc
What would have happened if you hadn't given a sufficient amount of rotation at the beginning?
The speed at the end of the blades would not have been enough for the flow to reimpinge on the profile. So no driving force. No creation of an autorotation regime:the model would drop like a stone.
And the autogiro?
Nevertheless it turns (*)
In short, the autogiro is a distant cousin of the kite with a canvas of diminishing porosity, from the centre to the edge, through which the turbulent air passes.
Now that I've understood the mystery of the rotor's autorotation we just need to add a pinch of obliqueness. Then the rotor will behave like a disc whose porosity diminishes from the centre to the periphery.
(*) e pur si muove (Galileo)


150m
15m
Now let's see: an aeroplane needs 150 metres to land. The autogiro can manage with 15 metres. But the tower terrace is too short to land there, it would really need a vertical descent. What flying machine can do such a thing?
?
If there is a solution, it isn't that one.

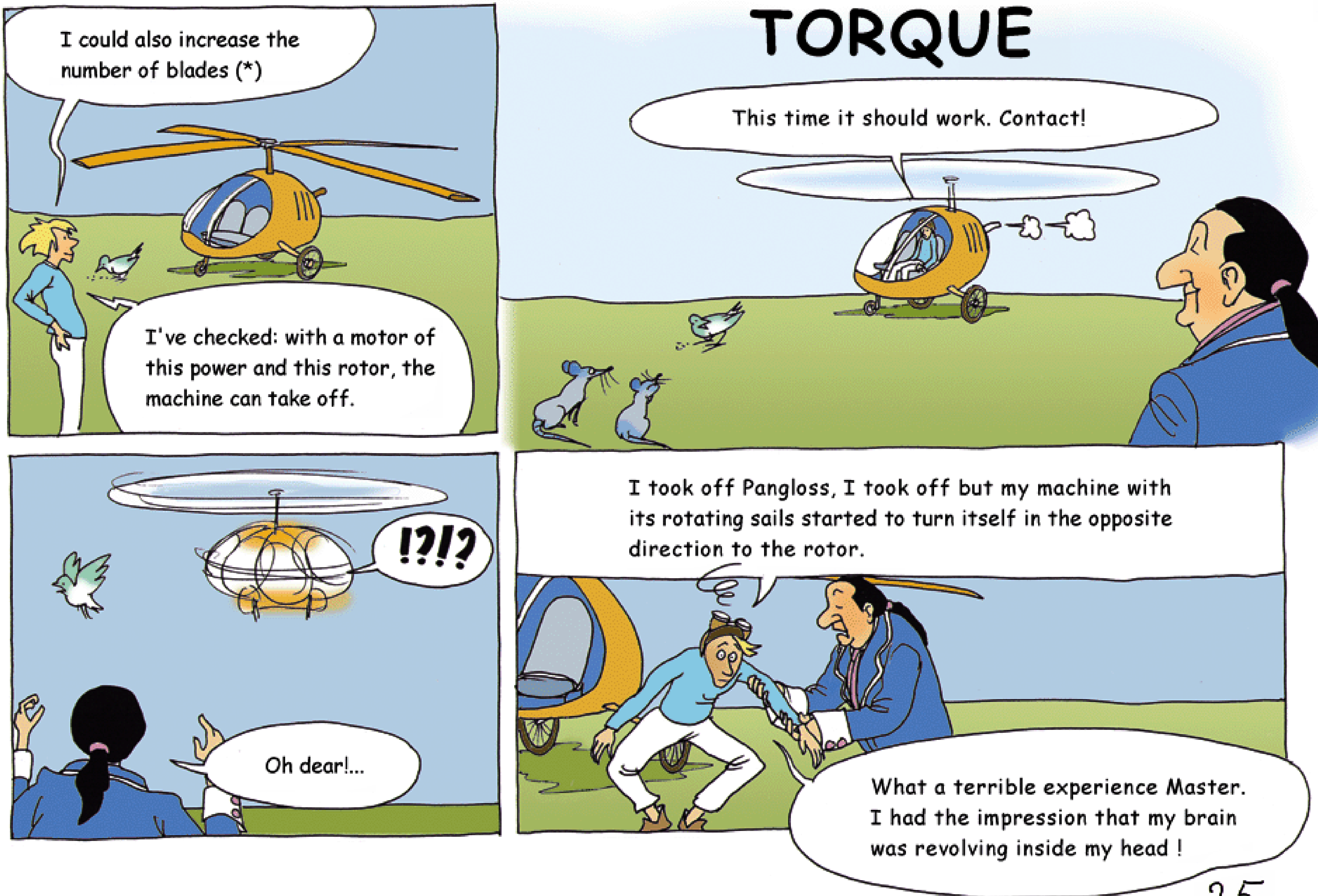

Come quickly, something's happening in the tower.
What is it now?
I think Cunegonde is smashing everything
Careful, you're walking on my train.
Why the devil do you wear such long things?
You don't understand anything about fashion my dear.
I WANT to marry Candide!


You'll do no such thing! My daughter will never marry a simple commoner
But Candide isn't a commoner, he is the son of one of your relations!
... and 80 hunters... or one of them at least
But father, the 80 hunters were all high-born
Hmmm... I think when it comes to diplomacy we aren't quite there yet.

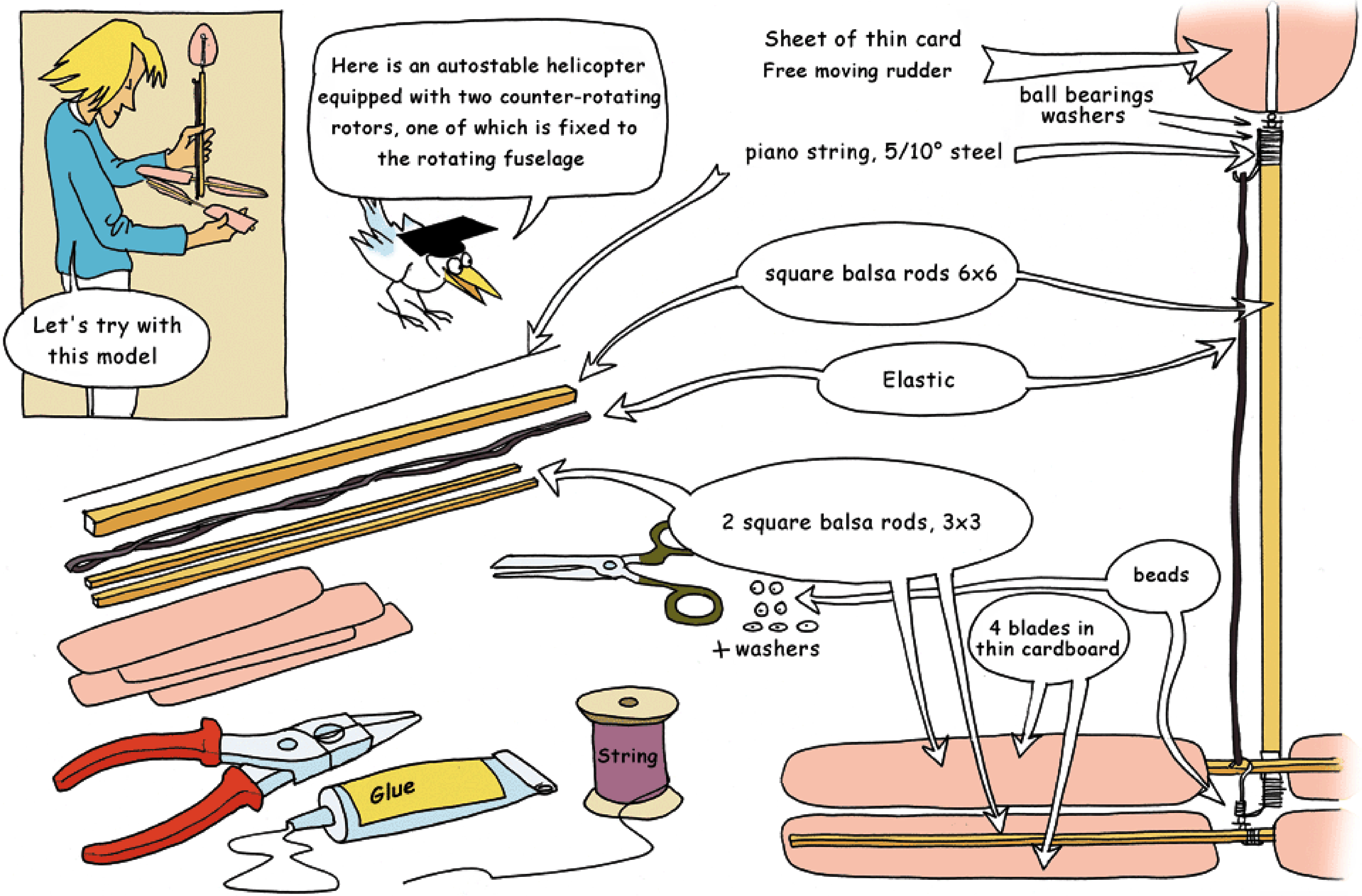

In fact the aeroplane pilot wasn't wrong to want to nose up his machine. The best thing would be to change his tractive propellor into a system of lift. Then, while we're at it, we might as well remove the wings completely.
Well professor, what do you think of that?
You can take the ladder away, I'm going to give it full throttle
WROAAR
NOTHING !?!
Don't hurt yourself. I'll bring the ladder back.


Wings can also be used for flying ?!?
Hmm ...
Come and look
What is induced speed anyway ?
Listen to what he's telling you
Is it true that we're going to be equipped with propellors?
Eh?
Fly? Ridiculous!
Can that thing fly backwards?
If I shorten the wings of an Albatross it won't be able to take off. And if I make penguins' wings longer...
Huh?
Get off me immediately!
Maybe my "penguin" has "wings" that are too short. I can't continue to increase the power of the motor indefinitely so as to increase propellor speed yet lift increases as a square of speed. The solution is to increase the lift surface while keeping the length. An albatross flies better than a pigeon. So I'm going to lengthen the propellor blades. I'll call it a **ROTOR**
IAARHH!!

TORQUE

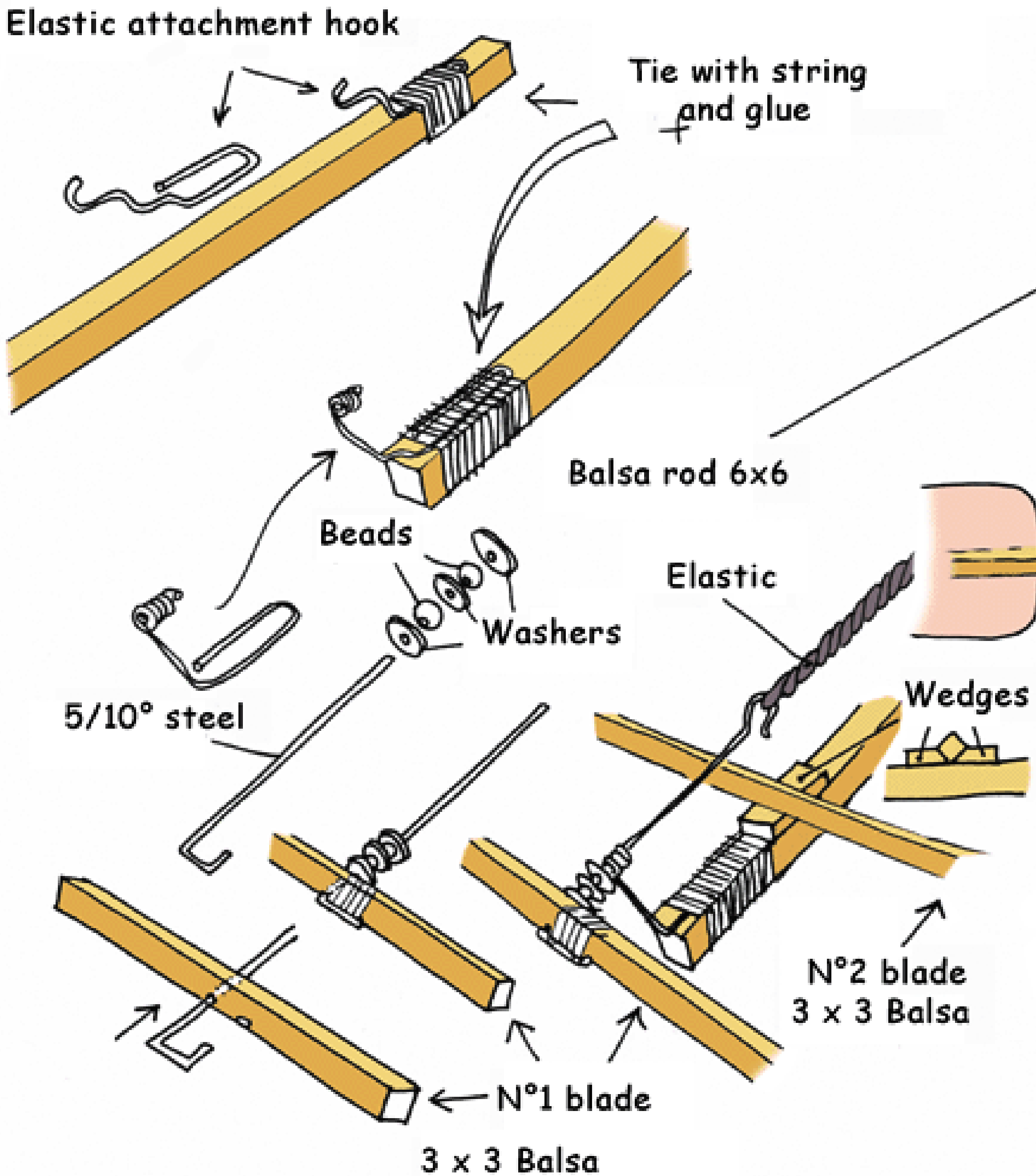


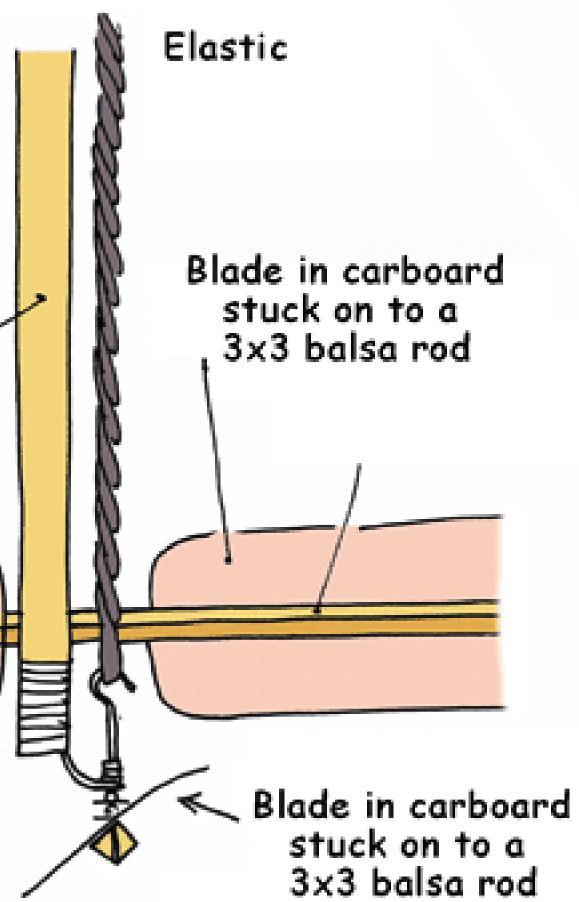
(*) but all the following applies to 2,3,4,5,6,7,8...blades

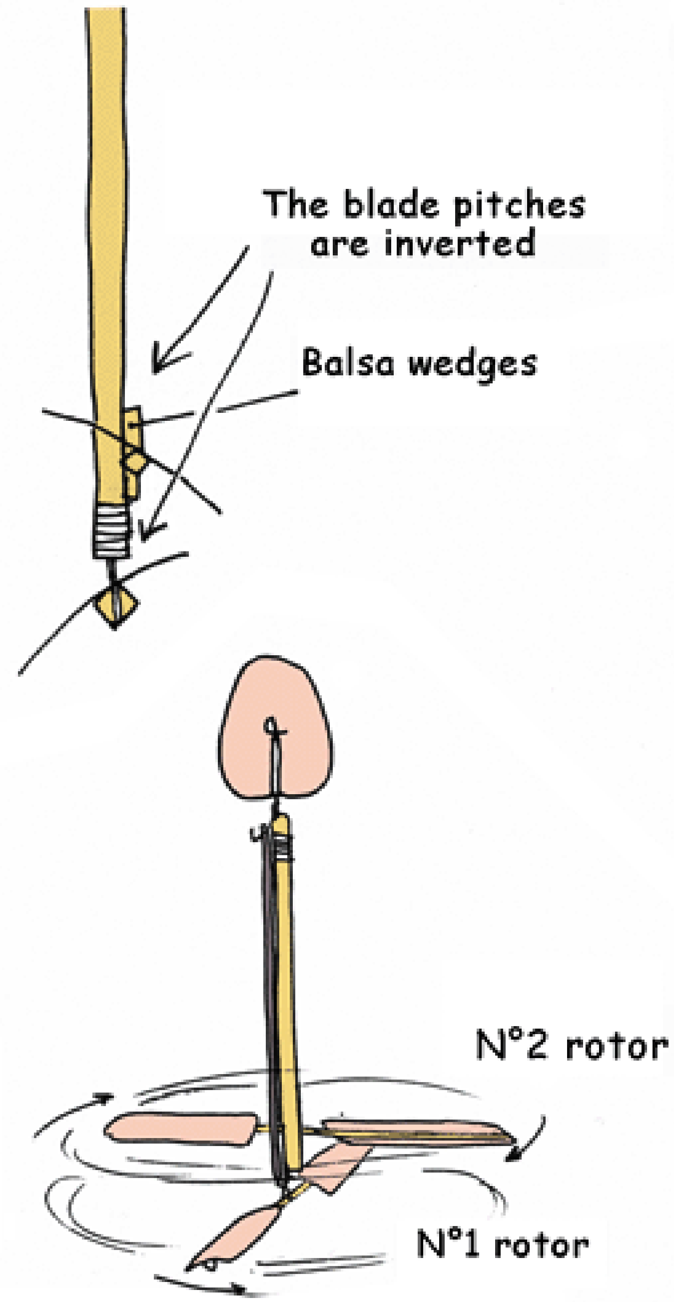


Let's try with this model
Here is an autostable helicopter equipped with two counter-rotating rotors, one of which is fixed to the rotating fuselage
Sheet of thin card
Free moving rudder
ball bearings
washers
piano string, 5/10° steel
square balsa rods 6x6
Elastic
2 square balsa rods, 3x3
beads
+ washers
4 blades in thin cardboard
String
Glue

The difficult part is bending the piano string. Use TWO pairs of pliers to make the following elements:

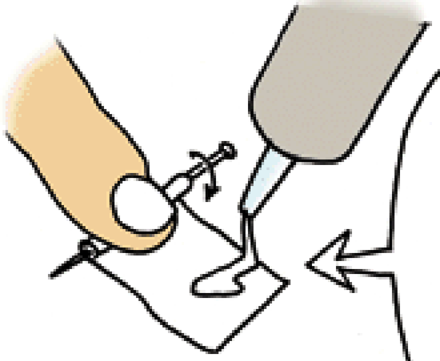




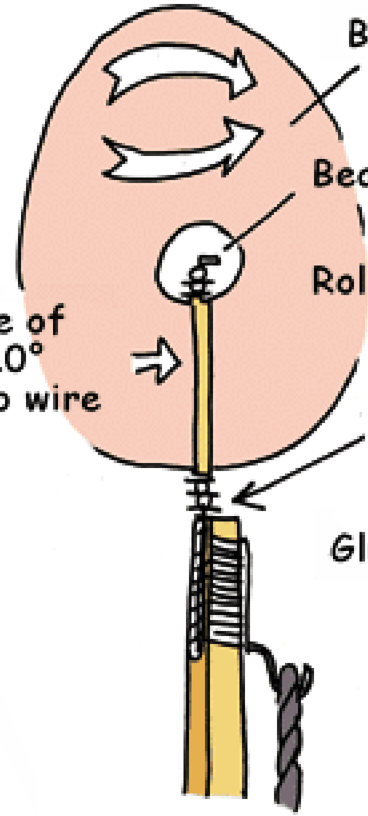


The elastic moves the lower rotor, n°1. Because of torque, rotor n°2, fixed to the rod-fuselage, begins to turn in the opposite direction.

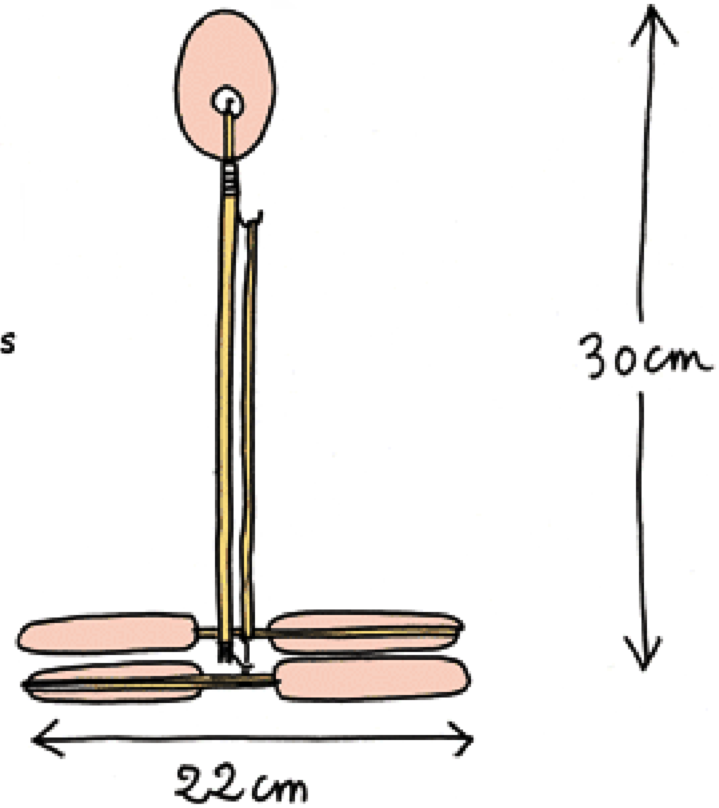
Construction of the upper blade which makes the machine autostable



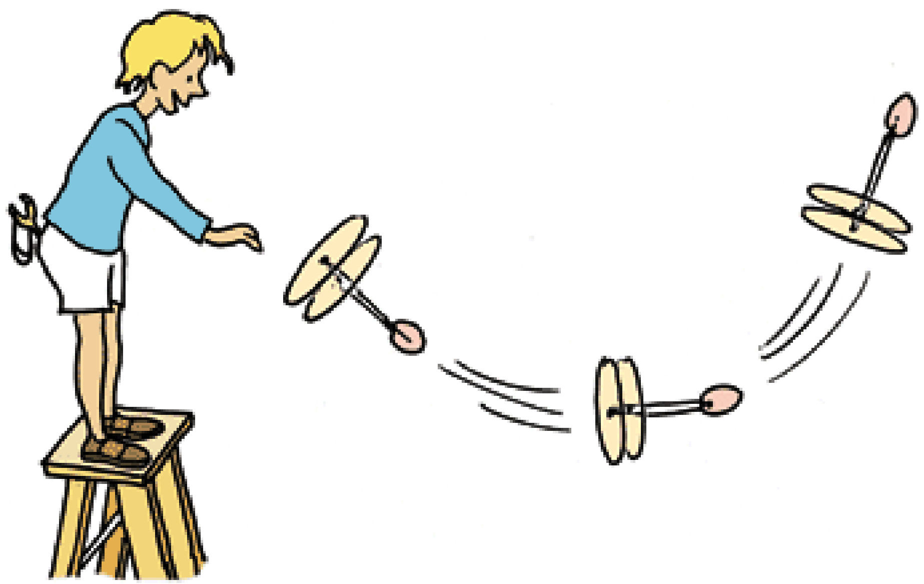
Roll a strip of paper around a big pin, add a bit of glue so as to make a small diameter tube.

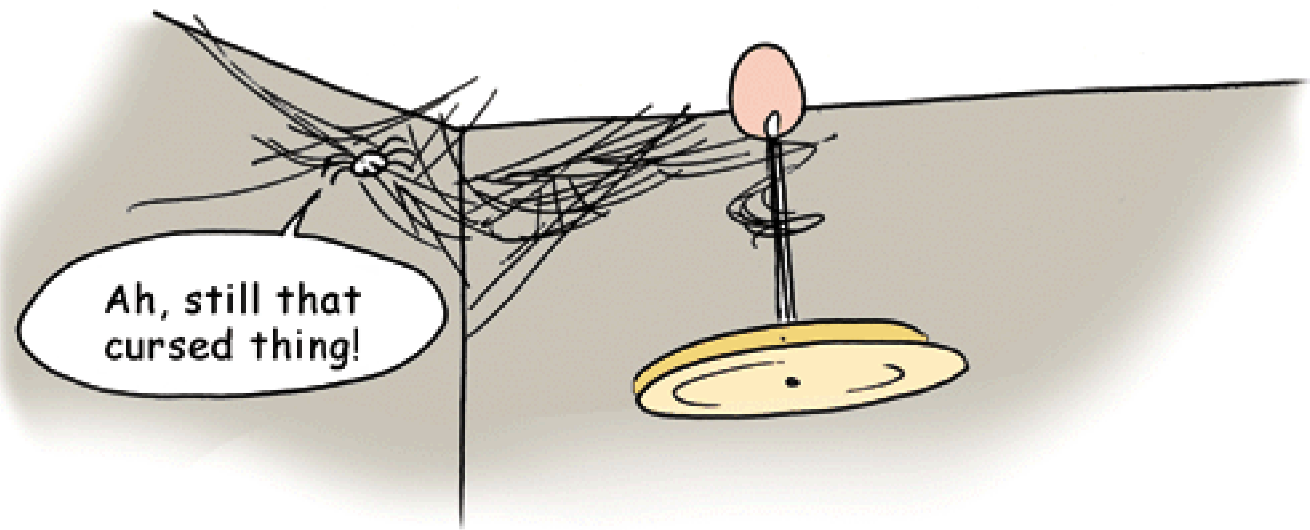


Proportions

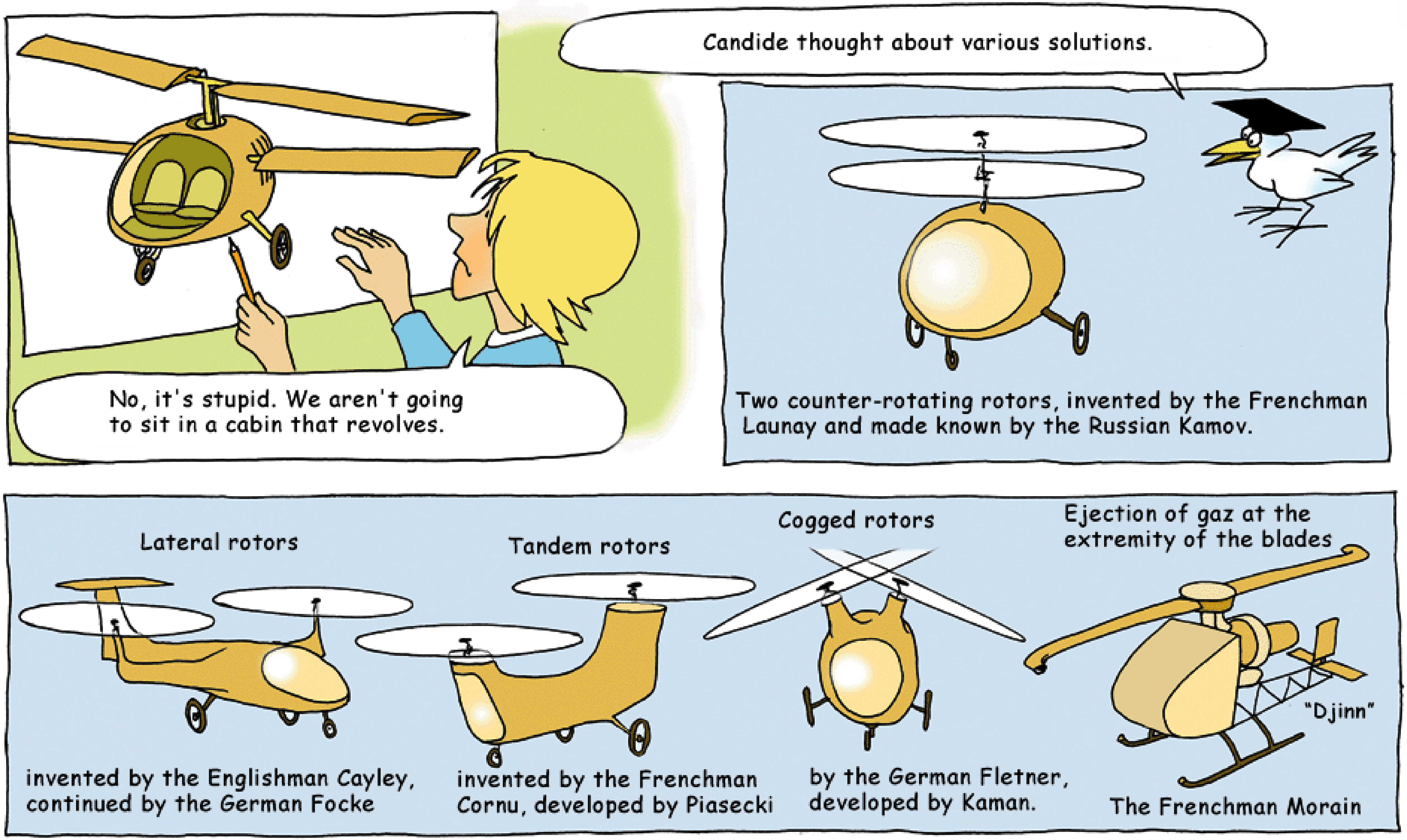


When the helicopter tilts it goes off to the side. The effort of the upper blade straightens it immediately. Left on its own, it goes up swaying from side to side (*)

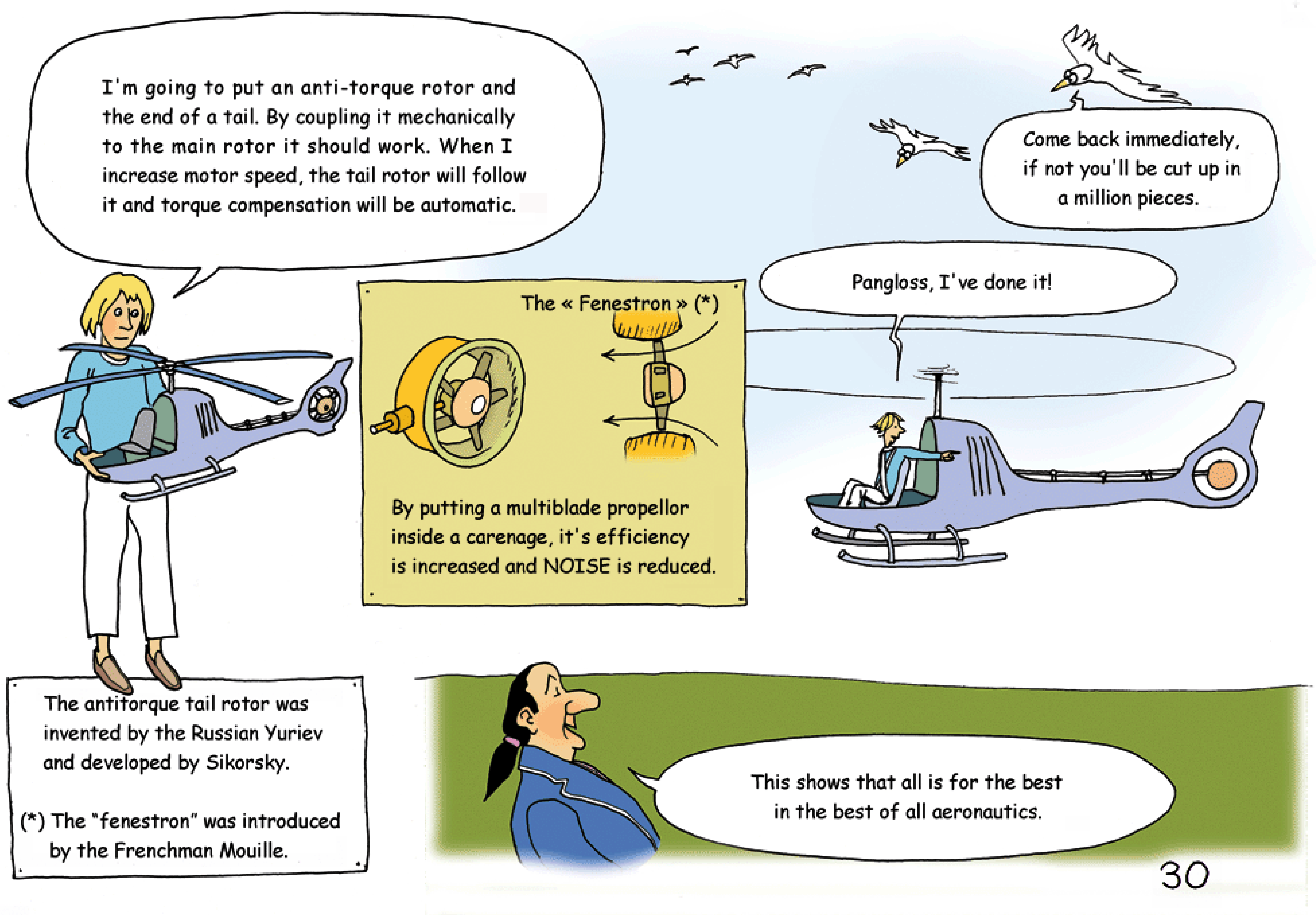




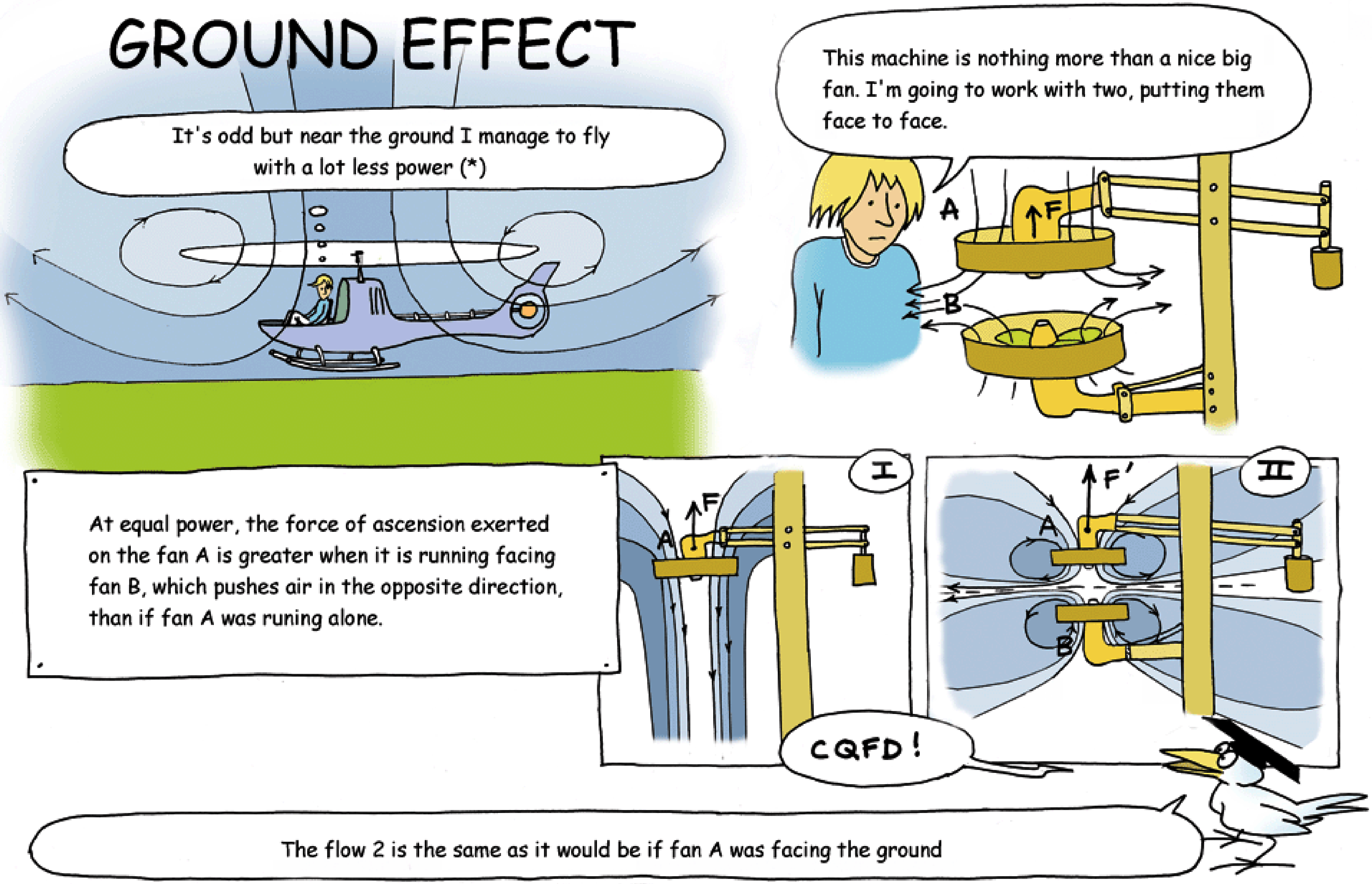
(*) When I was a child I used this to get rid of the spiders' webs on the ceiling of the Château de Thiors, in the Deux-Sevres (France).



Yves le Bec has written a book illustrated with fine drawings entitled « la véritable histoire de l'hélicoptère, de 1486 à 2005", published by Les Editions Jean Ducret S.A. CH-1022 Chavannes-près-Renens. ISBN 2-8399 -0100-5. In it you'll find all the types of helicopter imagined by man.

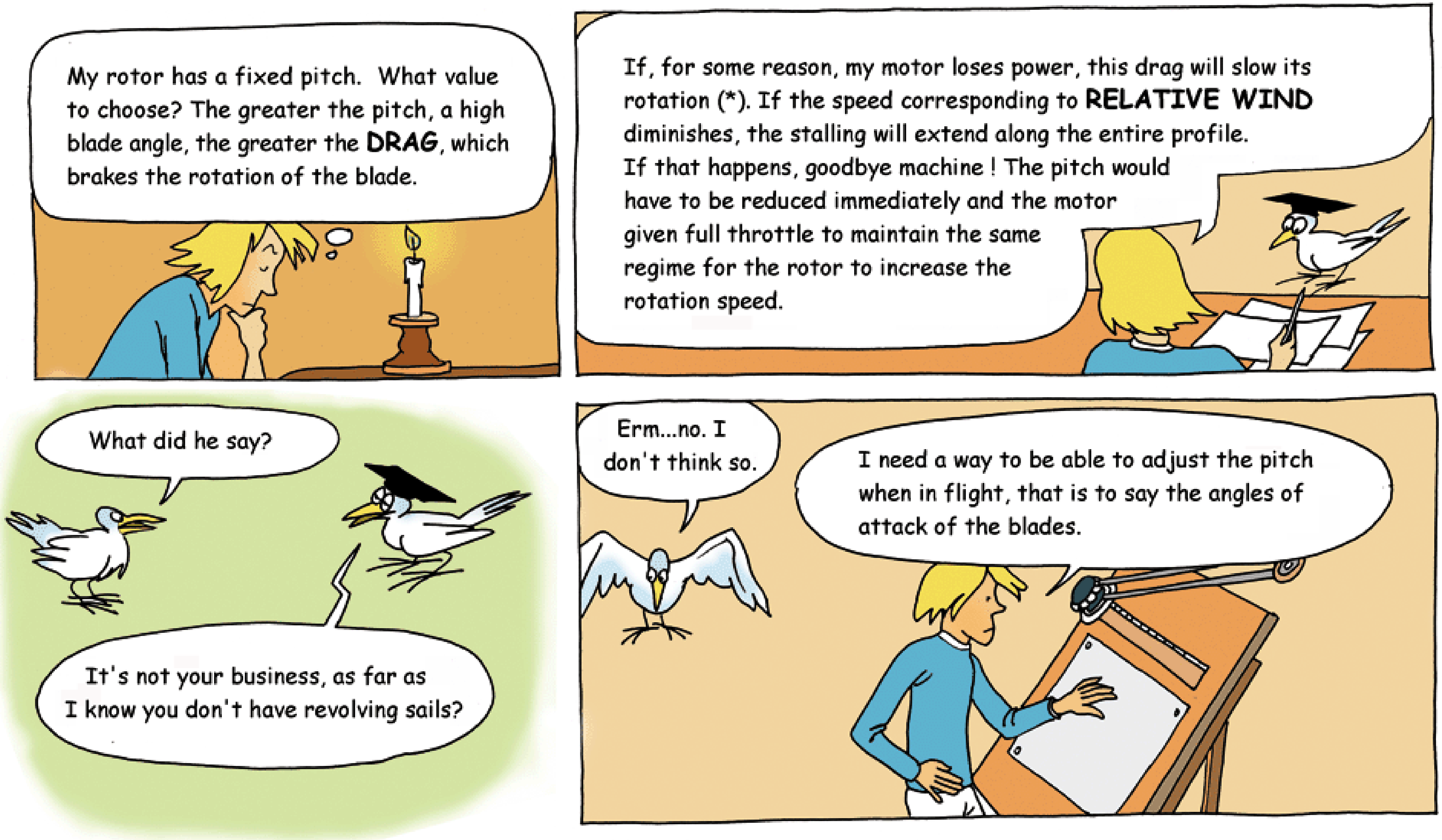


I'm going to put an anti-torque rotor and the end of a tail. By coupling it mechanically to the main rotor it should work. When I increase motor speed, the tail rotor will follow it and torque compensation will be automatic.
Come back immediately, if not you'll be cut up in a million pieces.
Pangloss, I've done it!
The « Fenestron » (*)
By putting a multiblade propellor inside a carenage, it's efficiency is increased and NOISE is reduced.
The antitorque tail rotor was invented by the Russian Yuriev and developed by Sikorsky.
(*) The "fenestron" was introduced by the Frenchman Mouille.
This shows that all is for the best in the best of all aeronautics.

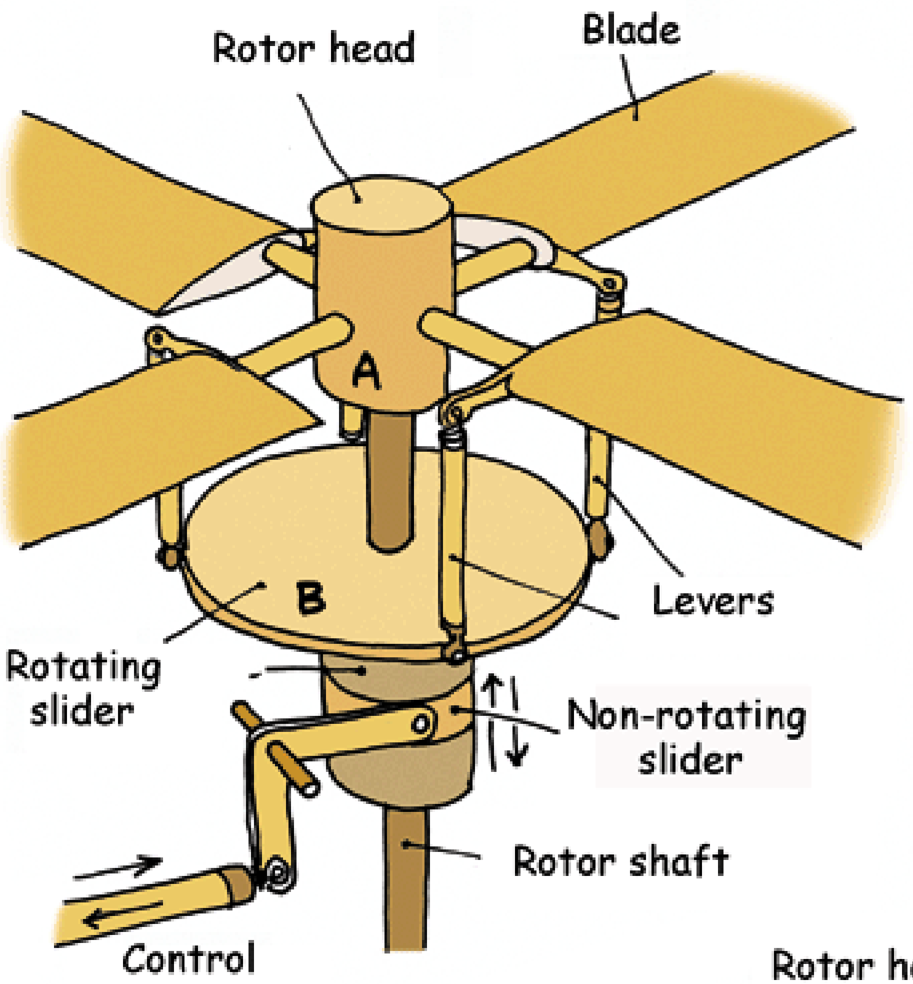


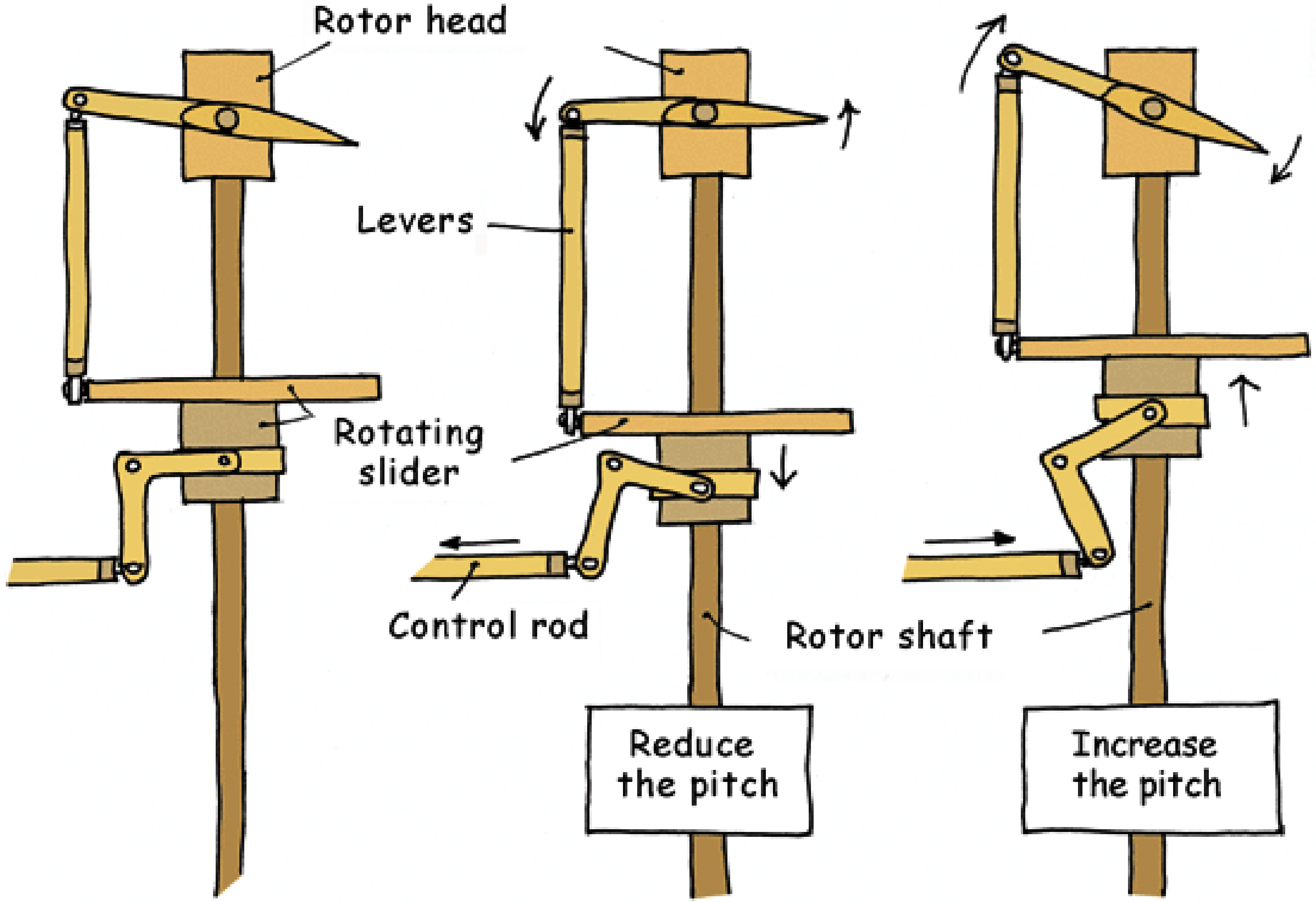
(*) The ground effect becomes important when the rotor is at a distance from the ground equal or inferior to half its diameter.

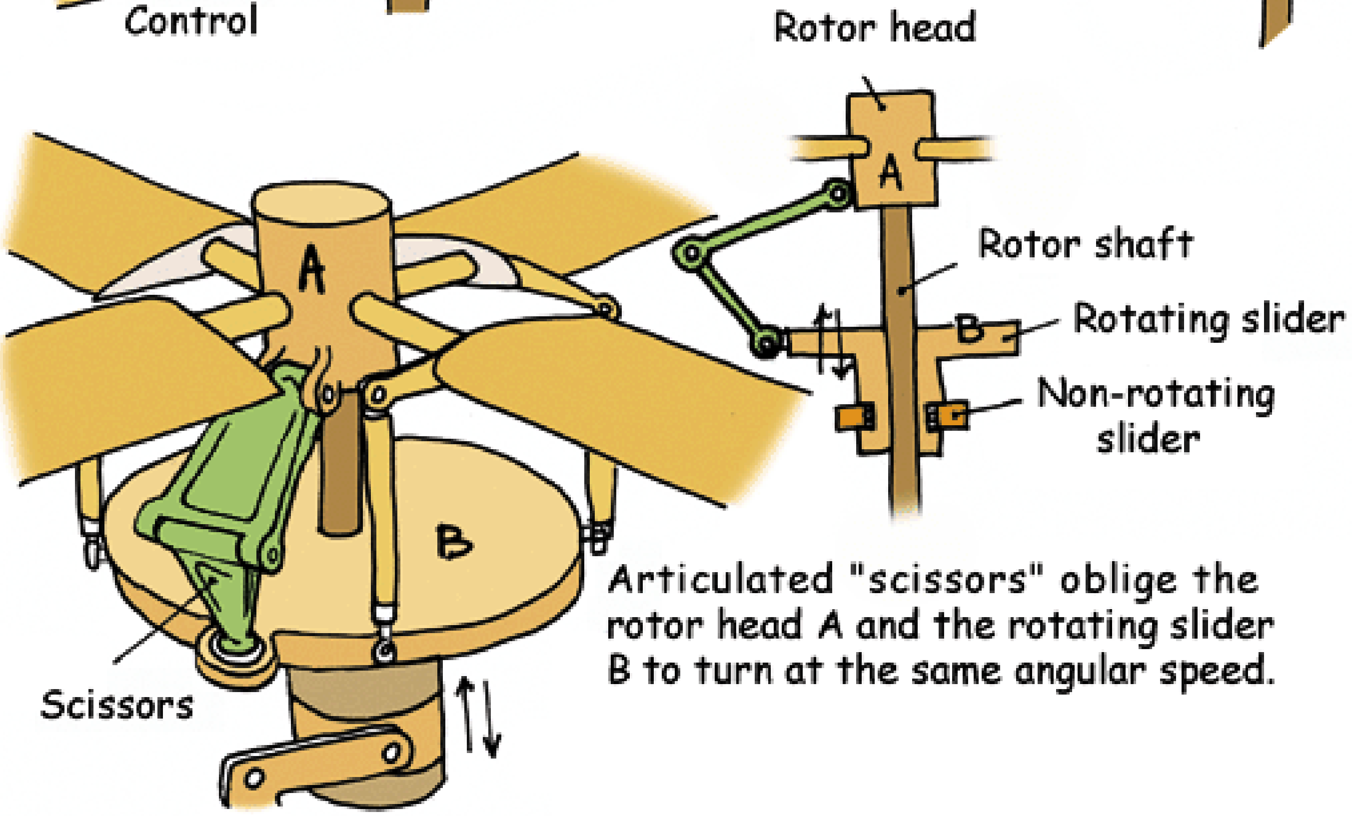
INCREASING RPM



(*) A rotor whose motor stopped suddenly would be dangerously slowed within...one second.



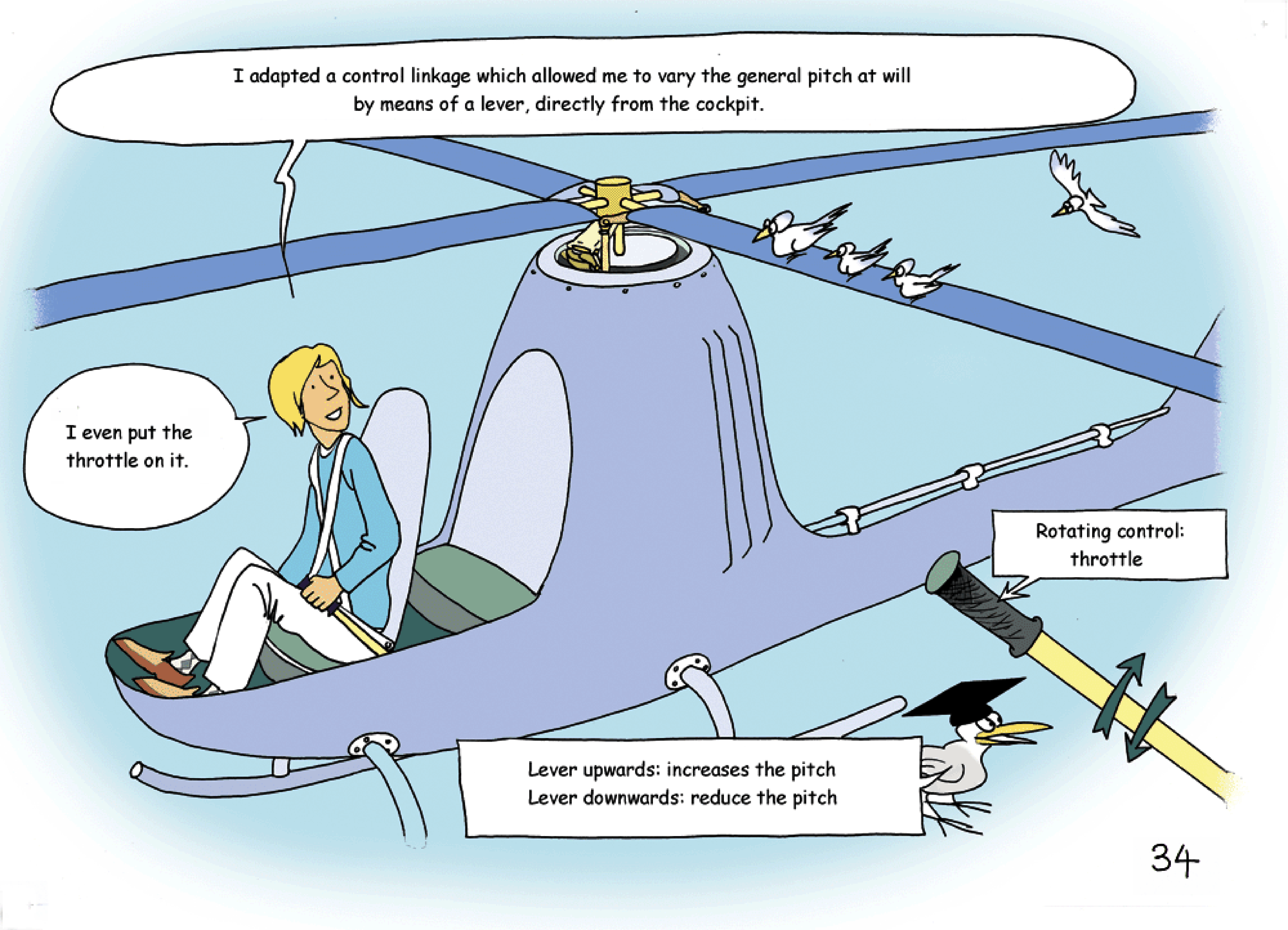


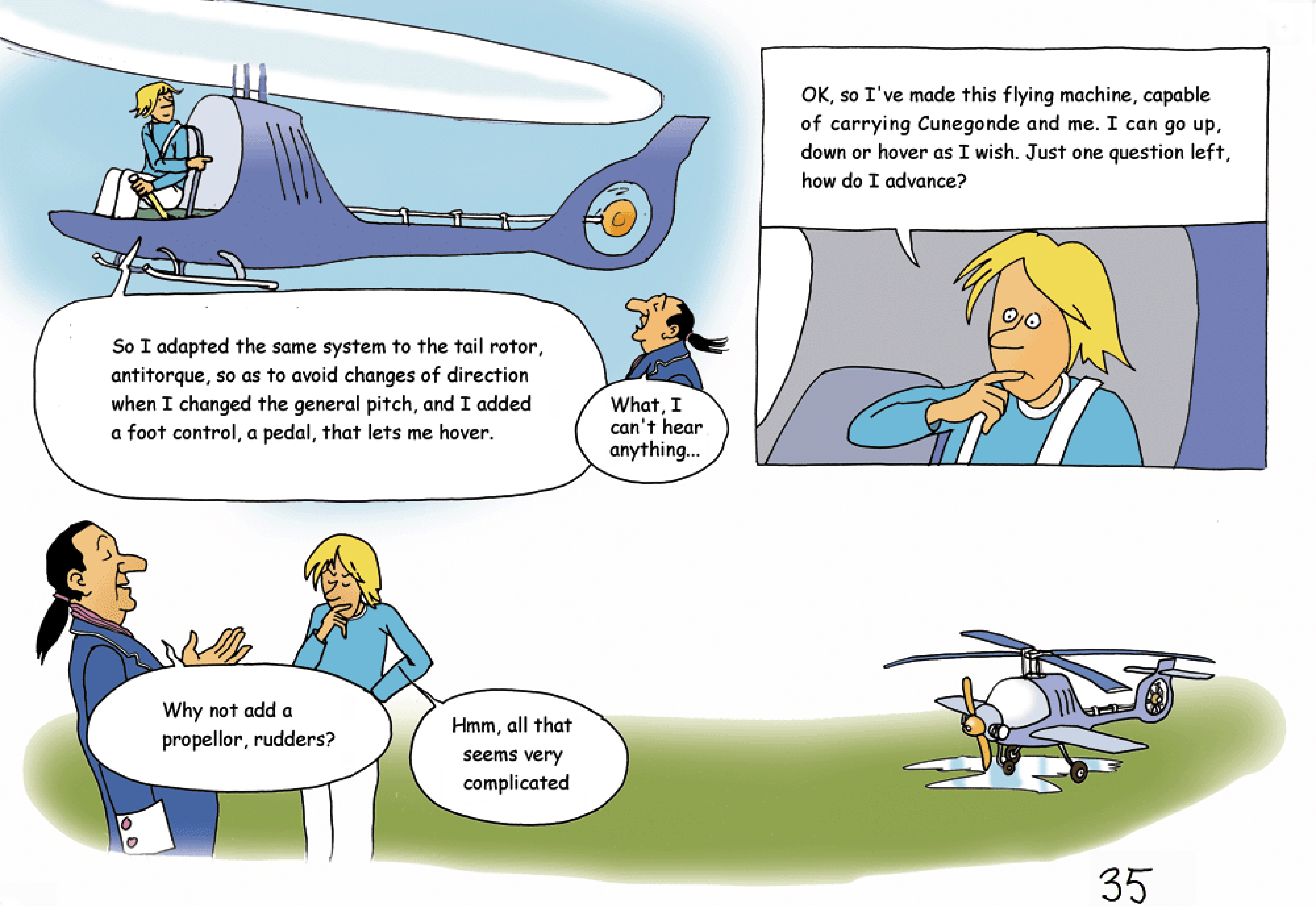


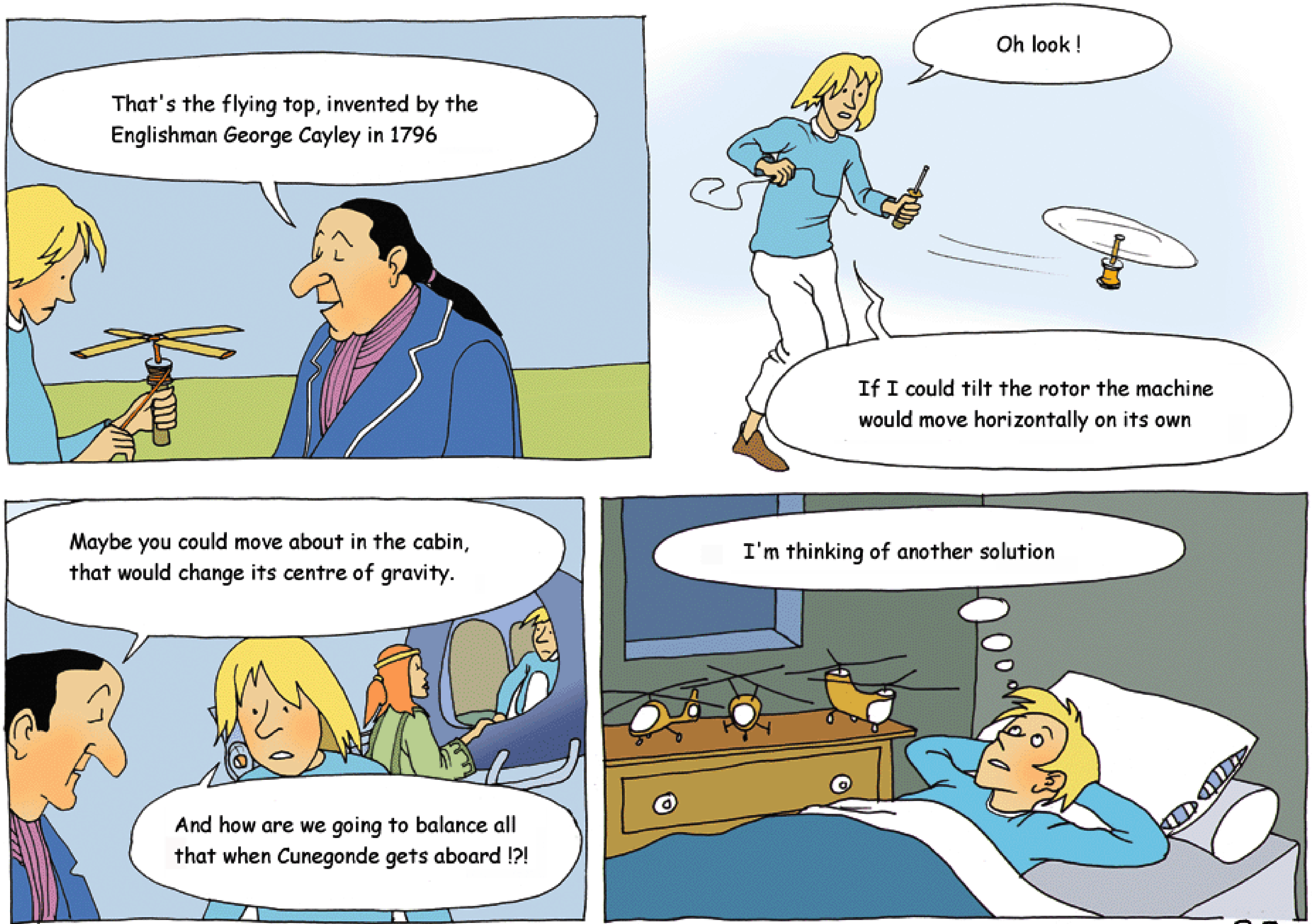
Articulated "scissors" oblige the rotor head A and the rotating slider B to turn at the same angular speed.

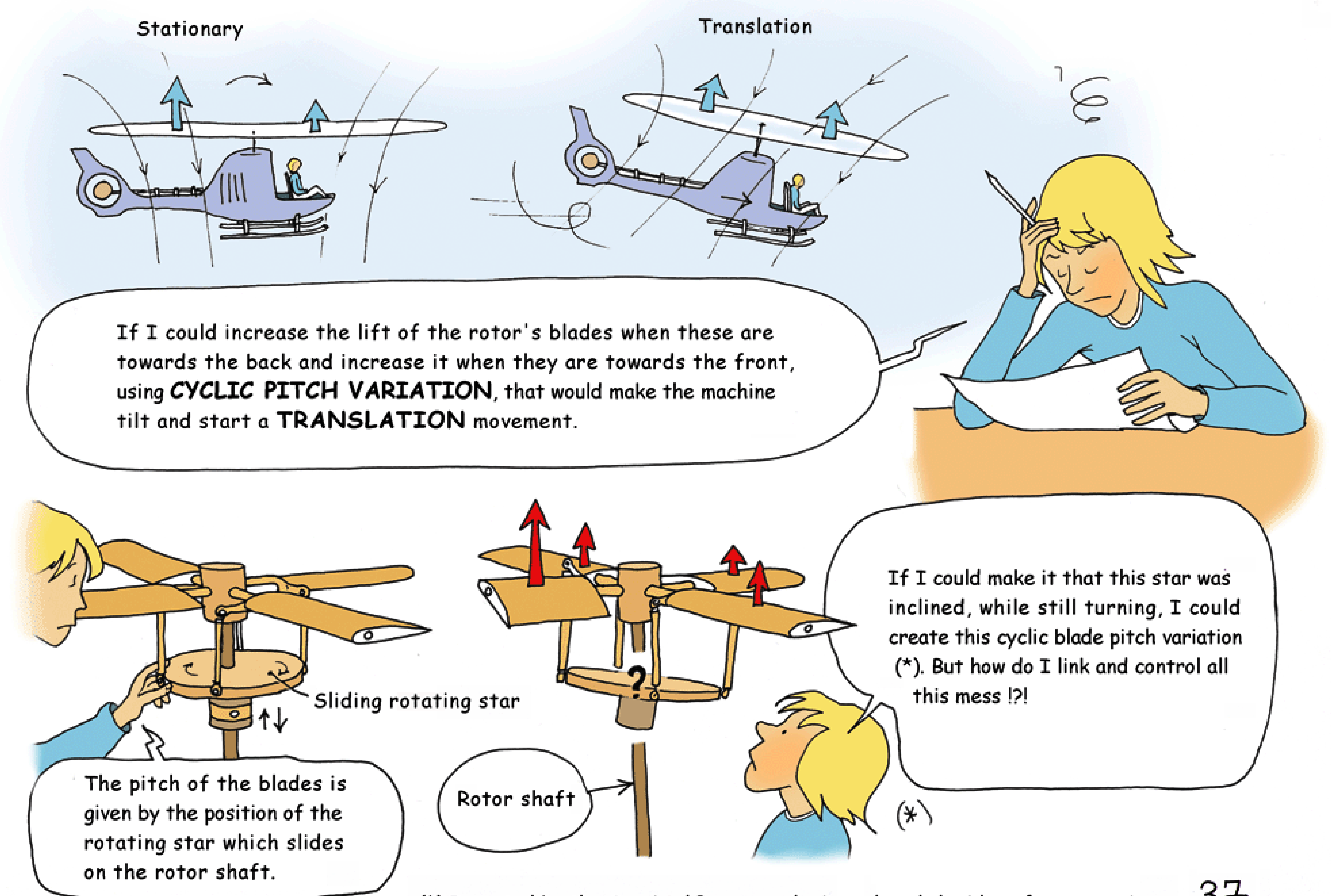
With such a system we can vary all the blades of a rotor at the same time by acting on the non rotating slider, linked via a ball-bearing and a rotating slider A, which retransmits the order to the blades via levers.

The Management.

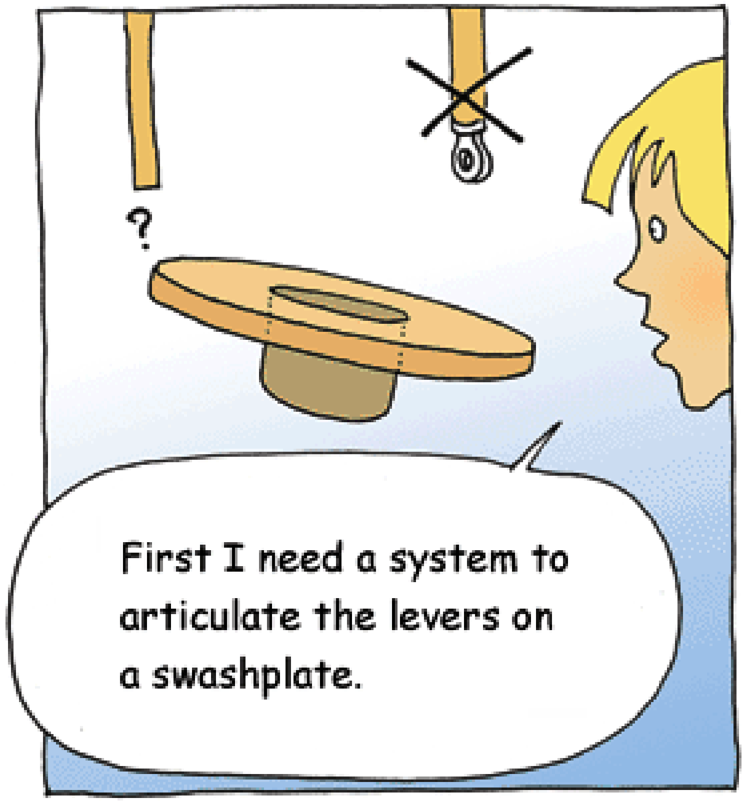

I adapted a control linkage which allowed me to vary the general pitch at will by means of a lever, directly from the cockpit.
I even put the throttle on it.
Rotating control: throttle
Lever upwards: increases the pitch
Lever downwards: reduce the pitch

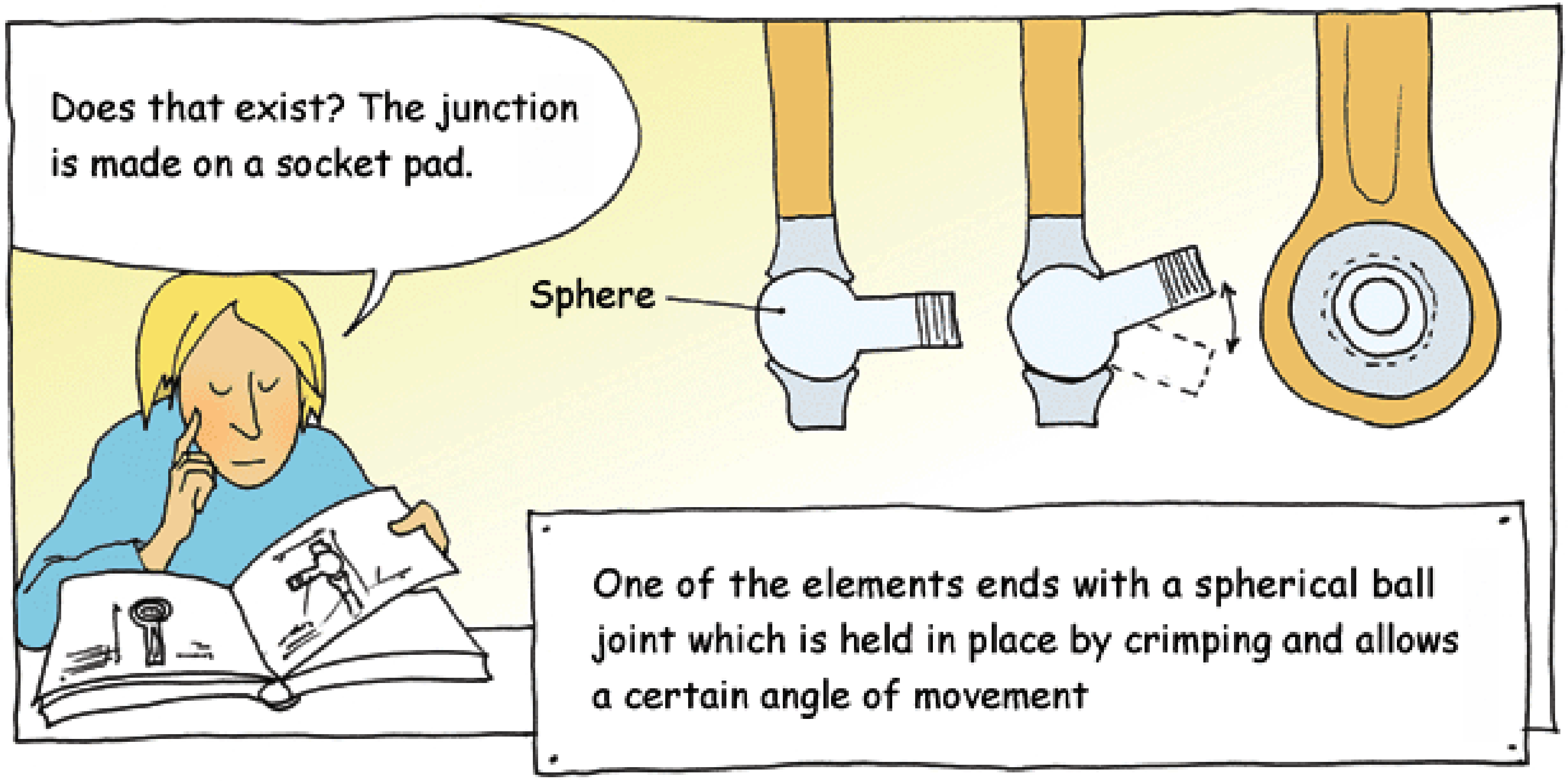

So I adapted the same system to the tail rotor, antitorque, so as to avoid changes of direction when I changed the general pitch, and I added a foot control, a pedal, that lets me hover.
What, I can't hear anything...
OK, so I've made this flying machine, capable of carrying Cunegonde and me. I can go up, down or hover as I wish. Just one question left, how do I advance?
Why not add a propellor, rudders?
Hmm, all that seems very complicated


That's the flying top, invented by the Englishman George Cayley in 1796
Oh look !
If I could tilt the rotor the machine would move horizontally on its own
Maybe you could move about in the cabin, that would change its centre of gravity.
And how are we going to balance all that when Cunegonde gets aboard !?!
I'm thinking of another solution

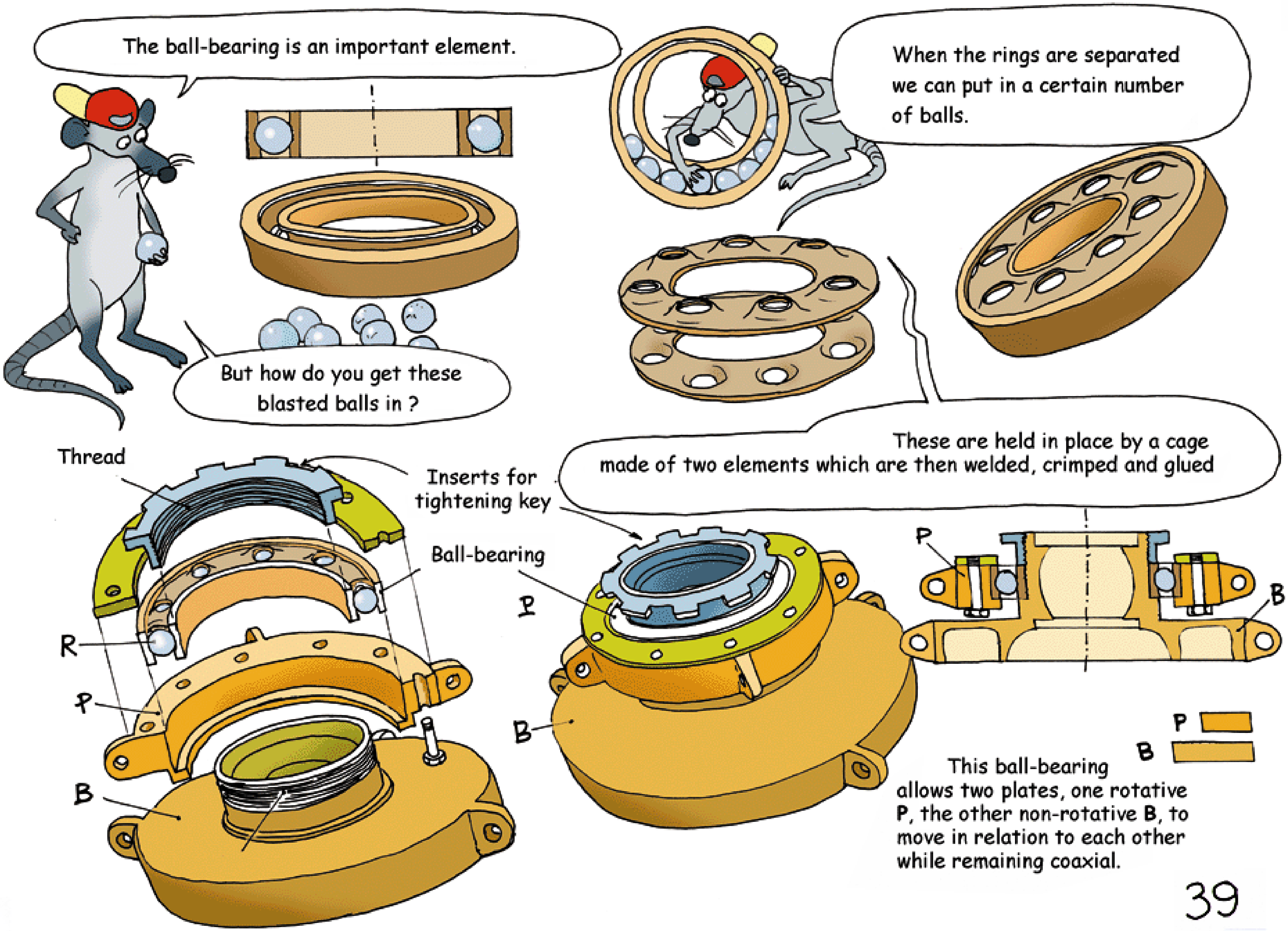


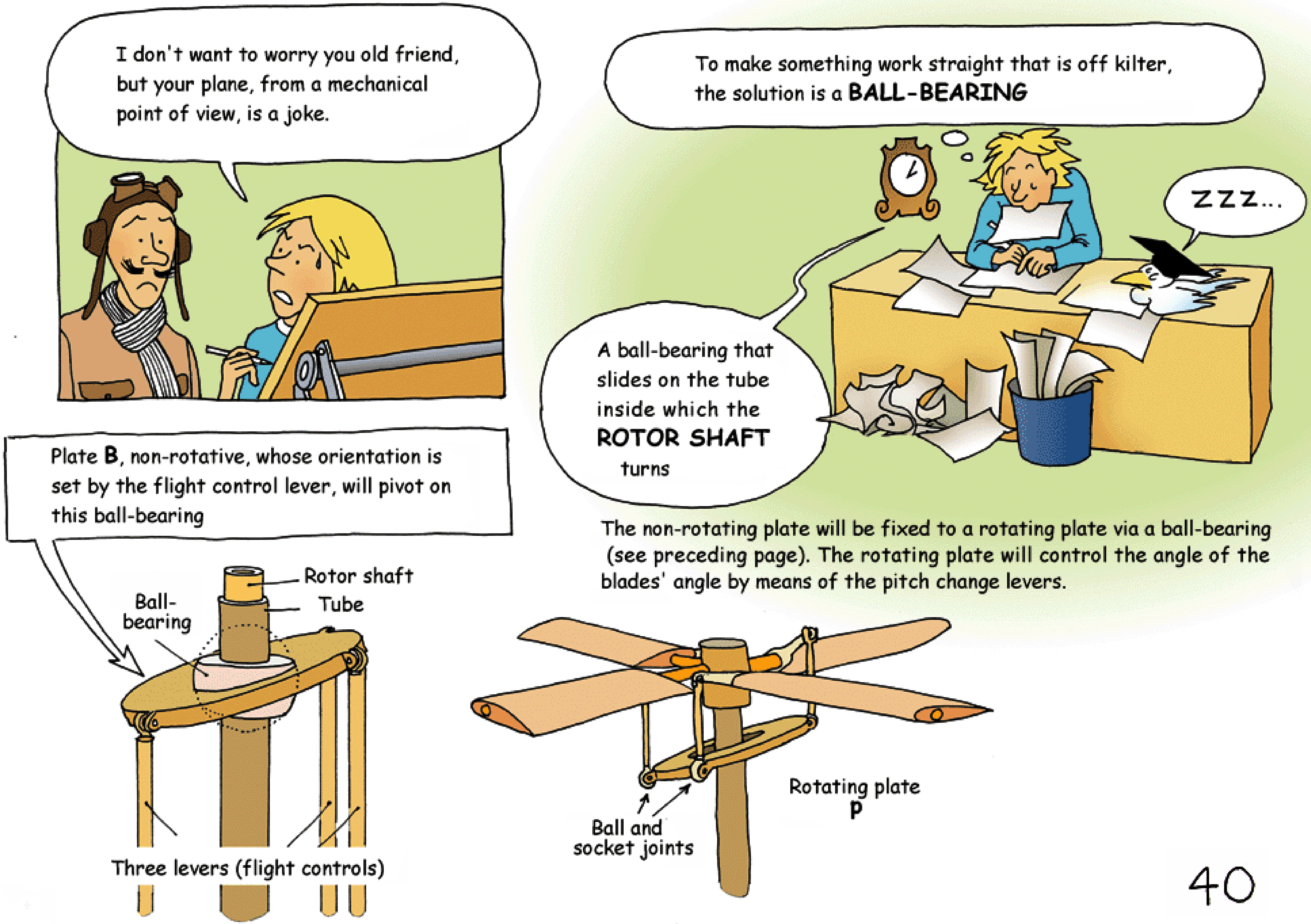
(*) Invented by the Spaniard Pescara, who introduced the idea of autorotation.

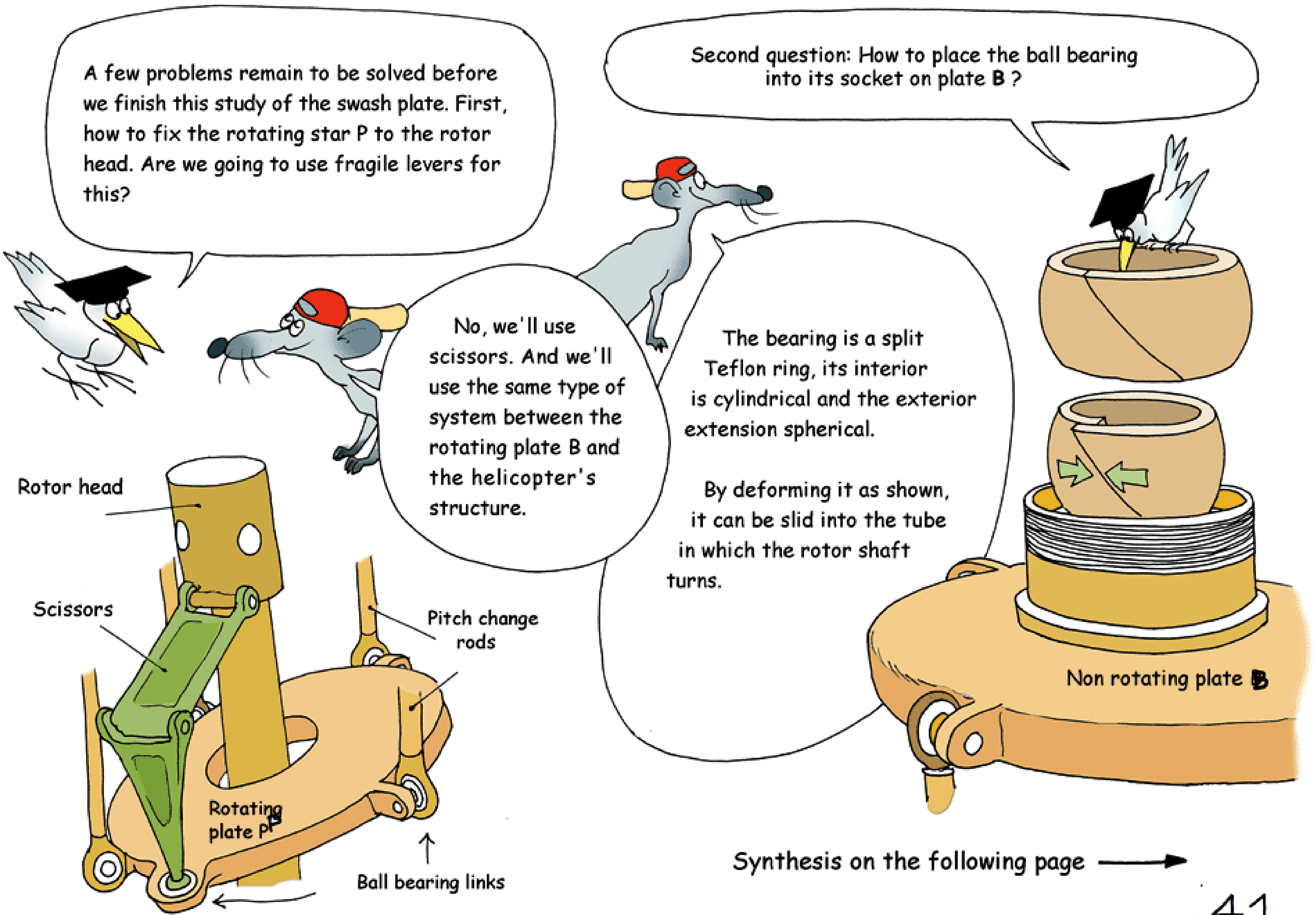




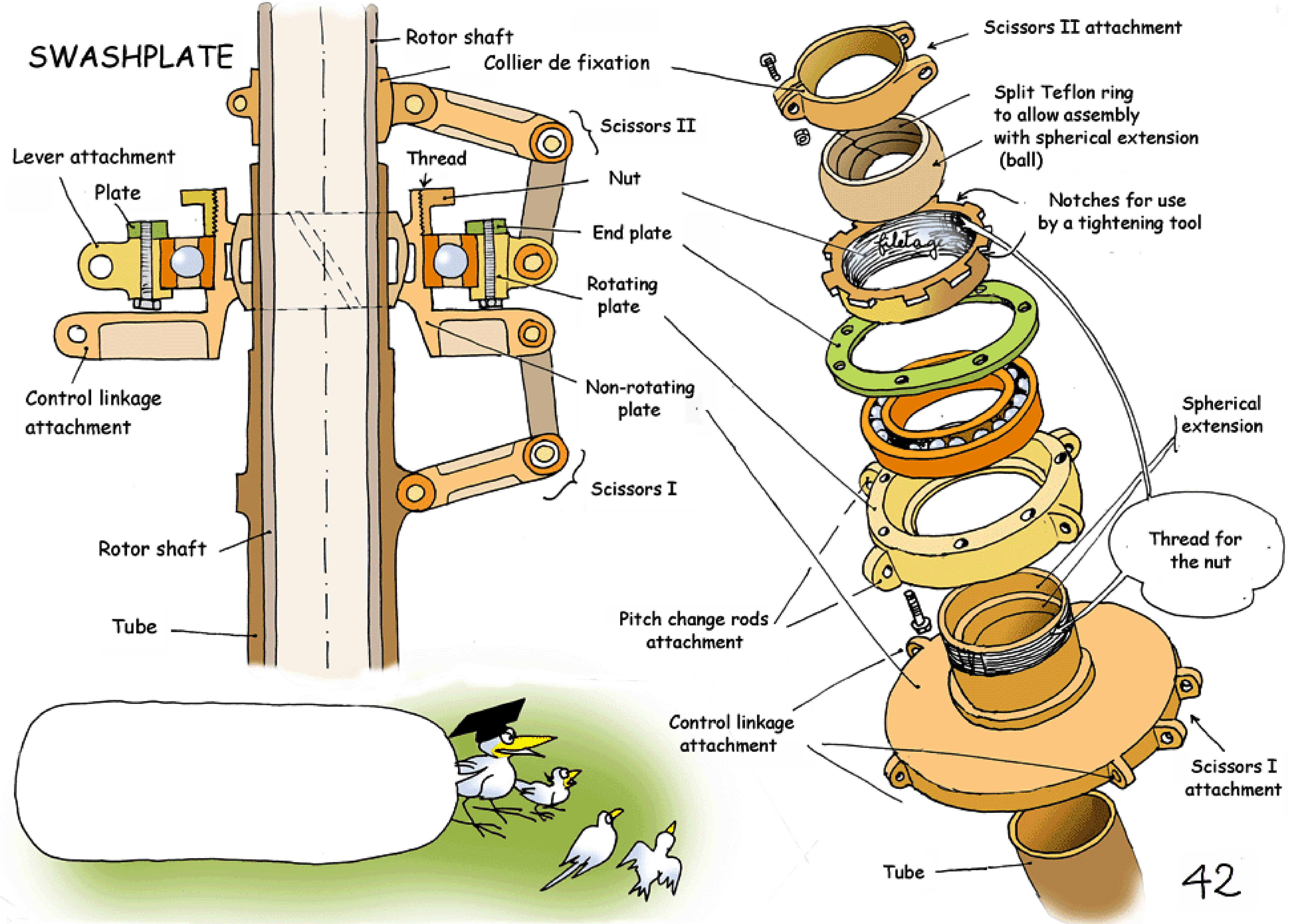
The life of a helicopter pilot hangs on a complex mechanical system bringing into play a set of levers of this type, cogwheels, ball-bearings. All these elements must be machined to the highest precision. Construction and maintenance costs are higher than for a plane. Since the 70s, new materials have been used, composites, elastomers and self-lubricating components, which have helped reduce their complexity, weight, construction costs and the maintenance schedule while improving reliability. But this is outside the scope of this book.


The ball-bearing is an important element.
But how do you get these blasted balls in ?
When the rings are separated we can put in a certain number of balls.
These are held in place by a cage made of two elements which are then welded, crimped and glued
Thread
Inserts for tightening key
Ball-bearing
R
P
B
P
B
P
B
P
B
This ball-bearing allows two plates, one rotative **P**, the other non-rotative **B**, to move in relation to each other while remaining coaxial.

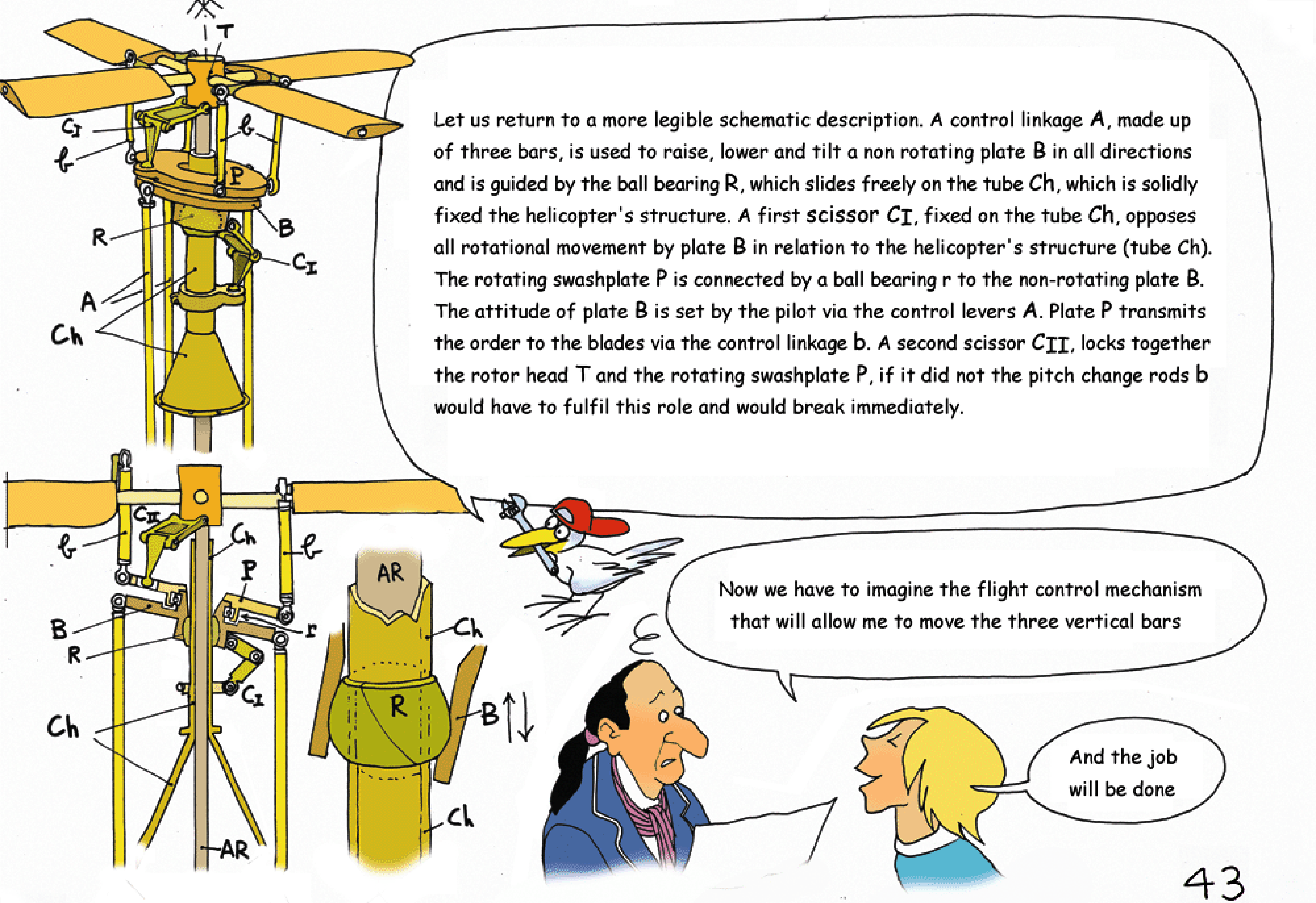

I don't want to worry you old friend, but your plane, from a mechanical point of view, is a joke.
To make something work straight that is off kilter, the solution is a BALL-BEARING
ZZZ...
A ball-bearing that slides on the tube inside which the ROTOR SHAFT turns
Plate B, non-rotative, whose orientation is set by the flight control lever, will pivot on this ball-bearing
Rotor shaft
Tube
Ball-bearing
Three levers (flight controls)
The non-rotating plate will be fixed to a rotating plate via a ball-bearing (see preceding page). The rotating plate will control the angle of the blades' angle by means of the pitch change levers.
Rotating plate P
Ball and socket joints

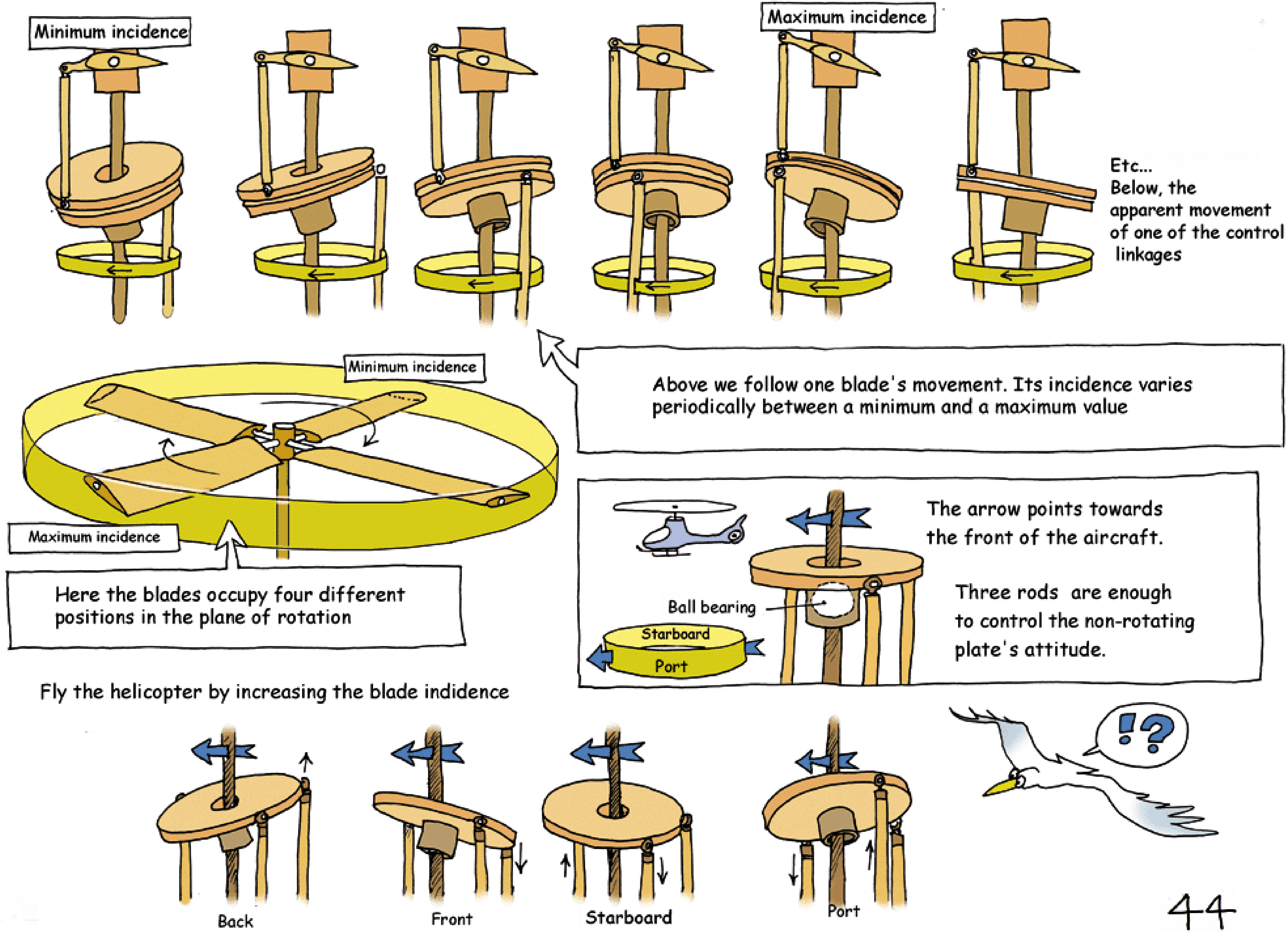

A few problems remain to be solved before we finish this study of the swash plate. First, how to fix the rotating star P to the rotor head. Are we going to use fragile levers for this?
No, we'll use scissors. And we'll use the same type of system between the rotating plate B and the helicopter's structure.
Rotor head
Scissors
Pitch change rods
Rotating plate P
Ball bearing links
Second question: How to place the ball bearing into its socket on plate B ?
The bearing is a split Teflon ring, its interior is cylindrical and the exterior extension spherical.
By deforming it as shown, it can be slid into the tube in which the rotor shaft turns.
Non rotating plate B
Synthesis on the following page

SWASHPLATE

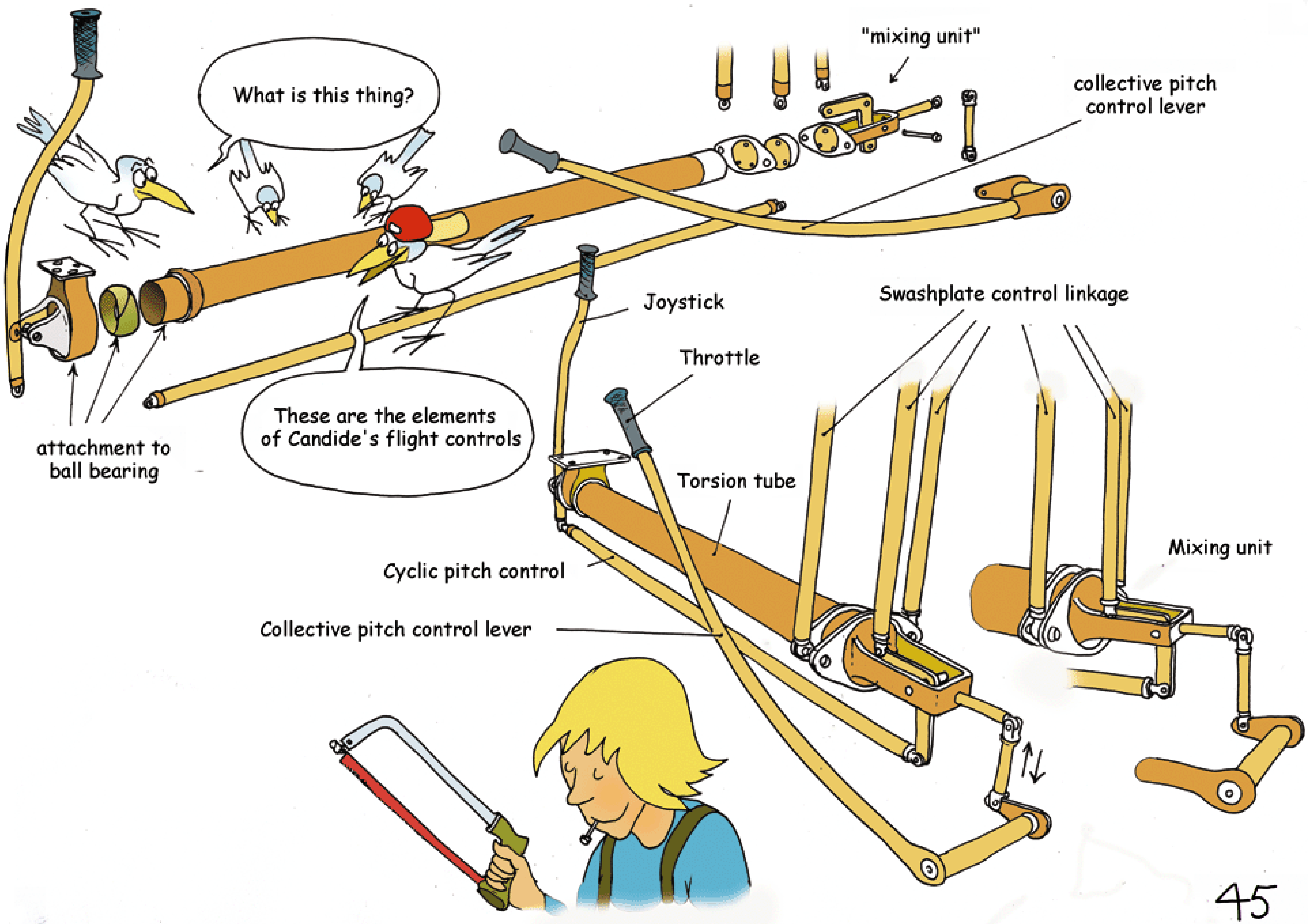


Rotor shaft
Collier de fixation
Scissors II
Lever attachment
Plate
Thread
Nut
End plate
Rotating plate
Non-rotating plate
Control linkage attachment
Scissors I
Rotor shaft
Tube
Scissors II attachment
Split Teflon ring to allow assembly with spherical extension (ball)
Notches for use by a tightening tool
Spherical extension
Thread for the nut
Pitch change rods attachment
Control linkage attachment
Scissors I attachment
Tube

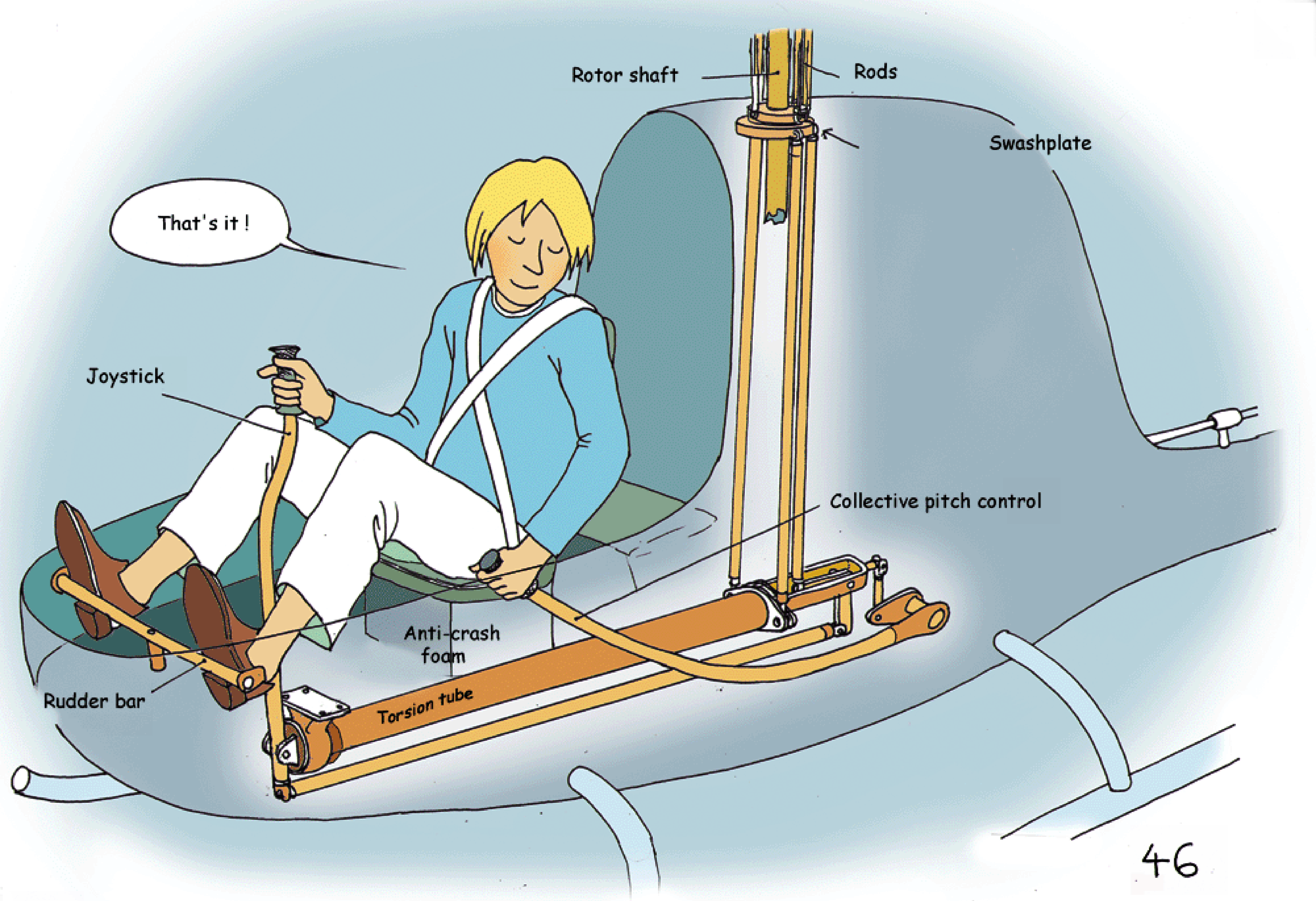

Let us return to a more legible schematic description. A control linkage A, made up of three bars, is used to raise, lower and tilt a non rotating plate B in all directions and is guided by the ball bearing R, which slides freely on the tube Ch, which is solidly fixed the helicopter's structure. A first scissor C_I, fixed on the tube Ch, opposes all rotational movement by plate B in relation to the helicopter's structure (tube Ch). The rotating swashplate P is connected by a ball bearing r to the non-rotating plate B. The attitude of plate B is set by the pilot via the control levers A. Plate P transmits the order to the blades via the control linkage b. A second scissor C_{II}, locks together the rotor head T and the rotating swashplate P, if it did not the pitch change rods b would have to fulfil this role and would break immediately.
Now we have to imagine the flight control mechanism that will allow me to move the three vertical bars
And the job will be done
T
C_I
b
P
B
R
A
Ch
C_{II}
r
AR

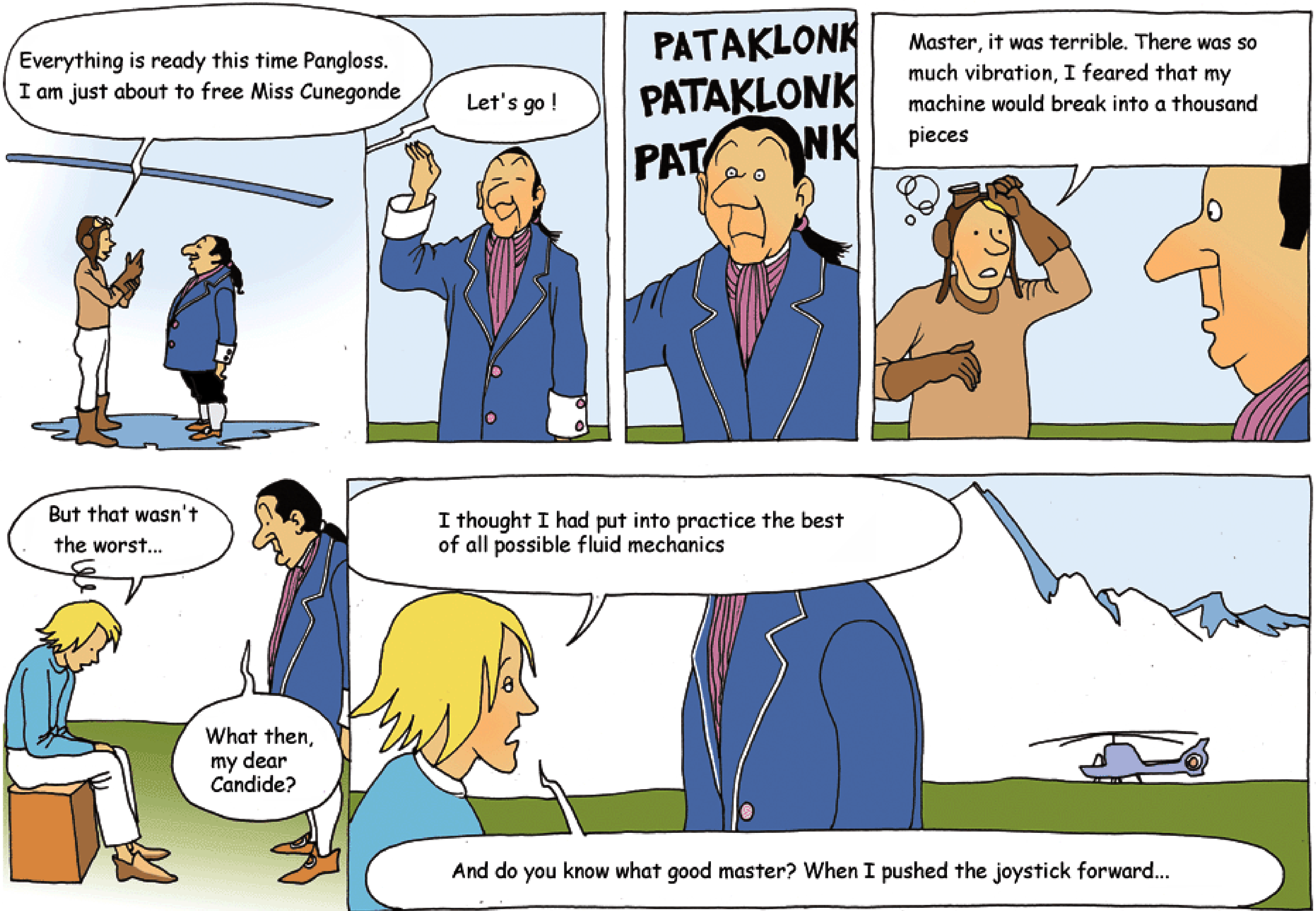


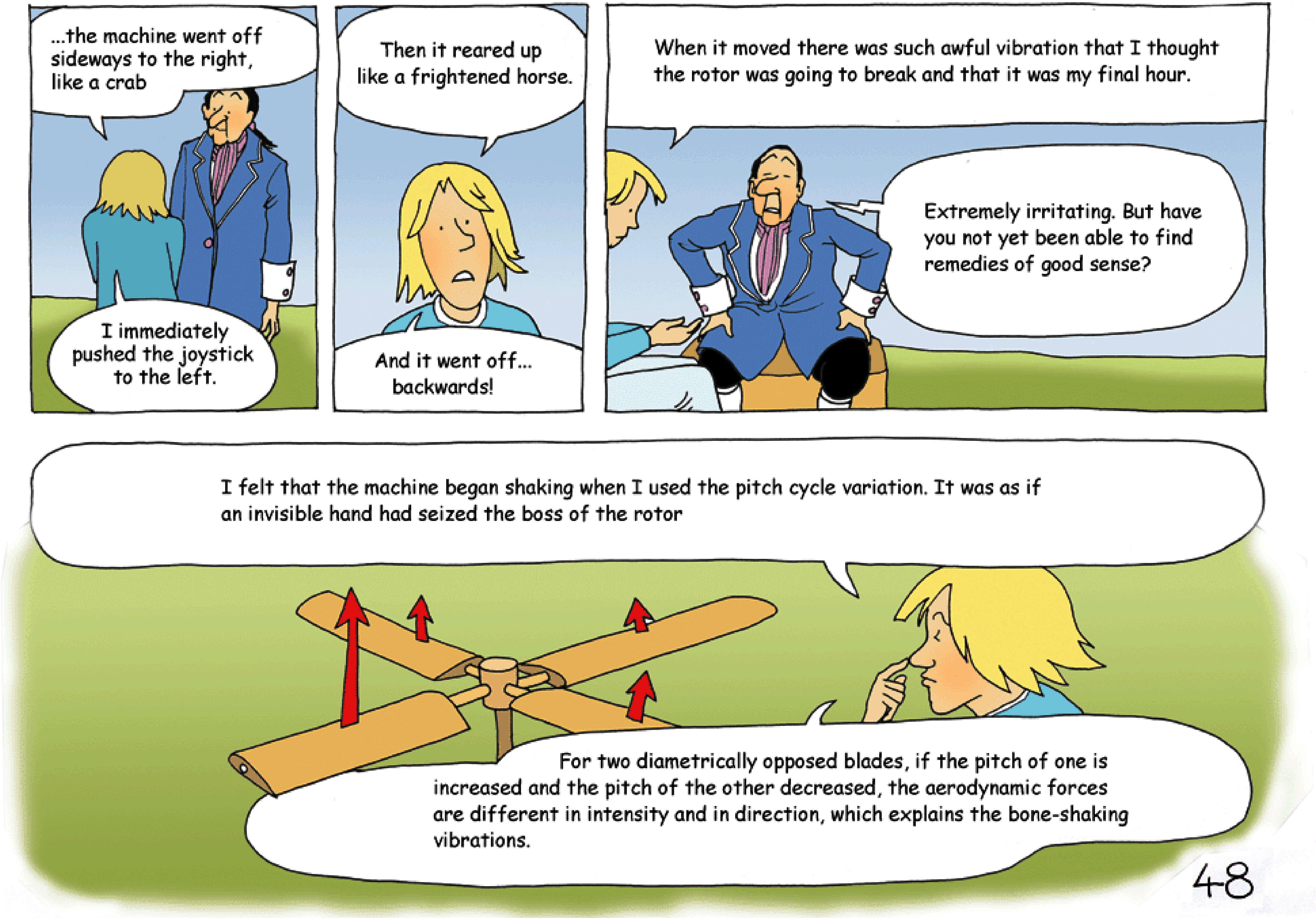
Minimum incidence
Maximum incidence
Etc...
Below, the apparent movement of one of the control linkages
Minimum incidence
Maximum incidence
Above we follow one blade's movement. Its incidence varies periodically between a minimum and a maximum value
Here the blades occupy four different positions in the plane of rotation
The arrow points towards the front of the aircraft.
Ball bearing
Starboard
Port
Three rods are enough to control the non-rotating plate's attitude.
Fly the helicopter by increasing the blade indidence
!?
Back
Front
Starboard
Port

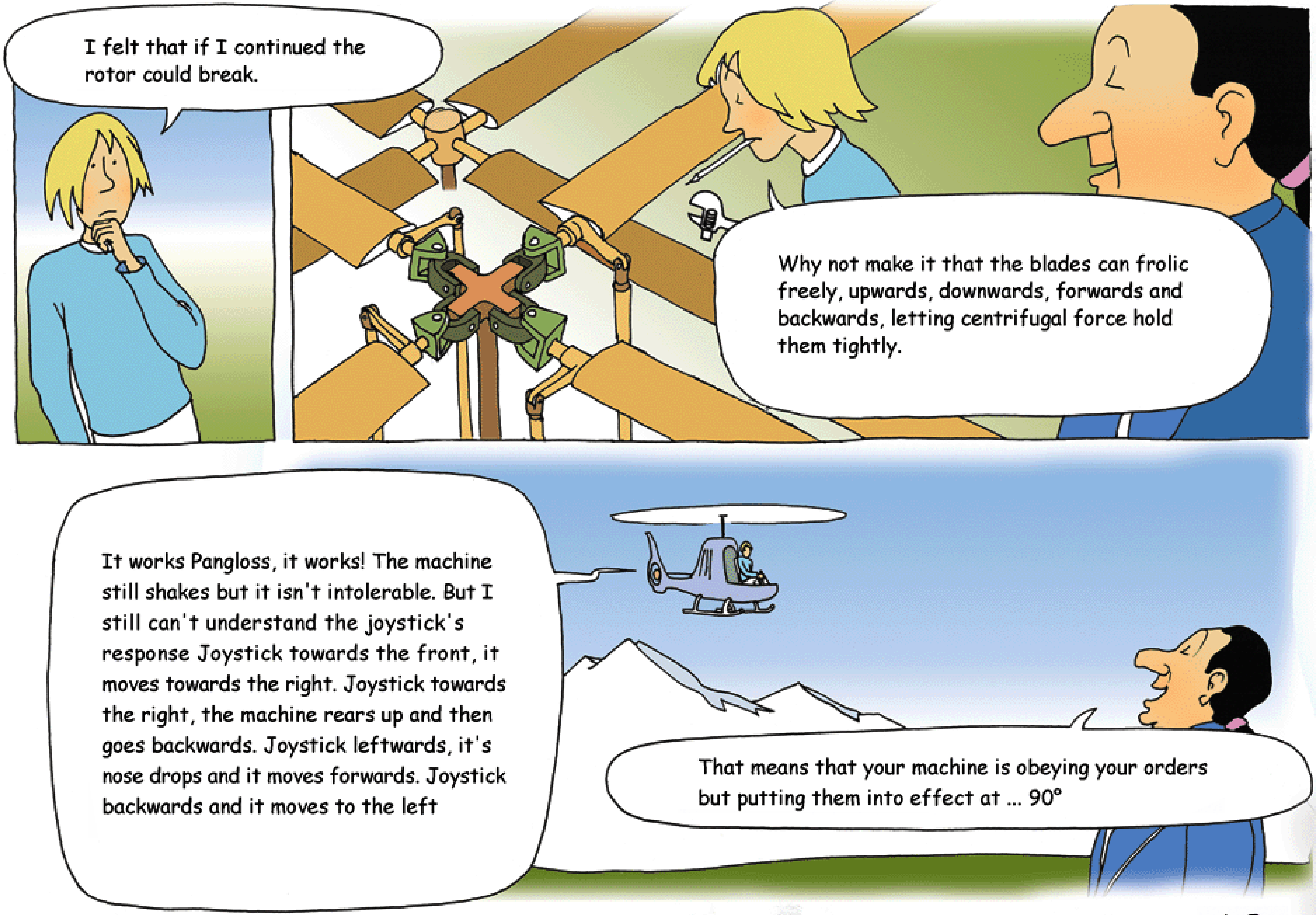


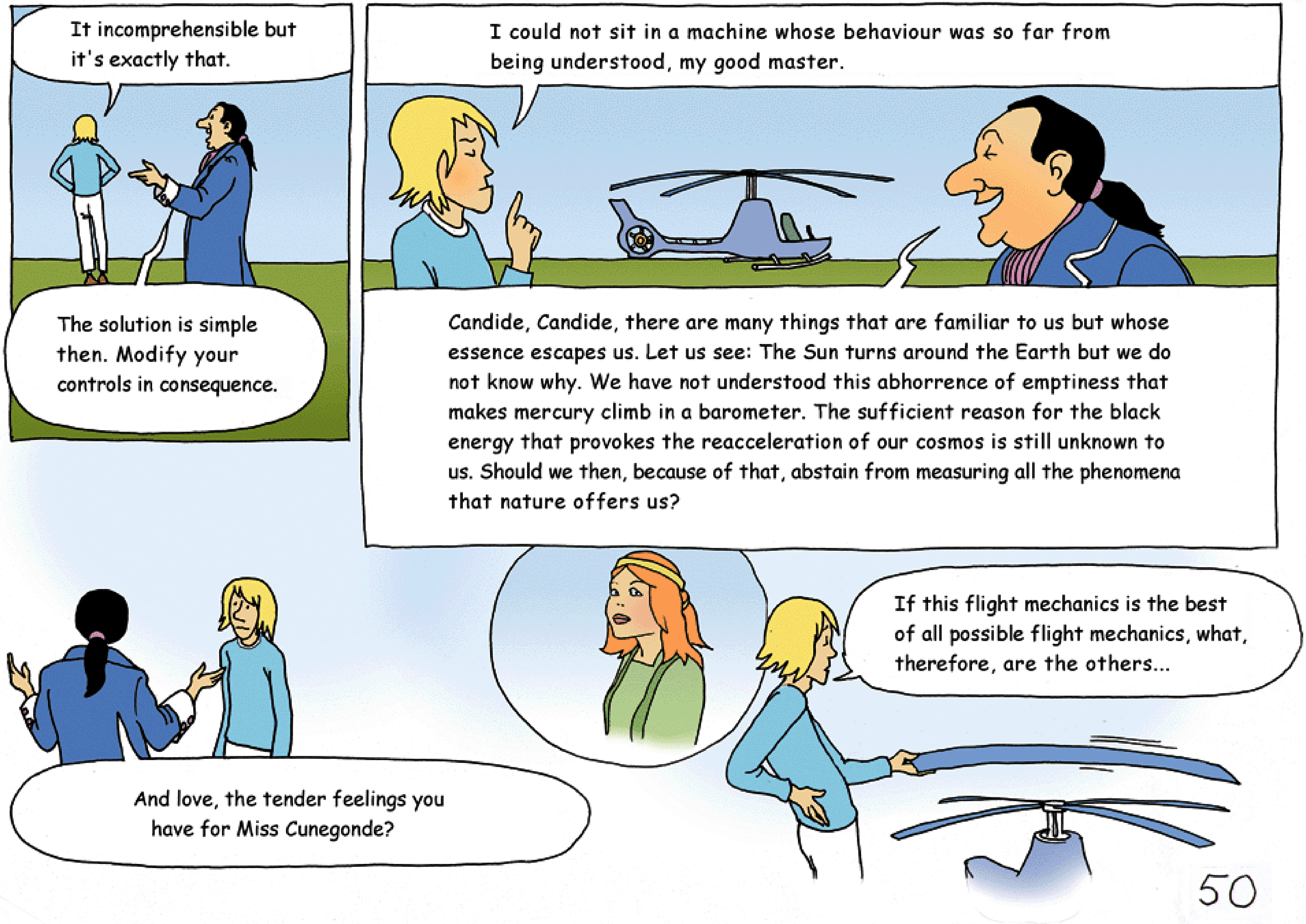
What is this thing?
"mixing unit"
collective pitch control lever
attachment to ball bearing
These are the elements of Candide's flight controls
Joystick
Swashplate control linkage
Throttle
Torsion tube
Mixing unit
Cyclic pitch control
Collective pitch control lever


Rotor shaft
Rods
Swashplate
That's it !
Joystick
Collective pitch control
Anti-crash foam
Rudder bar
Torsion tube


Everything is ready this time Pangloss. I am just about to free Miss Cunegonde
Let's go !
PATAKLONK
PATAKLONK
PAT NK
Master, it was terrible. There was so much vibration, I feared that my machine would break into a thousand pieces
But that wasn't the worst...
What then, my dear Candide?
I thought I had put into practice the best of all possible fluid mechanics
And do you know what good master? When I pushed the joystick forward...

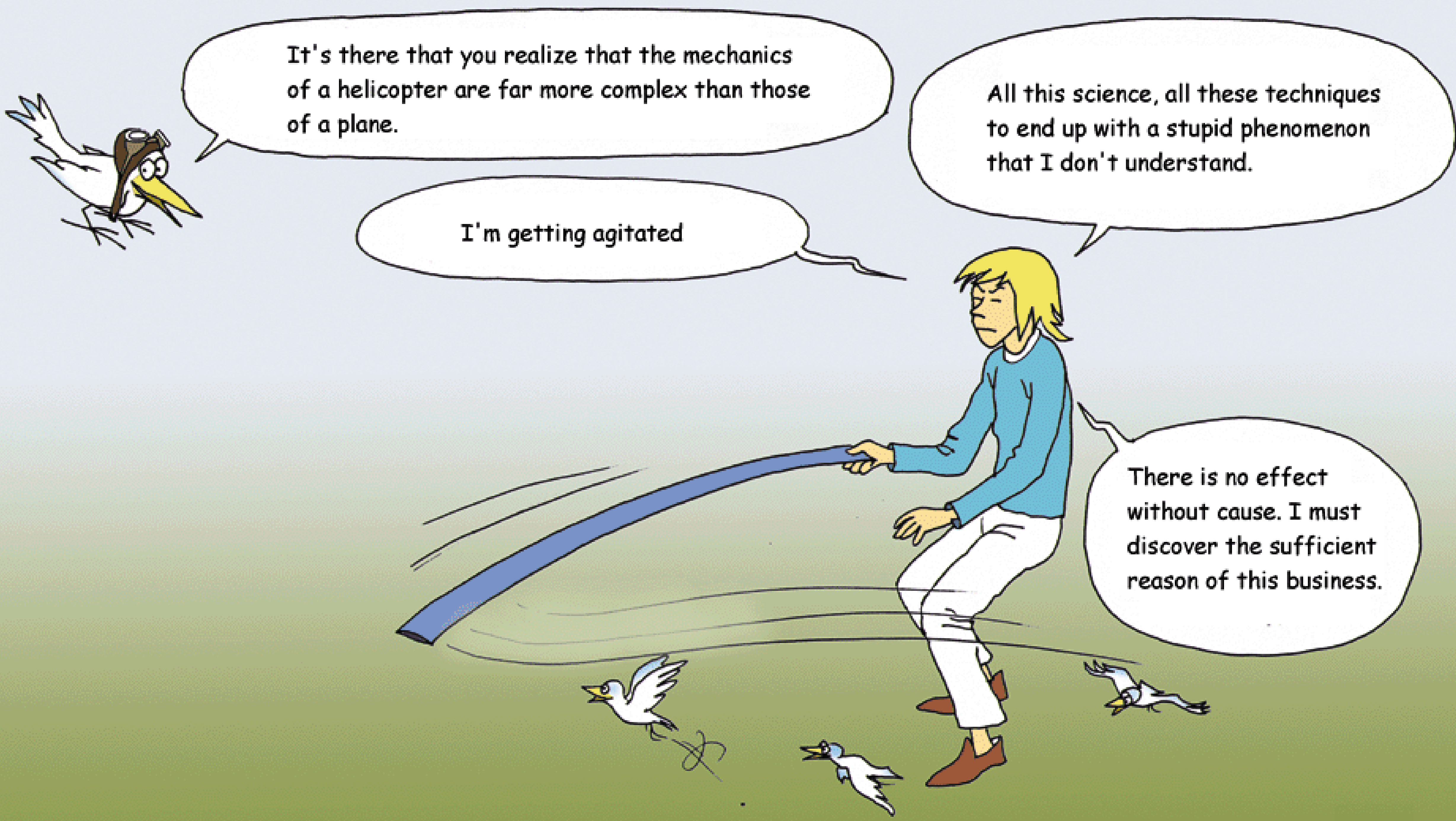

...the machine went off sideways to the right, like a crab
I immediately pushed the joystick to the left.
Then it reared up like a frightened horse.
And it went off... backwards!
When it moved there was such awful vibration that I thought the rotor was going to break and that it was my final hour.
Extremely irritating. But have you not yet been able to find remedies of good sense?
I felt that the machine began shaking when I used the pitch cycle variation. It was as if an invisible hand had seized the boss of the rotor
For two diametrically opposed blades, if the pitch of one is increased and the pitch of the other decreased, the aerodynamic forces are different in intensity and in direction, which explains the bone-shaking vibrations.

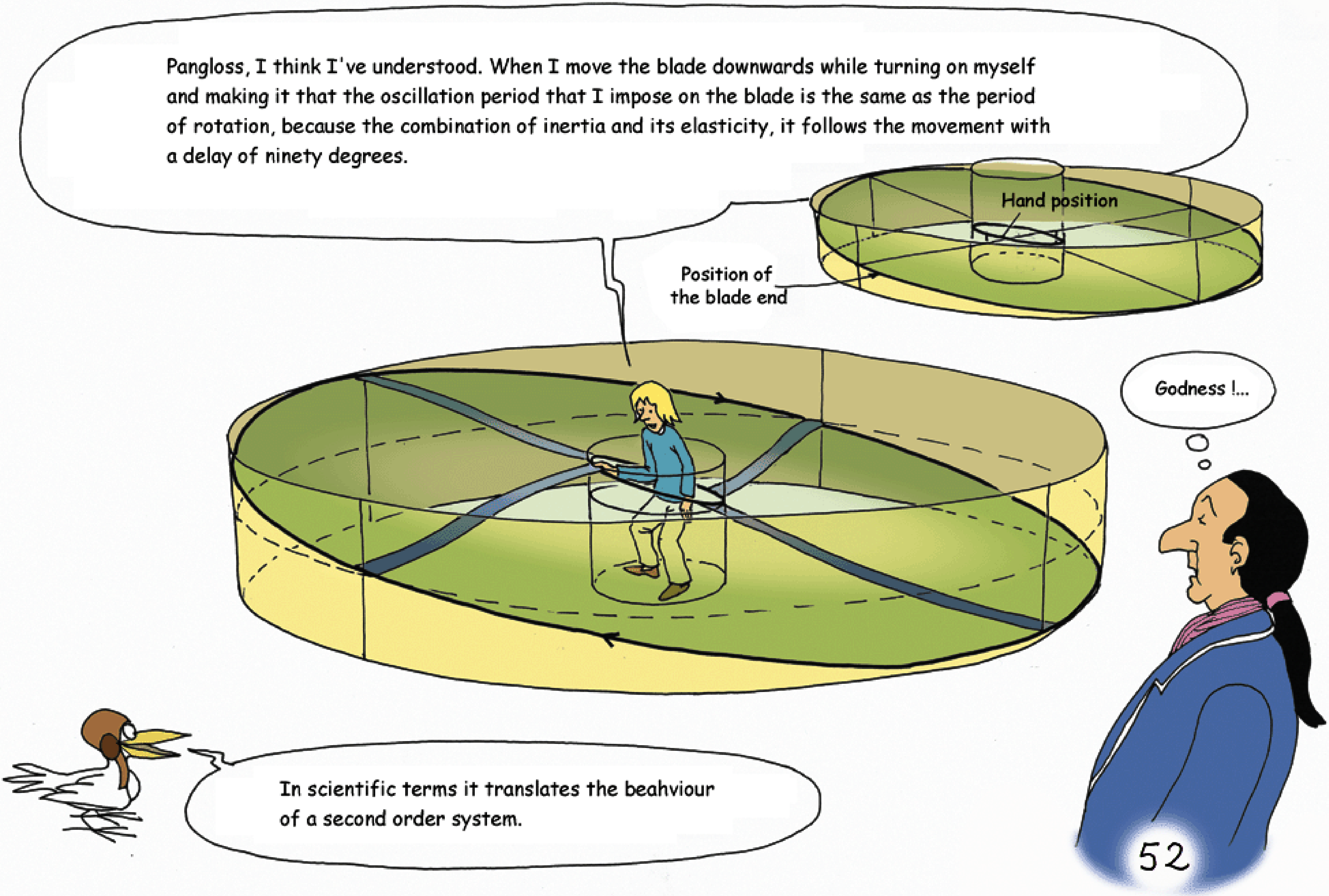

I felt that if I continued the rotor could break.
Why not make it that the blades can frolic freely, upwards, downwards, forwards and backwards, letting centrifugal force hold them tightly.
It works Pangloss, it works! The machine still shakes but it isn't intolerable. But I still can't understand the joystick's response Joystick towards the front, it moves towards the right. Joystick towards the right, the machine rears up and then goes backwards. Joystick leftwards, it's nose drops and it moves forwards. Joystick backwards and it moves to the left
That means that your machine is obeying your orders but putting them into effect at ... 90°

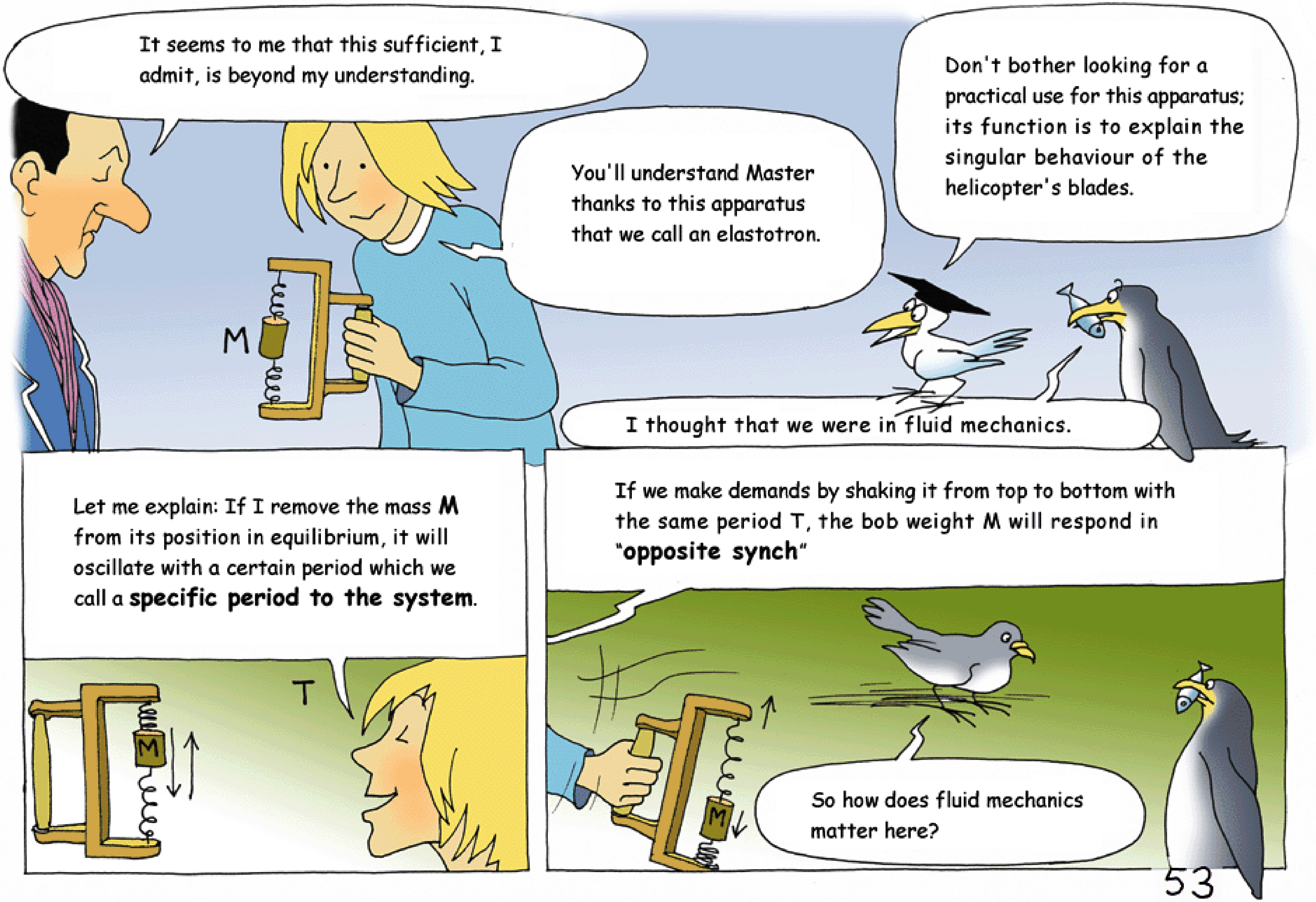


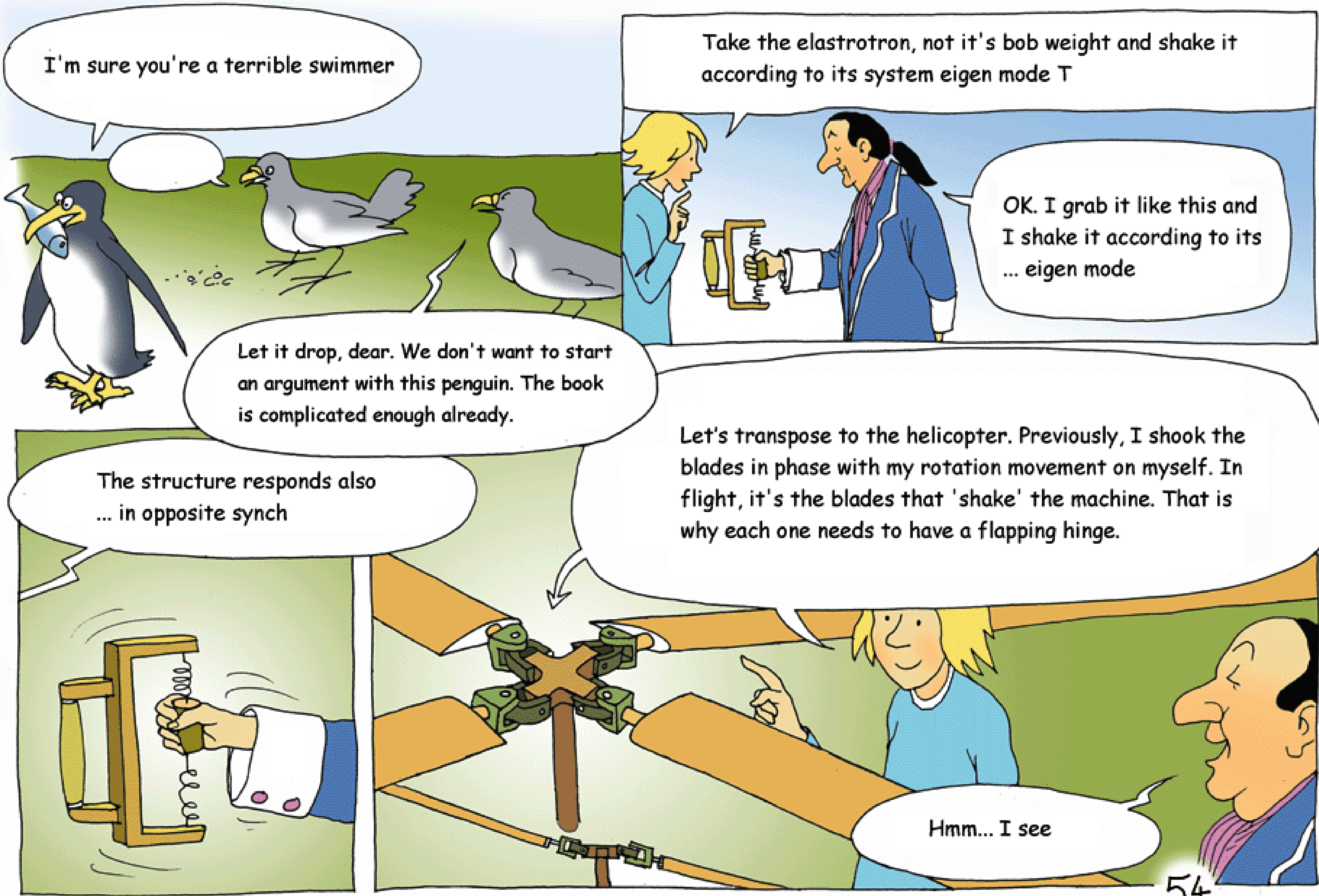
It incomprehensible but it's exactly that.
The solution is simple then. Modify your controls in consequence.
I could not sit in a machine whose behaviour was so far from being understood, my good master.
Candide, Candide, there are many things that are familiar to us but whose essence escapes us. Let us see: The Sun turns around the Earth but we do not know why. We have not understood this abhorrence of emptiness that makes mercury climb in a barometer. The sufficient reason for the black energy that provokes the reacceleration of our cosmos is still unknown to us. Should we then, because of that, abstain from measuring all the phenomena that nature offers us?
And love, the tender feelings you have for Miss Cunegonde?
If this flight mechanics is the best of all possible flight mechanics, what, therefore, are the others...

DECALAGE DU CYCLIQUE

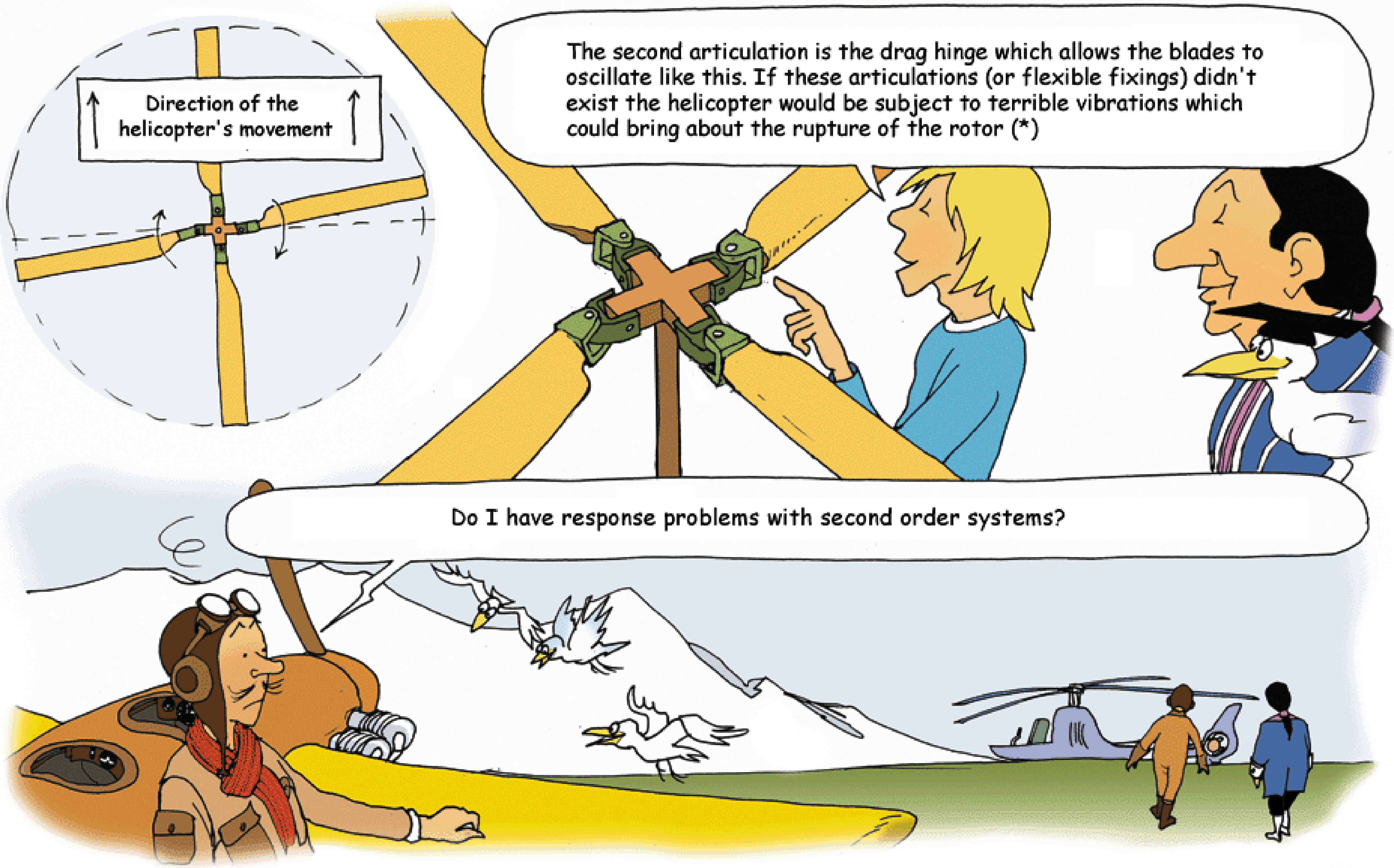



Pangloss, I think I've understood. When I move the blade downwards while turning on myself and making it that the oscillation period that I impose on the blade is the same as the period of rotation, because the combination of inertia and its elasticity, it follows the movement with a delay of ninety degrees.
Hand position
Position of the blade end
Godness !...
In scientific terms it translates the beahviour of a second order system.

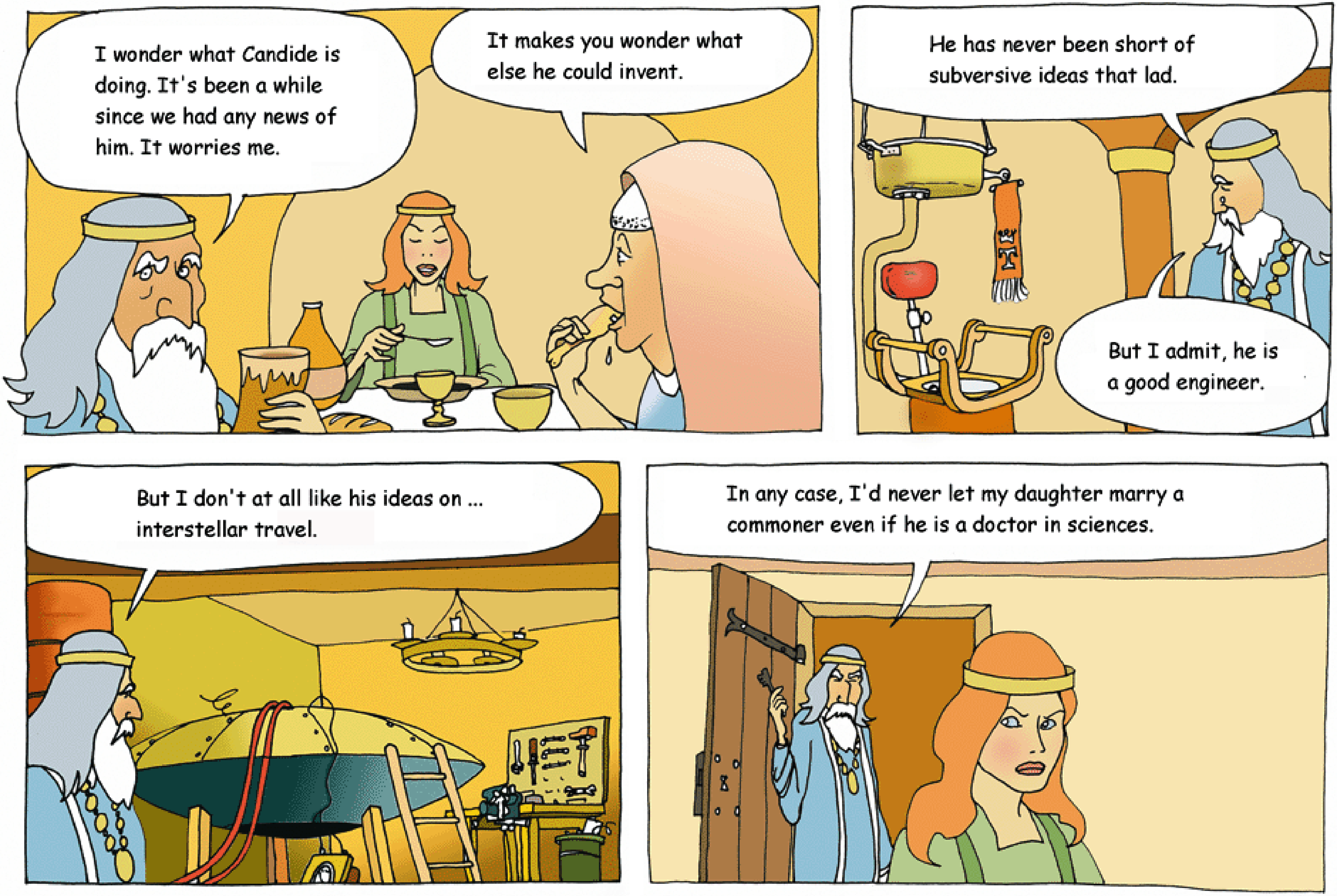

It seems to me that this sufficient, I admit, is beyond my understanding.
You'll understand Master thanks to this apparatus that we call an elastotron.
Don't bother looking for a practical use for this apparatus; its function is to explain the singular behaviour of the helicopter's blades.
M
I thought that we were in fluid mechanics.
Let me explain: If I remove the mass **M** from its position in equilibrium, it will oscillate with a certain period which we call a **specific period to the system**.
T
M
If we make demands by shaking it from top to bottom with the same period T, the bob weight M will respond in "**opposite synch**"
M
So how does fluid mechanics matter here?



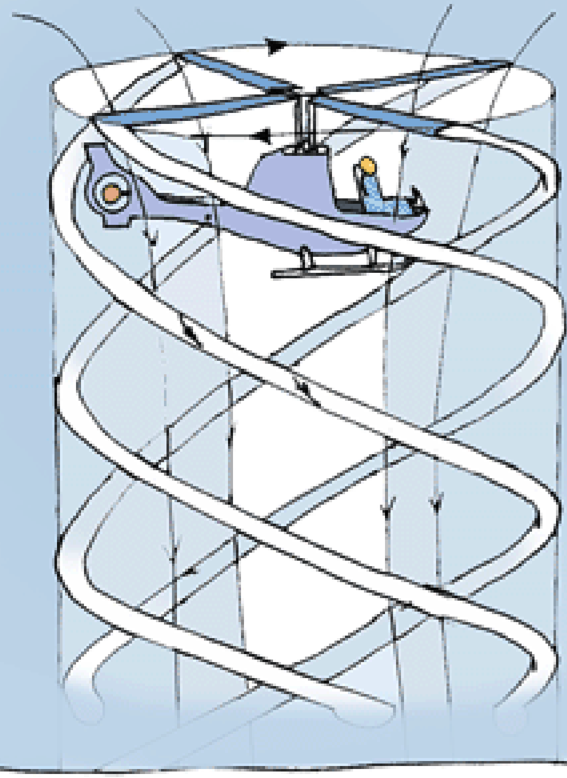
I'm sure you're a terrible swimmer
Let it drop, dear. We don't want to start an argument with this penguin. The book is complicated enough already.
Take the elastrotron, not it's bob weight and shake it according to its system eigen mode T
OK. I grab it like this and I shake it according to its ... eigen mode
The structure responds also ... in opposite synch
Let's transpose to the helicopter. Previously, I shook the blades in phase with my rotation movement on myself. In flight, it's the blades that 'shake' the machine. That is why each one needs to have a flapping hinge.
Hmm... I see

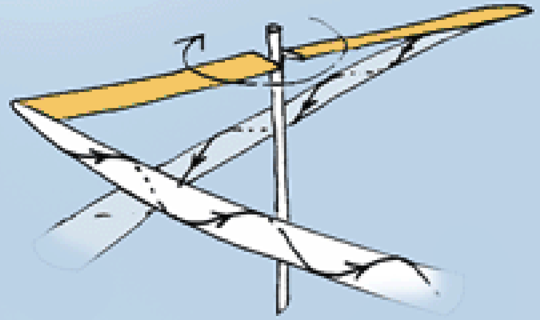


(*) Because of the problems he encountered during his experiments with his autogiro, the Spaniard de la Cierva had to hurriedly introduce a system of "articulated blades plus shock absorbers" or else his rotor would have broken.

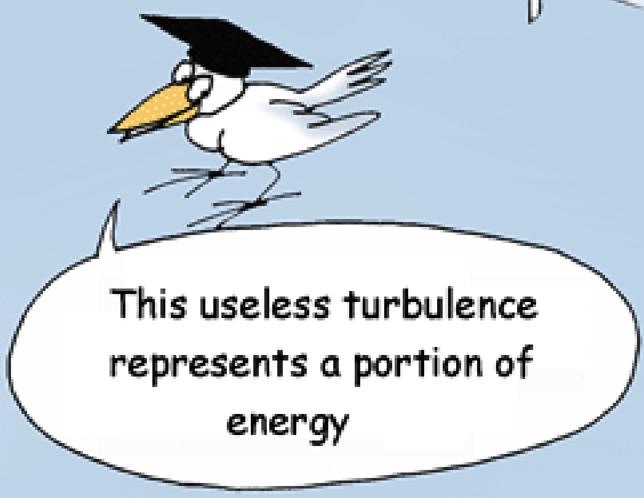

I wonder what Candide is doing. It's been a while since we had any news of him. It worries me.
It makes you wonder what else he could invent.
He has never been short of subversive ideas that lad.
But I admit, he is a good engineer.
But I don't at all like his ideas on ... interstellar travel.
In any case, I'd never let my daughter marry a commoner even if he is a doctor in sciences.

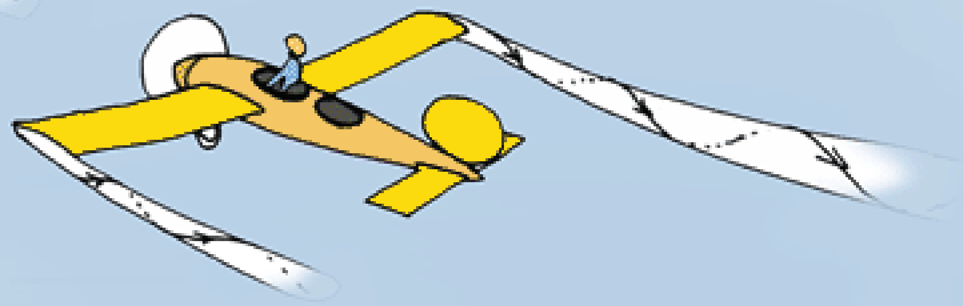
TRANSITION





The blades of a helicopter are very elongated wings which leave **tip vortices** in their wake.

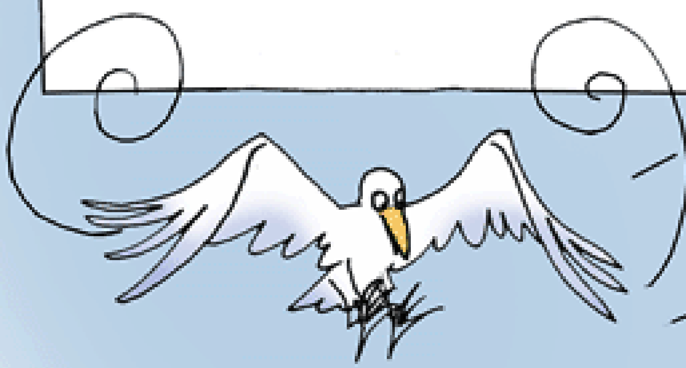




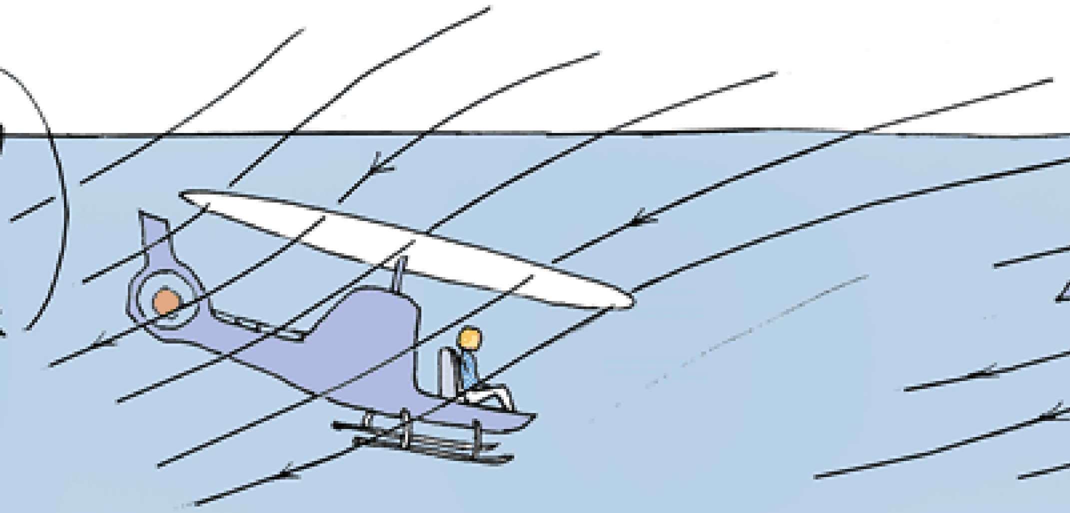
These vortices are created at the blade's extremity which causes water vapour condensation (condensation drag) at high altitude.

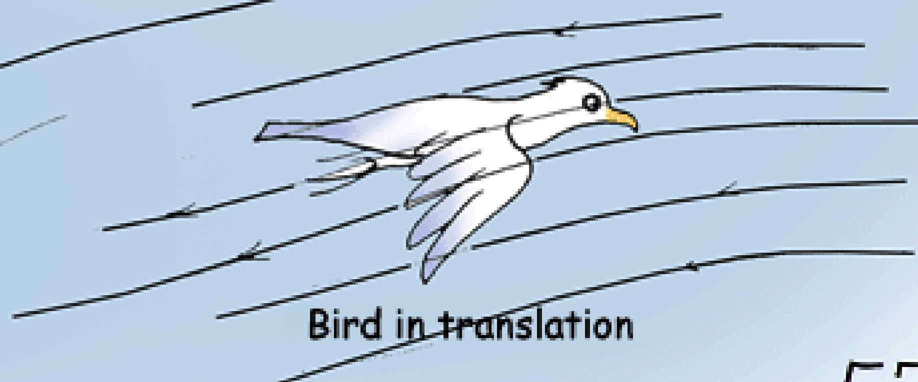
When the helicopter goes into transition the speed of flow is completely modified. The vortices lose their importance and, because of that, the machine can maintain lift with a reduced amount of energy.

The Management

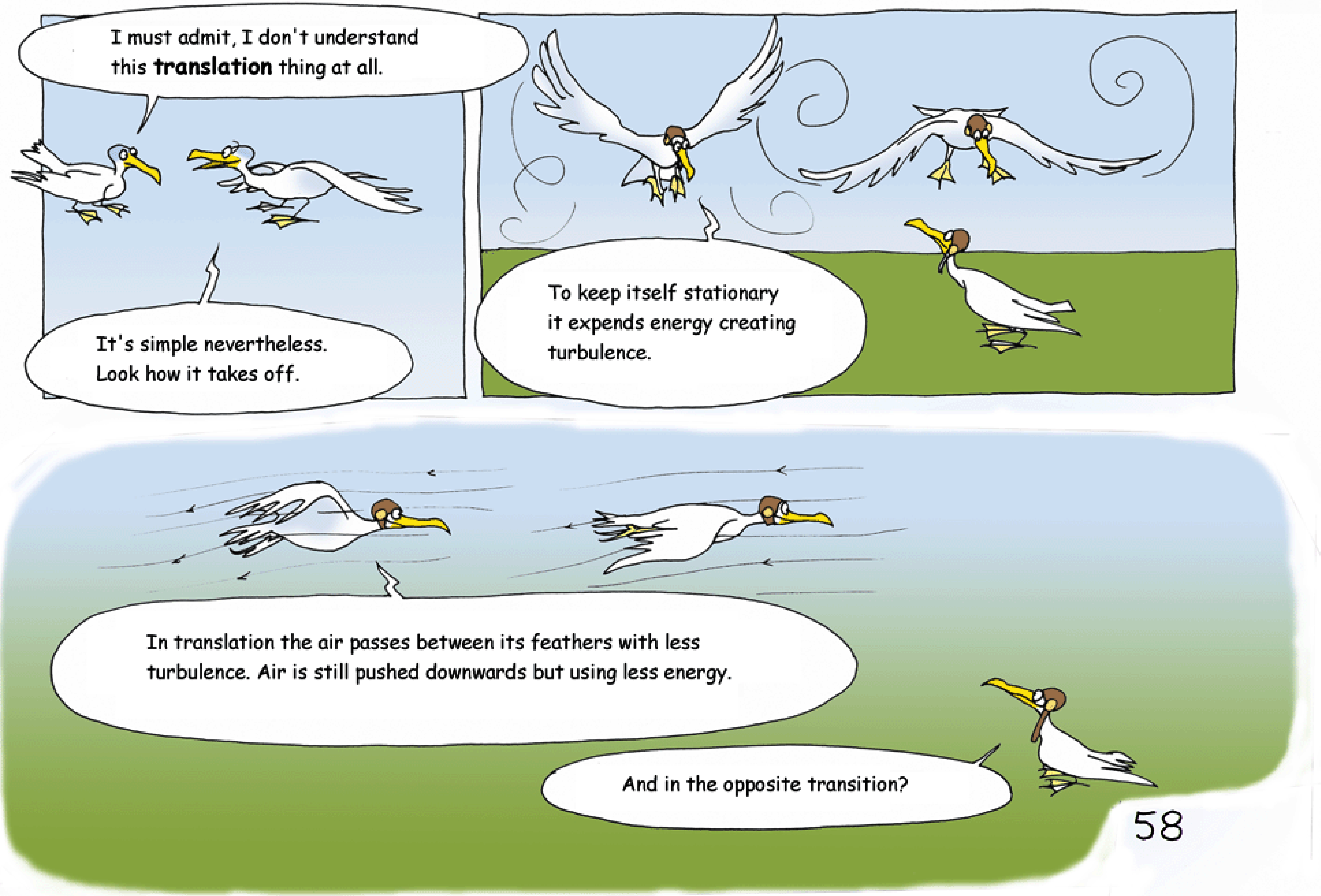


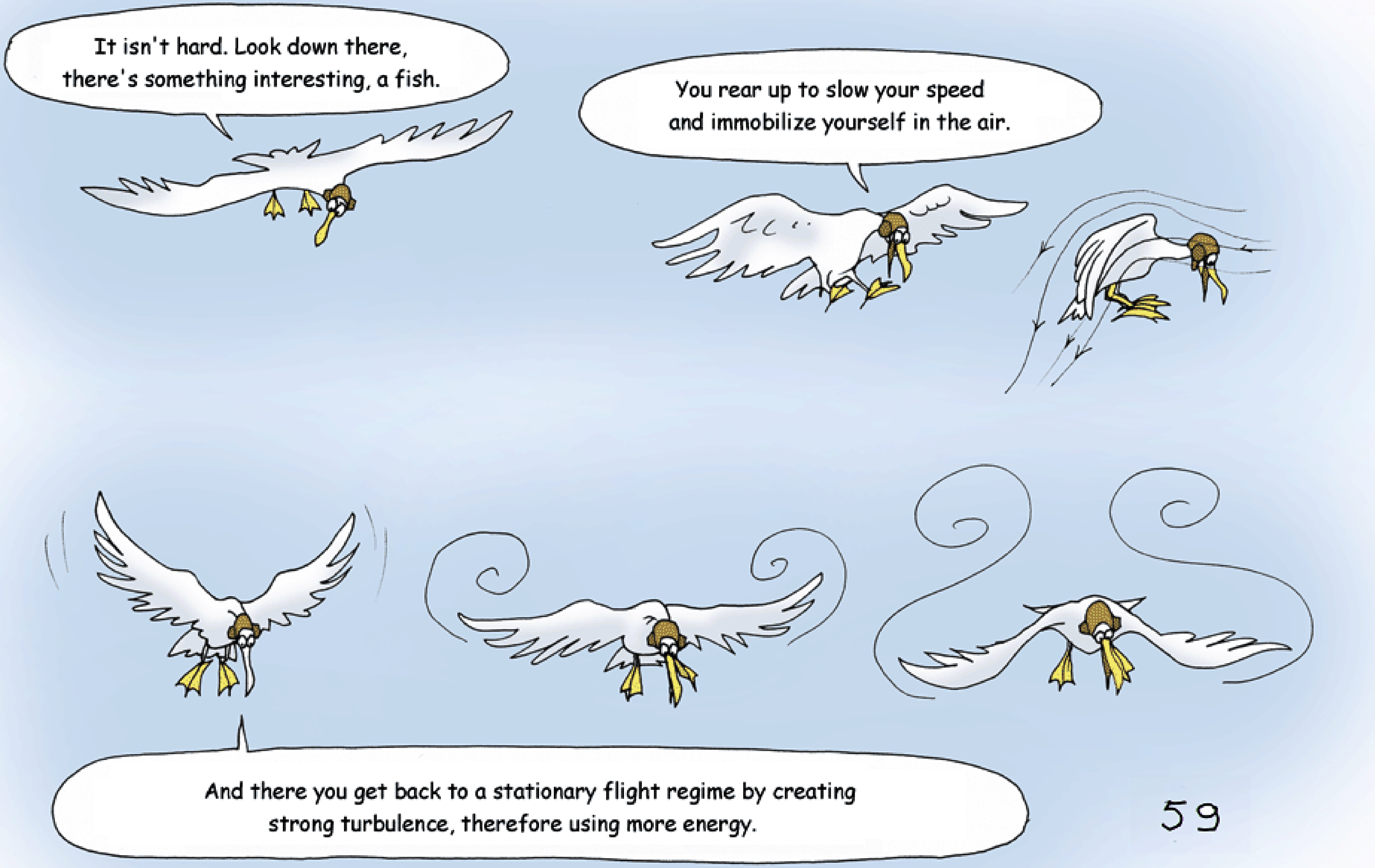
Bird in stationary flight
strong turbulence

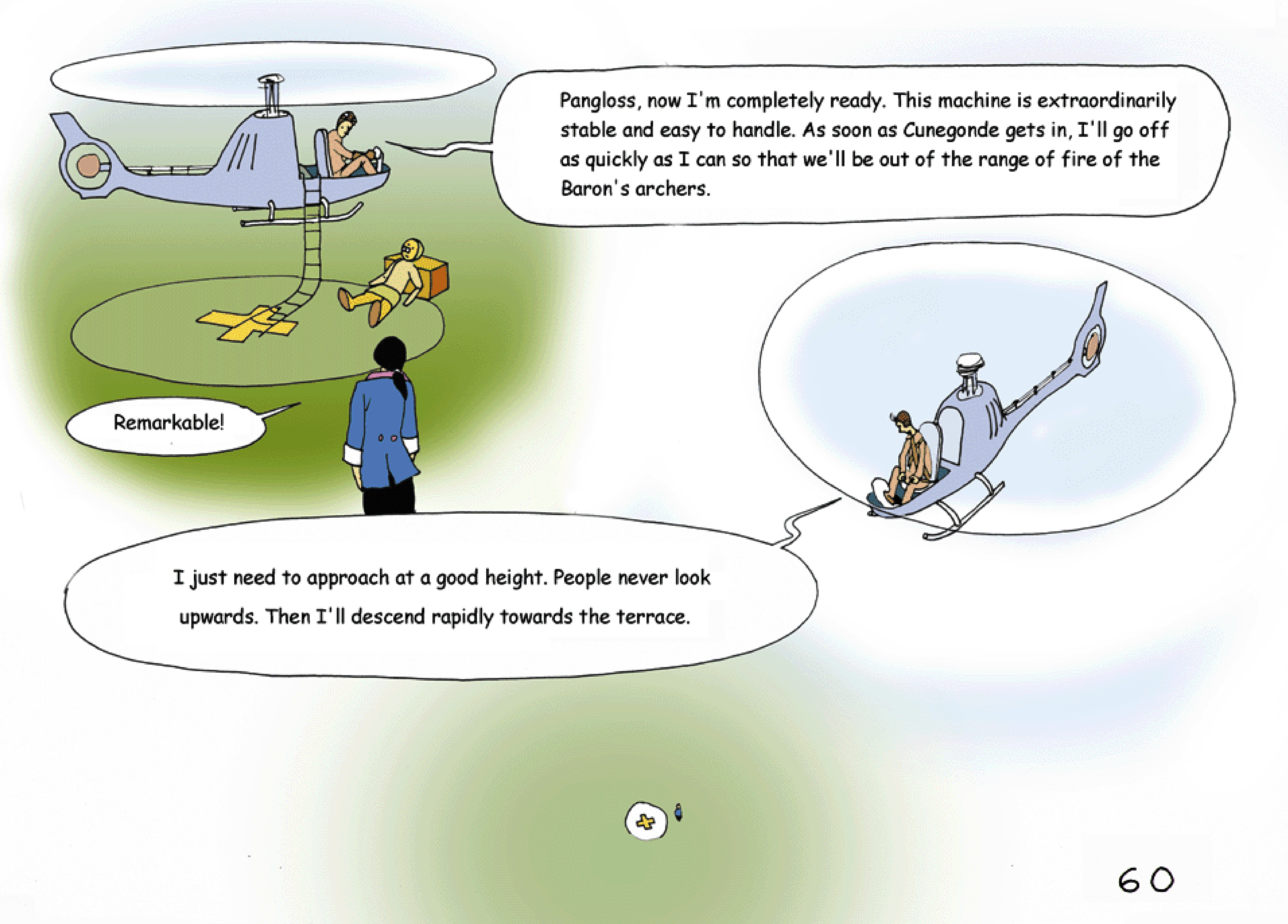


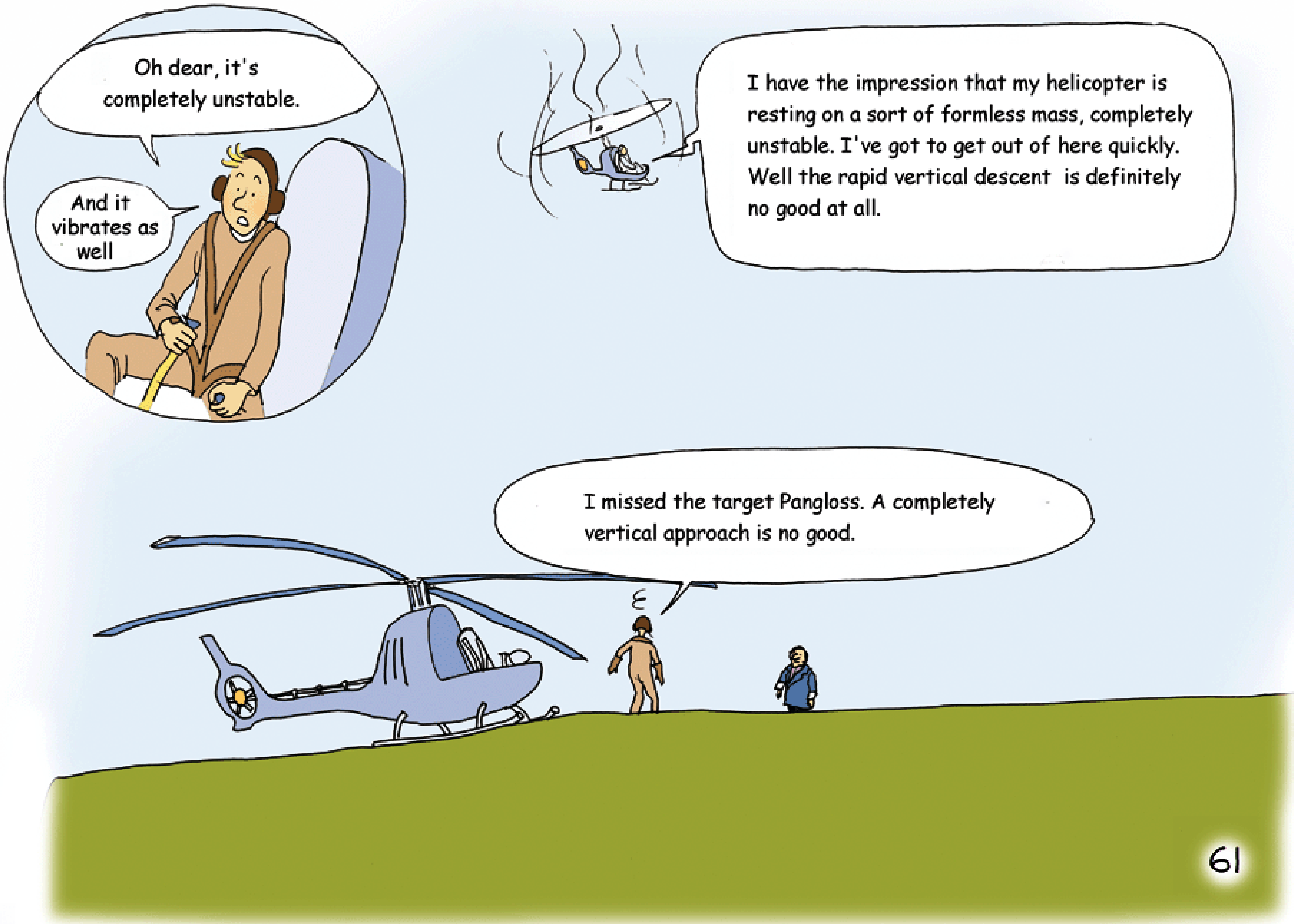


Bird in translation

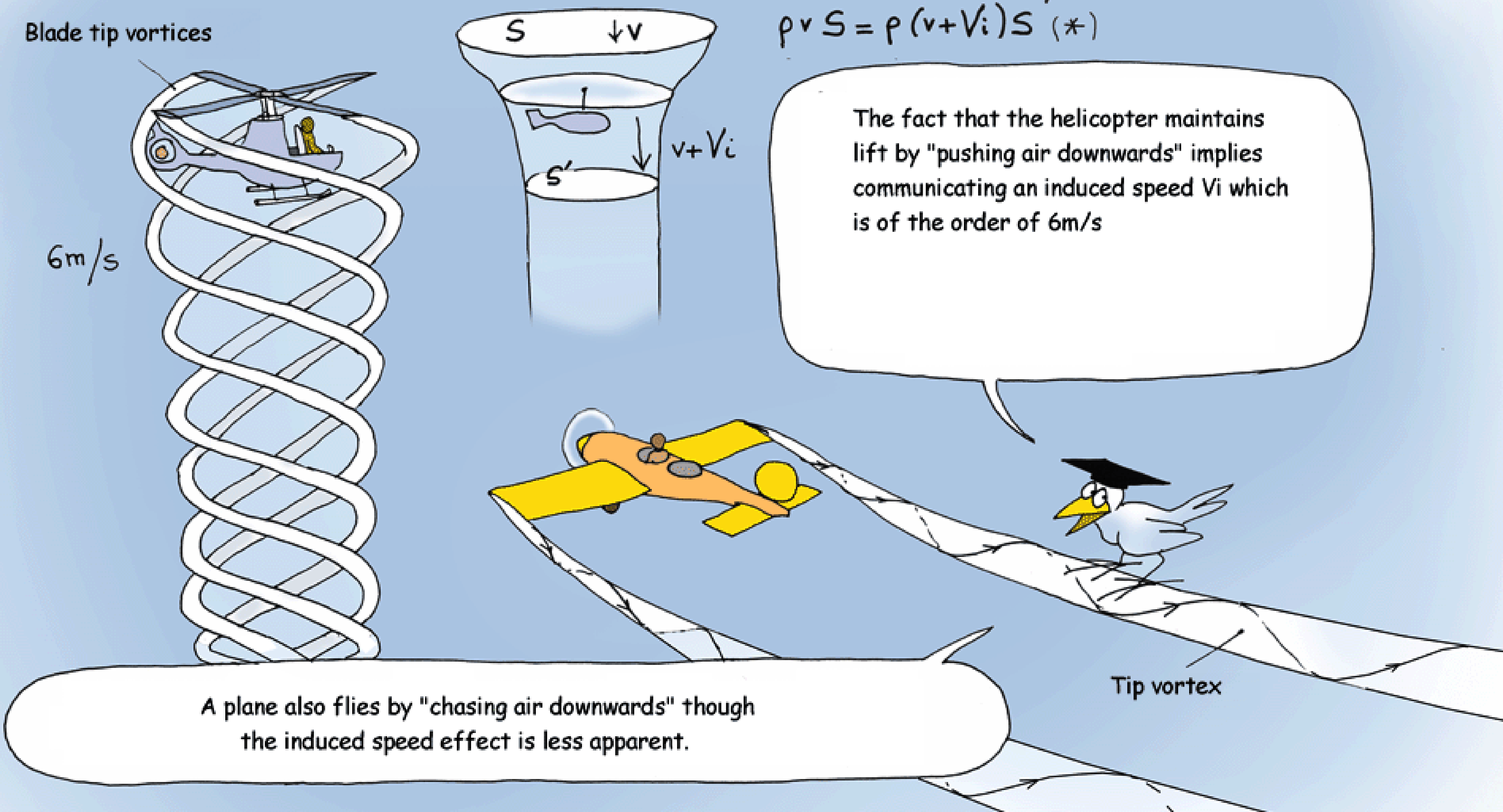

I must admit, I don't understand this **translation** thing at all.
It's simple nevertheless. Look how it takes off.
To keep itself stationary it expends energy creating turbulence.
In translation the air passes between its feathers with less turbulence. Air is still pushed downwards but using less energy.
And in the opposite transition?


It isn't hard. Look down there, there's something interesting, a fish.
You rear up to slow your speed and immobilize yourself in the air.
And there you get back to a stationary flight regime by creating strong turbulence, therefore using more energy.

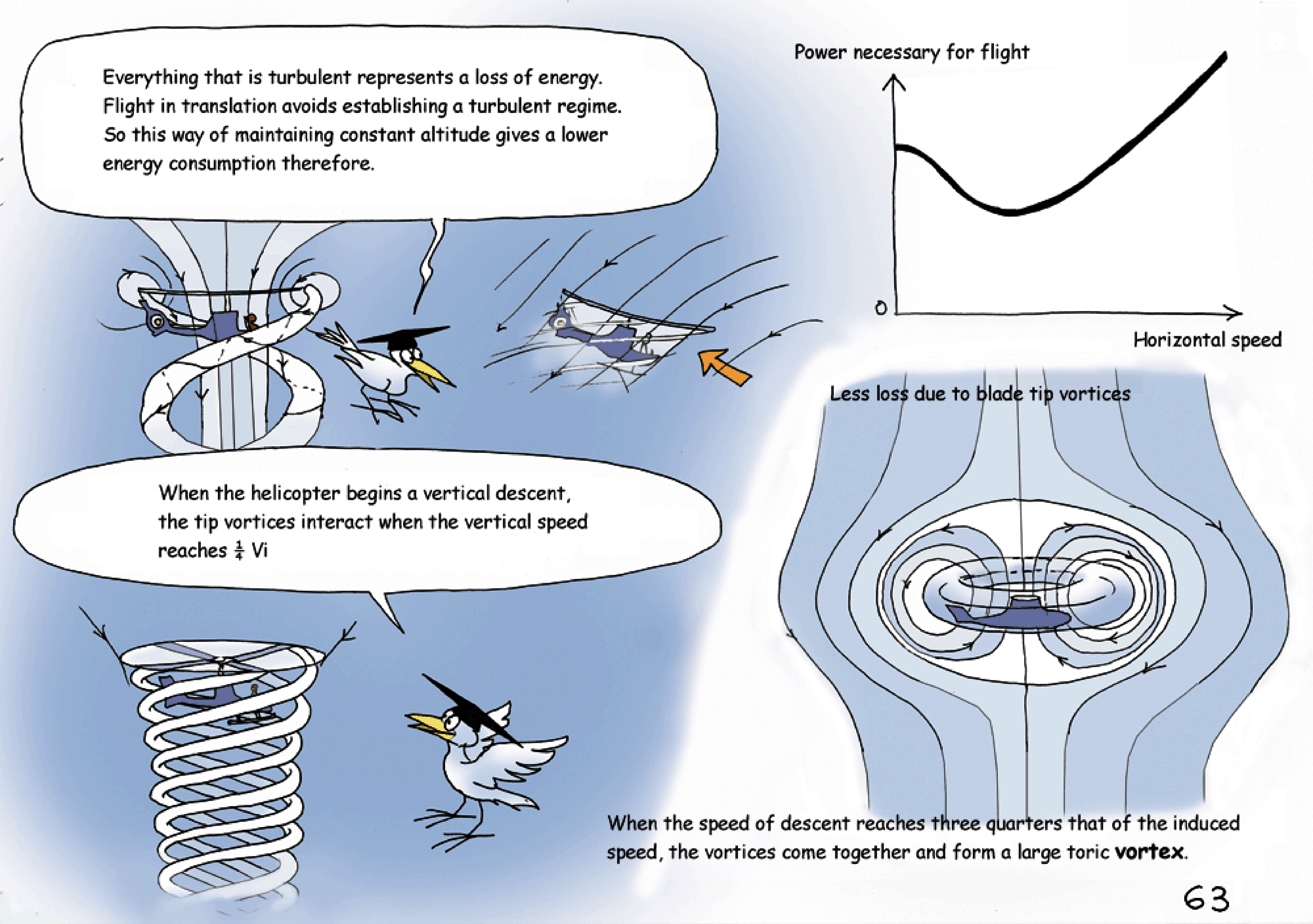

Pangloss, now I'm completely ready. This machine is extraordinarily stable and easy to handle. As soon as Cunegonde gets in, I'll go off as quickly as I can so that we'll be out of the range of fire of the Baron's archers.
Remarkable!
I just need to approach at a good height. People never look upwards. Then I'll descend rapidly towards the terrace.

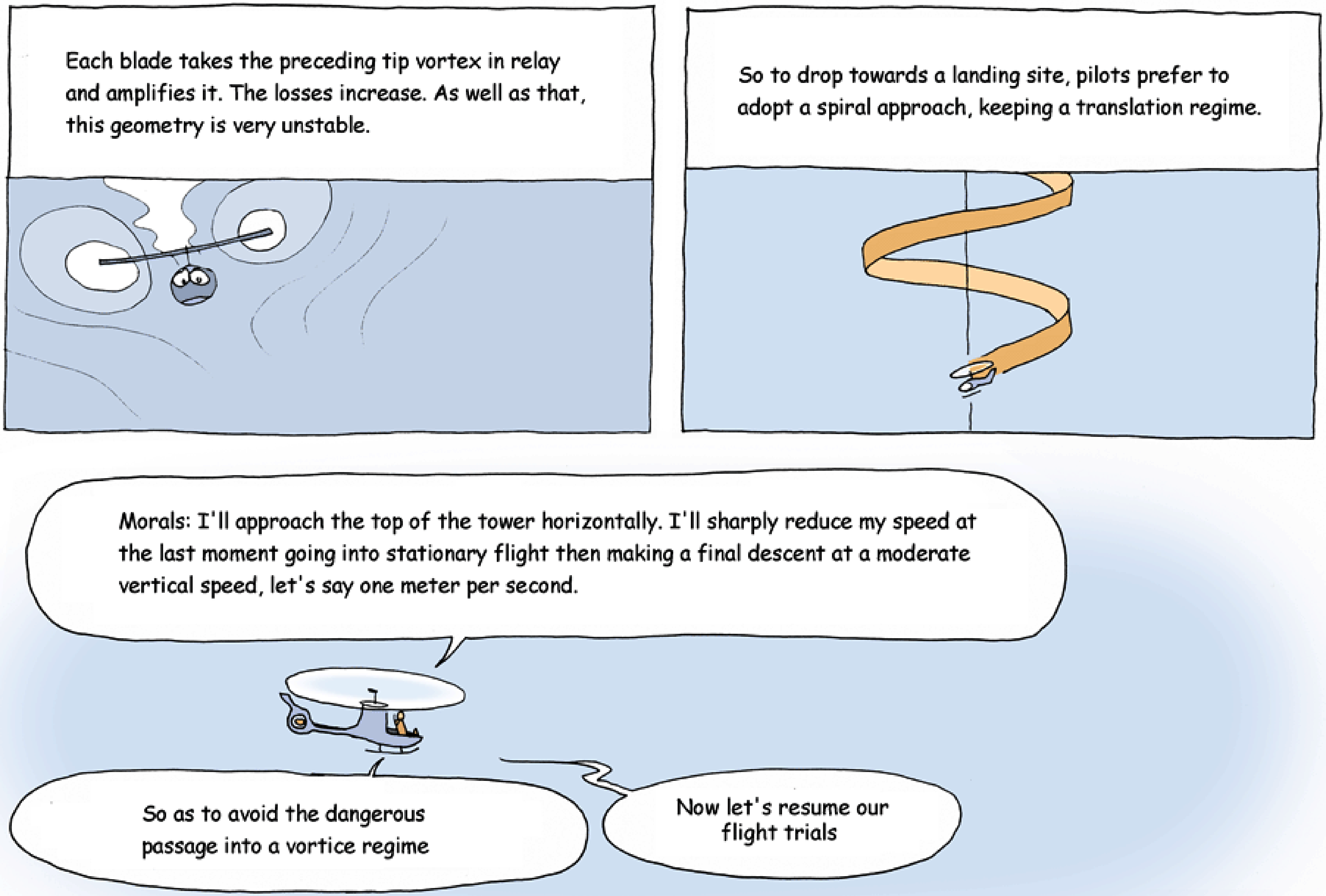

Oh dear, it's completely unstable.
And it vibrates as well
I have the impression that my helicopter is resting on a sort of formless mass, completely unstable. I've got to get out of here quickly. Well the rapid vertical descent is definitely no good at all.
I missed the target Pangloss. A completely vertical approach is no good.

INDUCED SPEED

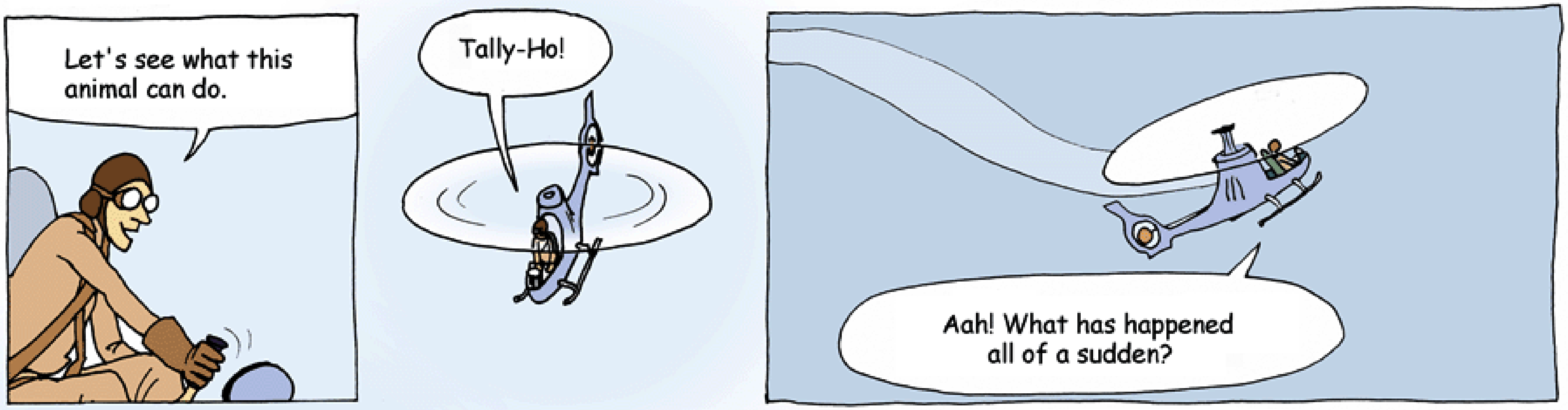


(*) This relation expresses the conservation of the airflow of a constant volume mass ρ
The requires that the section S' be smaller than the section S

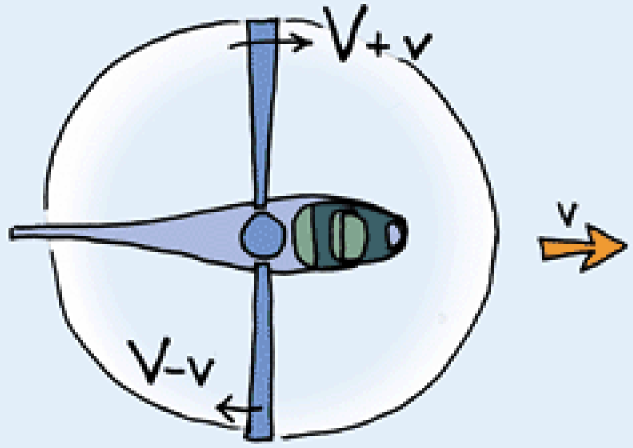

Everything that is turbulent represents a loss of energy. Flight in translation avoids establishing a turbulent regime. So this way of maintaining constant altitude gives a lower energy consumption therefore.
Power necessary for flight
0
Horizontal speed
Less loss due to blade tip vortices
When the helicopter begins a vertical descent, the tip vortices interact when the vertical speed reaches ¾ Vi
When the speed of descent reaches three quarters that of the induced speed, the vortices come together and form a large toric **vortex**.


Each blade takes the preceding tip vortex in relay and amplifies it. The losses increase. As well as that, this geometry is very unstable.
So to drop towards a landing site, pilots prefer to adopt a spiral approach, keeping a translation regime.
Morals: I'll approach the top of the tower horizontally. I'll sharply reduce my speed at the last moment going into stationary flight then making a final descent at a moderate vertical speed, let's say one meter per second.
So as to avoid the dangerous passage into a vortice regime
Now let's resume our flight trials

Loss of lift on the retreating blade

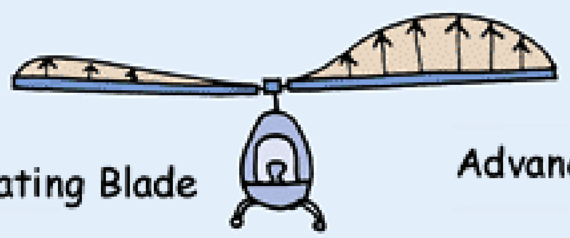


Advancing blade



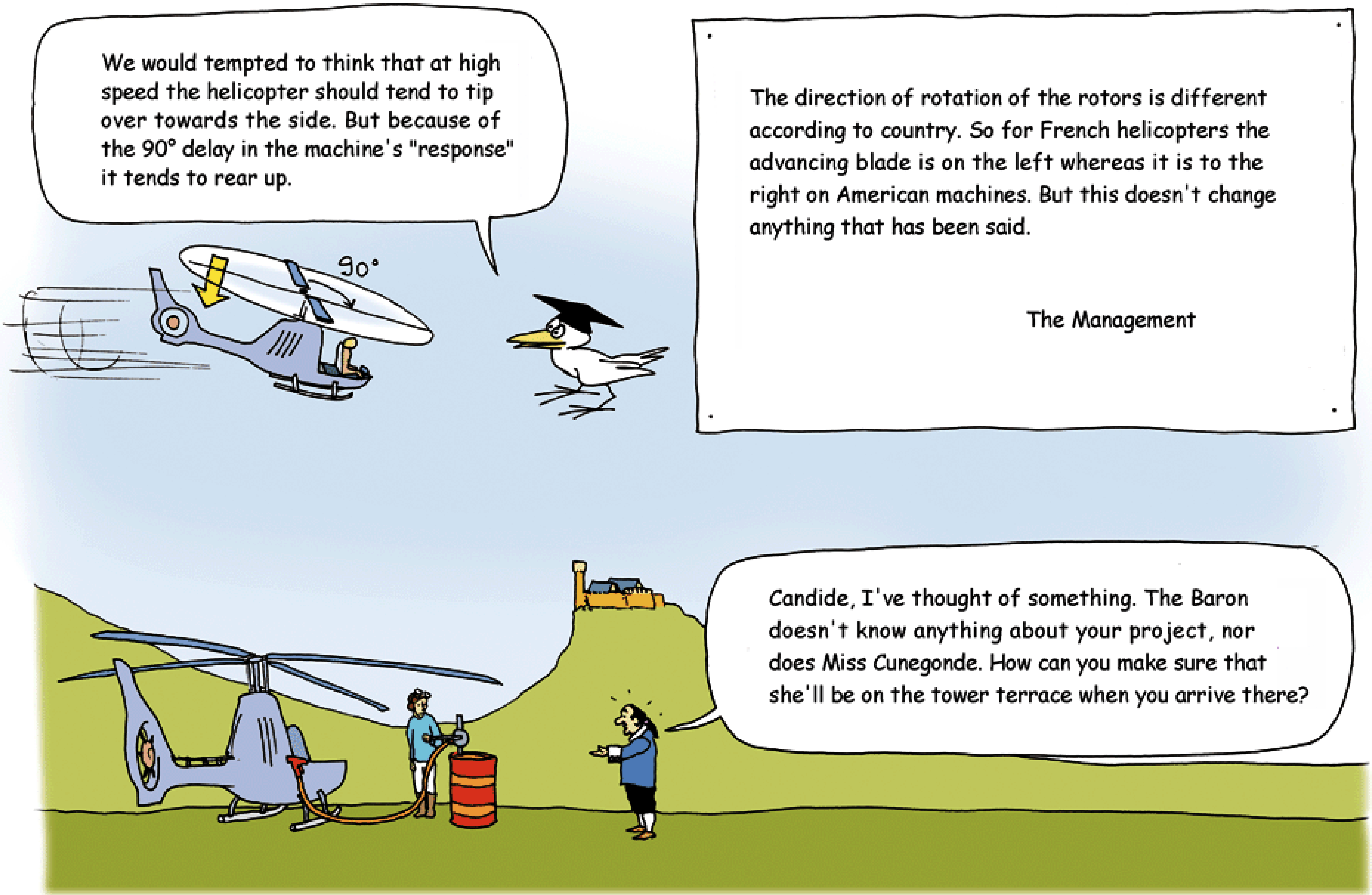
Retreating Blade

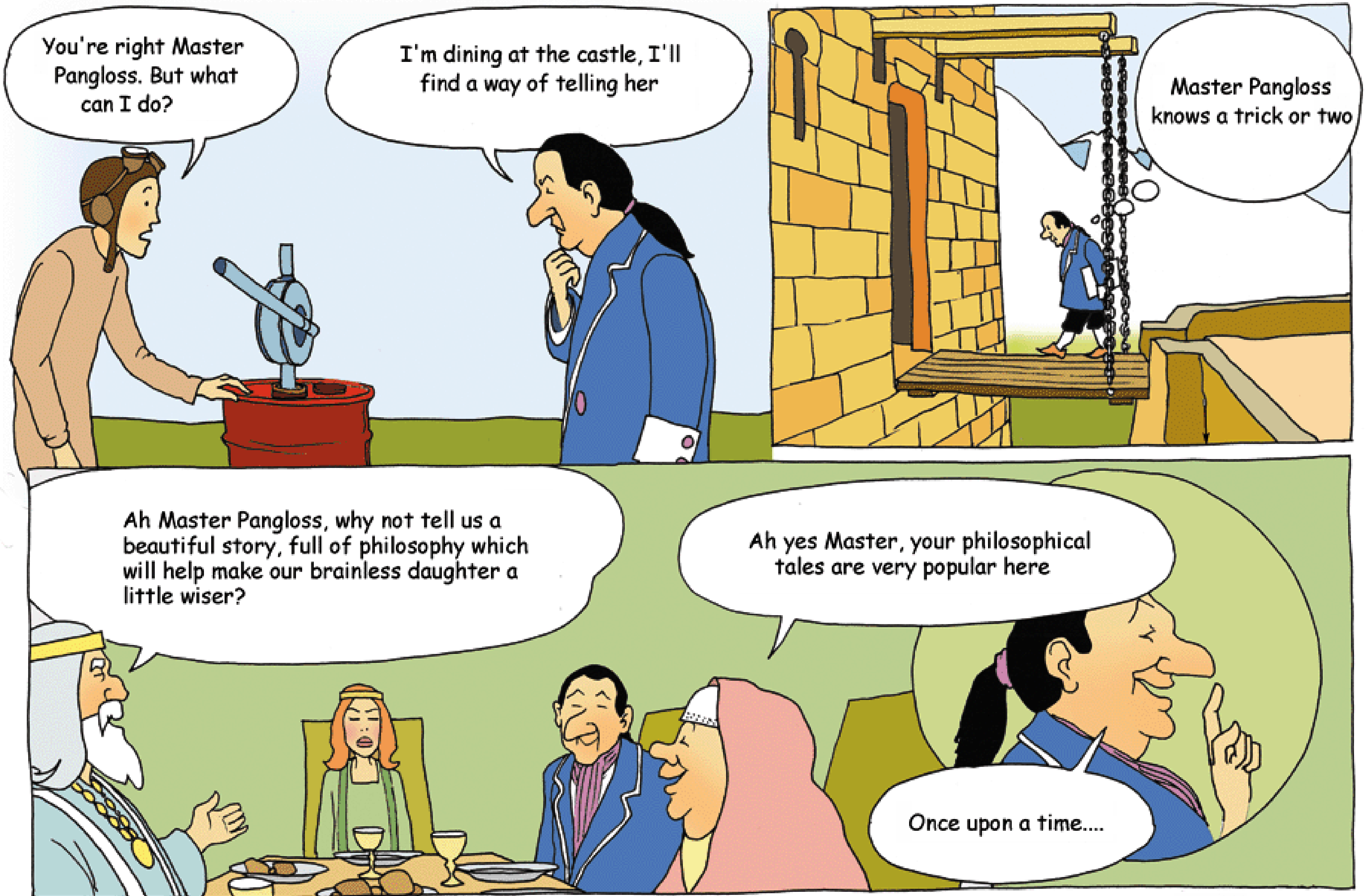
Either V, the speed at the tip of the blade or v, the helicopters flying speed, the relative wind applied on the advancing blade is V + v. That of the receding blade is V- v. So the pressure forces exerted on the two blades are very different.

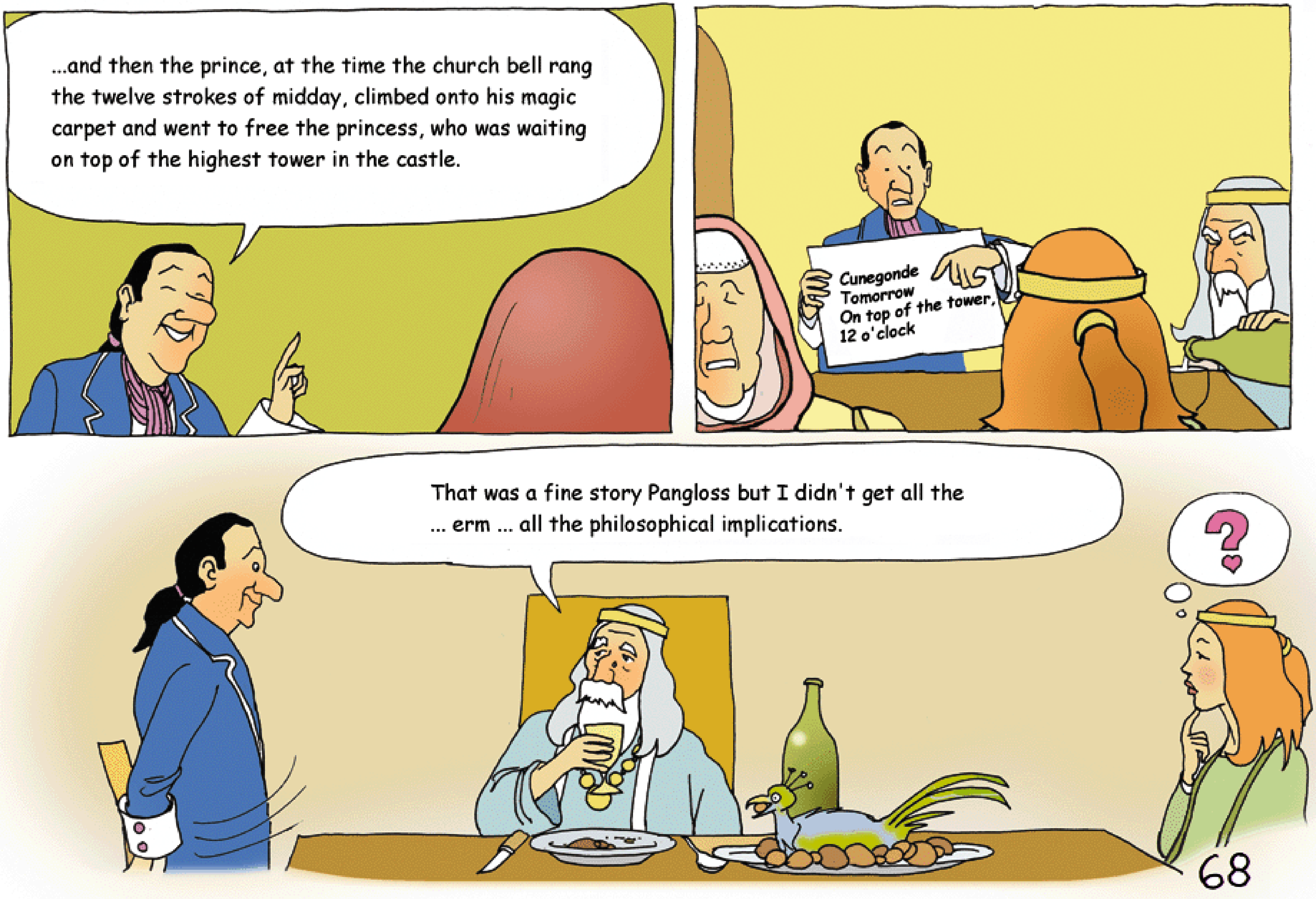


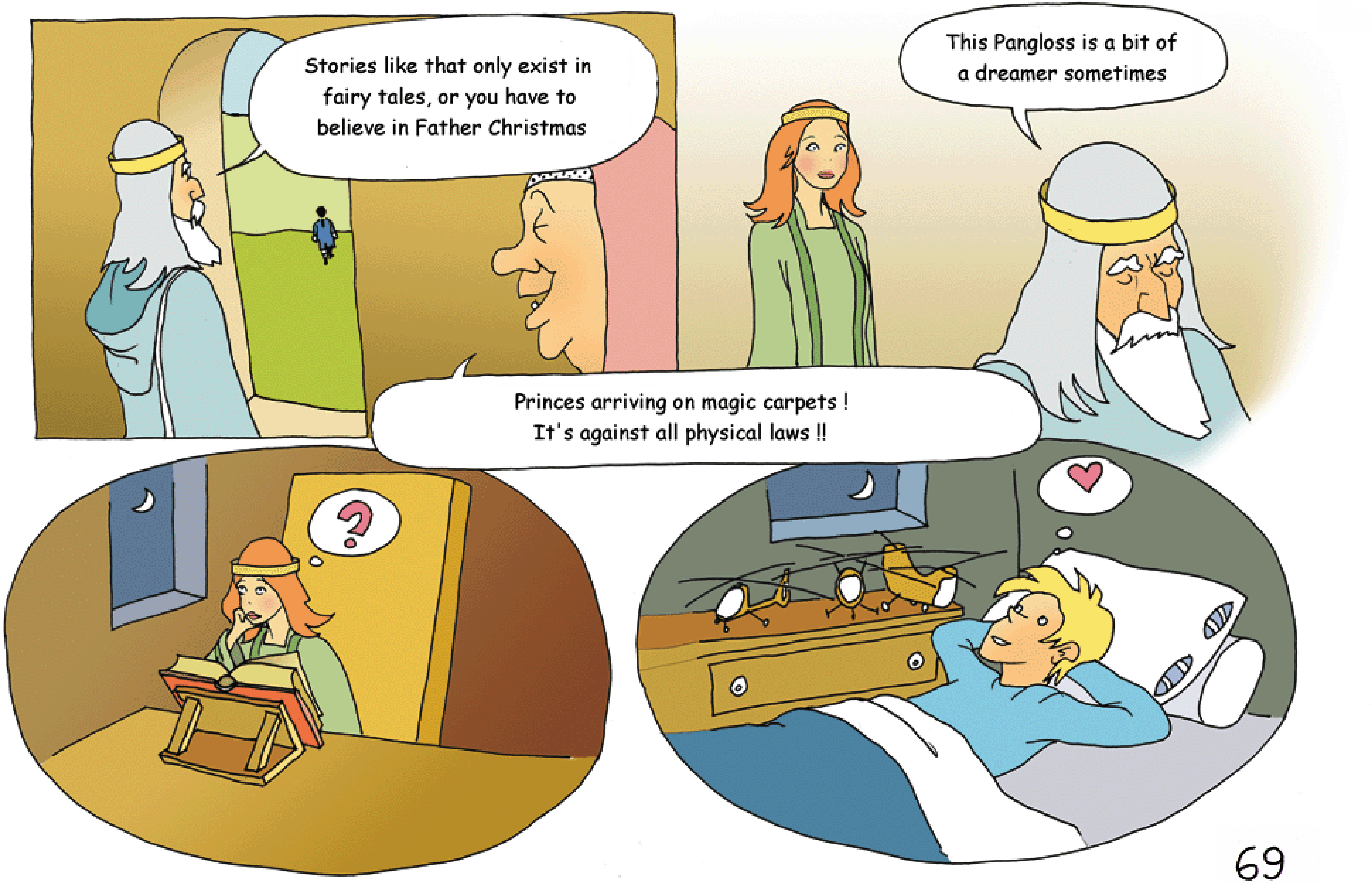
Retreating Blade

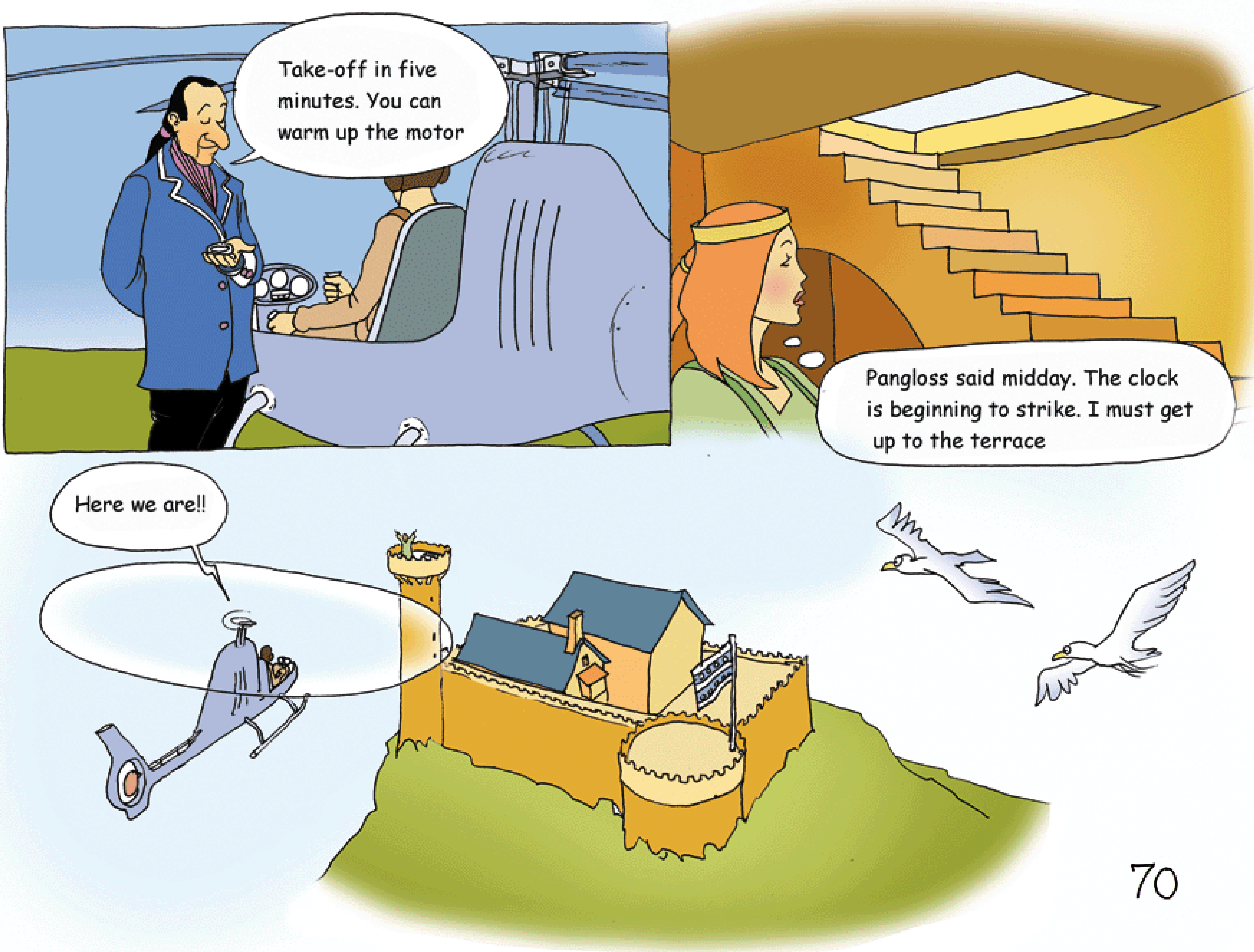
Advancing blade


We would tempted to think that at high speed the helicopter should tend to tip over towards the side. But because of the 90° delay in the machine's "response" it tends to rear up.
90°
The direction of rotation of the rotors is different according to country. So for French helicopters the advancing blade is on the left whereas it is to the right on American machines. But this doesn't change anything that has been said.
The Management
Candide, I've thought of something. The Baron doesn't know anything about your project, nor does Miss Cunegonde. How can you make sure that she'll be on the tower terrace when you arrive there?

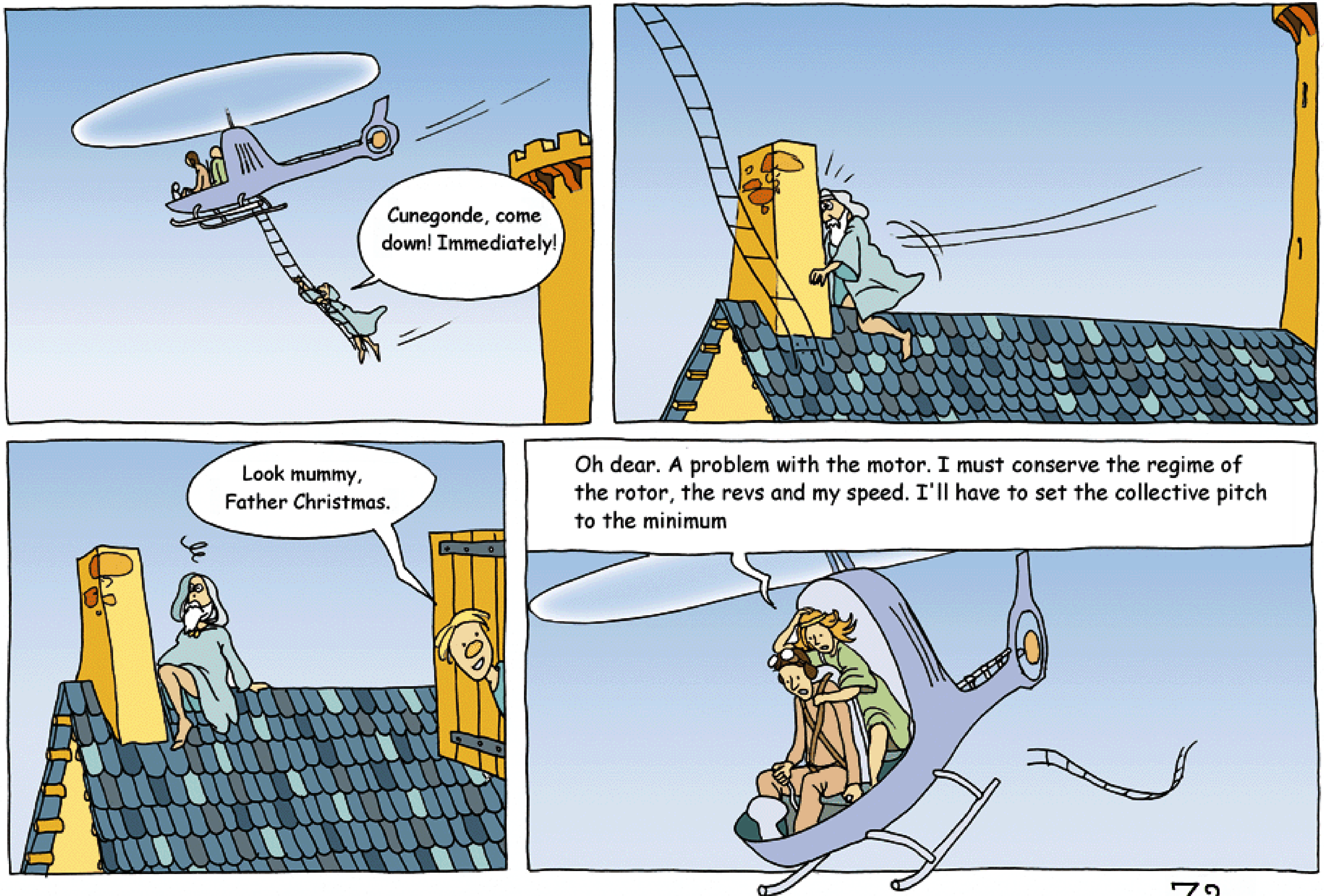

You're right Master Pangloss. But what can I do?
I'm dining at the castle, I'll find a way of telling her
Master Pangloss knows a trick or two
Ah Master Pangloss, why not tell us a beautiful story, full of philosophy which will help make our brainless daughter a little wiser?
Ah yes Master, your philosophical tales are very popular here
Once upon a time....

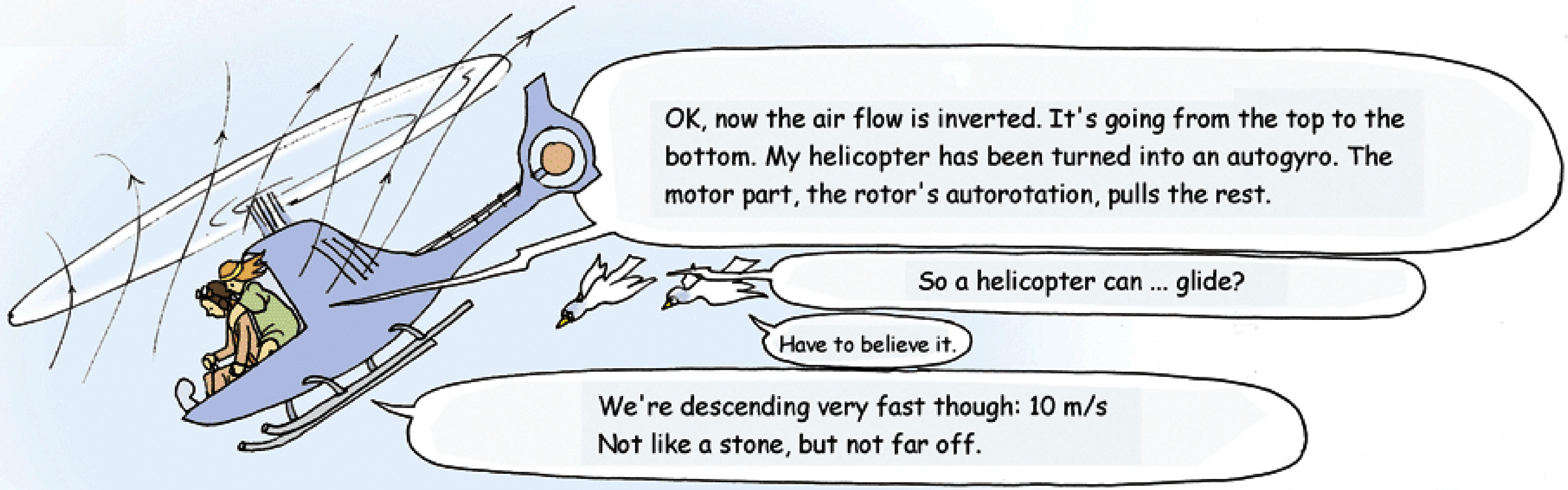

...and then the prince, at the time the church bell rang the twelve strokes of midday, climbed onto his magic carpet and went to free the princess, who was waiting on top of the highest tower in the castle.
Cunegonde Tomorrow On top of the tower, 12 o'clock
That was a fine story Pangloss but I didn't get all the ... erm ... all the philosophical implications.
?

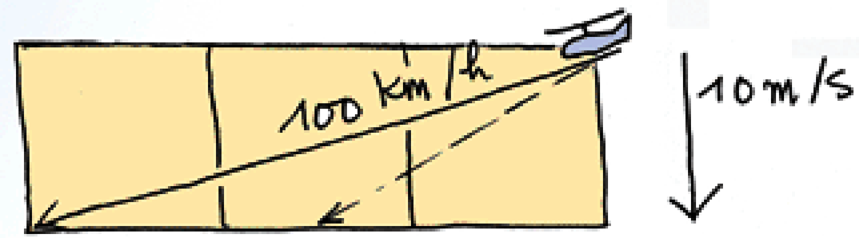

Stories like that only exist in fairy tales, or you have to believe in Father Christmas
This Pangloss is a bit of a dreamer sometimes
Princes arriving on magic carpets ! It's against all physical laws !!
?


Take-off in five minutes. You can warm up the motor
Pangloss said midday. The clock is beginning to strike. I must get up to the terrace
Here we are!!


What's Cunegonde doing? I don't like her being late at mealtimes.
She'll hear from me!
Quickly!

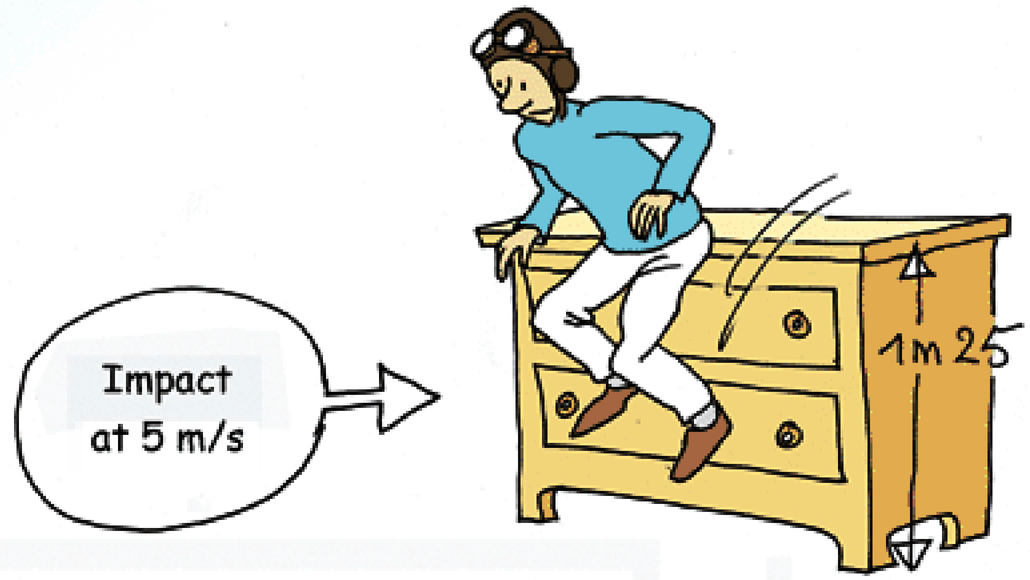

Cunegonde, come down! Immediately!
Look mummy, Father Christmas.
Oh dear. A problem with the motor. I must conserve the regime of the rotor, the revs and my speed. I'll have to set the collective pitch to the minimum





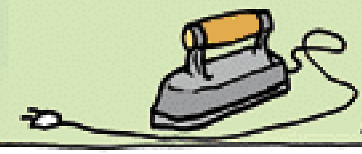
In an autorotation regime a helicopter has a speed of 100 km/h, which corresponds to a aerodynamic efficiency of 3 (♥). In a vertical autorotation regime the falling speed will be 20 m/s and on impact all passengers would be killed. To clarify, a man could support an impact at 5 m/s, which is equivalent to jumping off a wardrobe (*). An impact at 10 m/s corresponds to a drop from 5 meters.

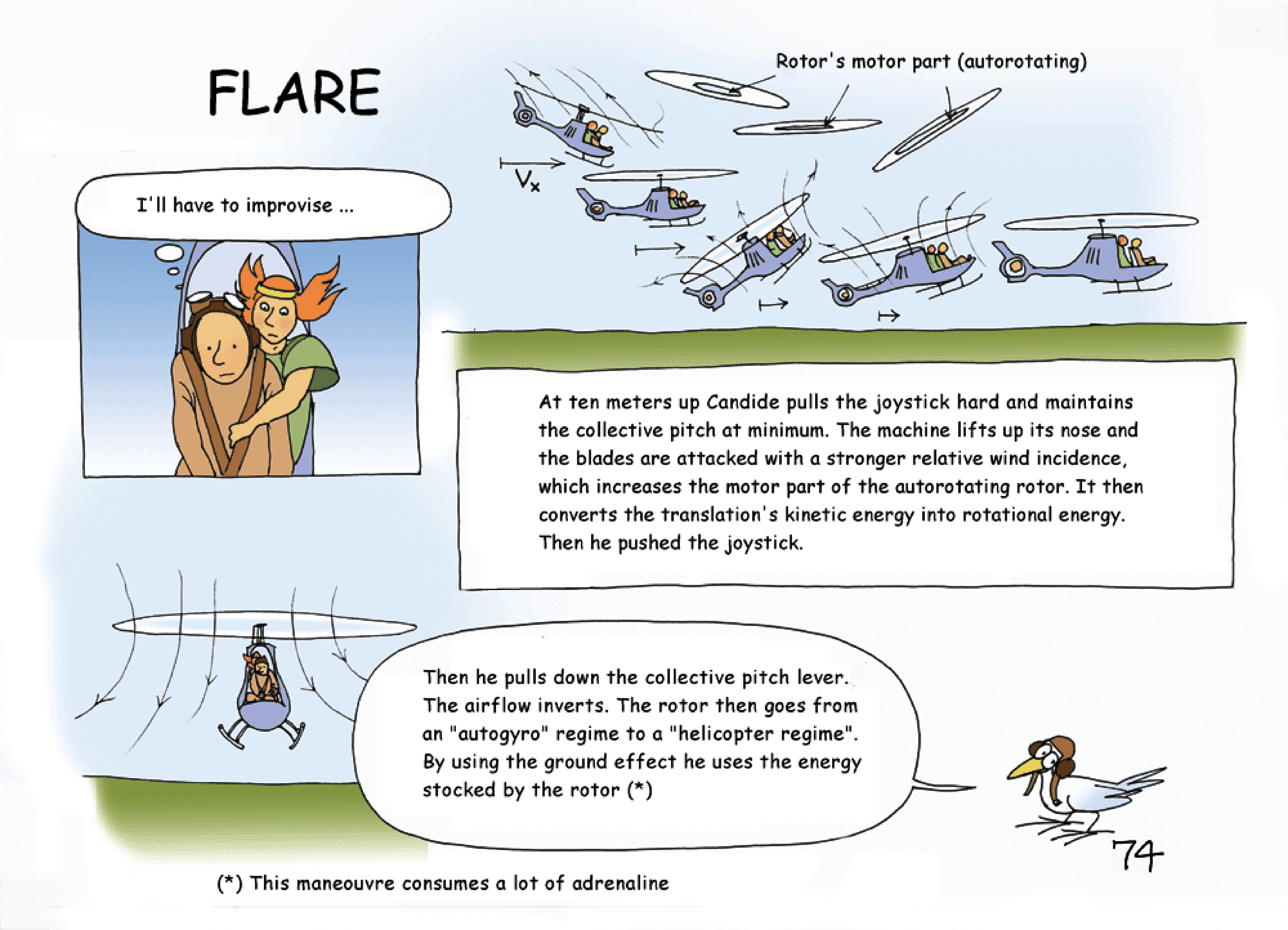
The Management

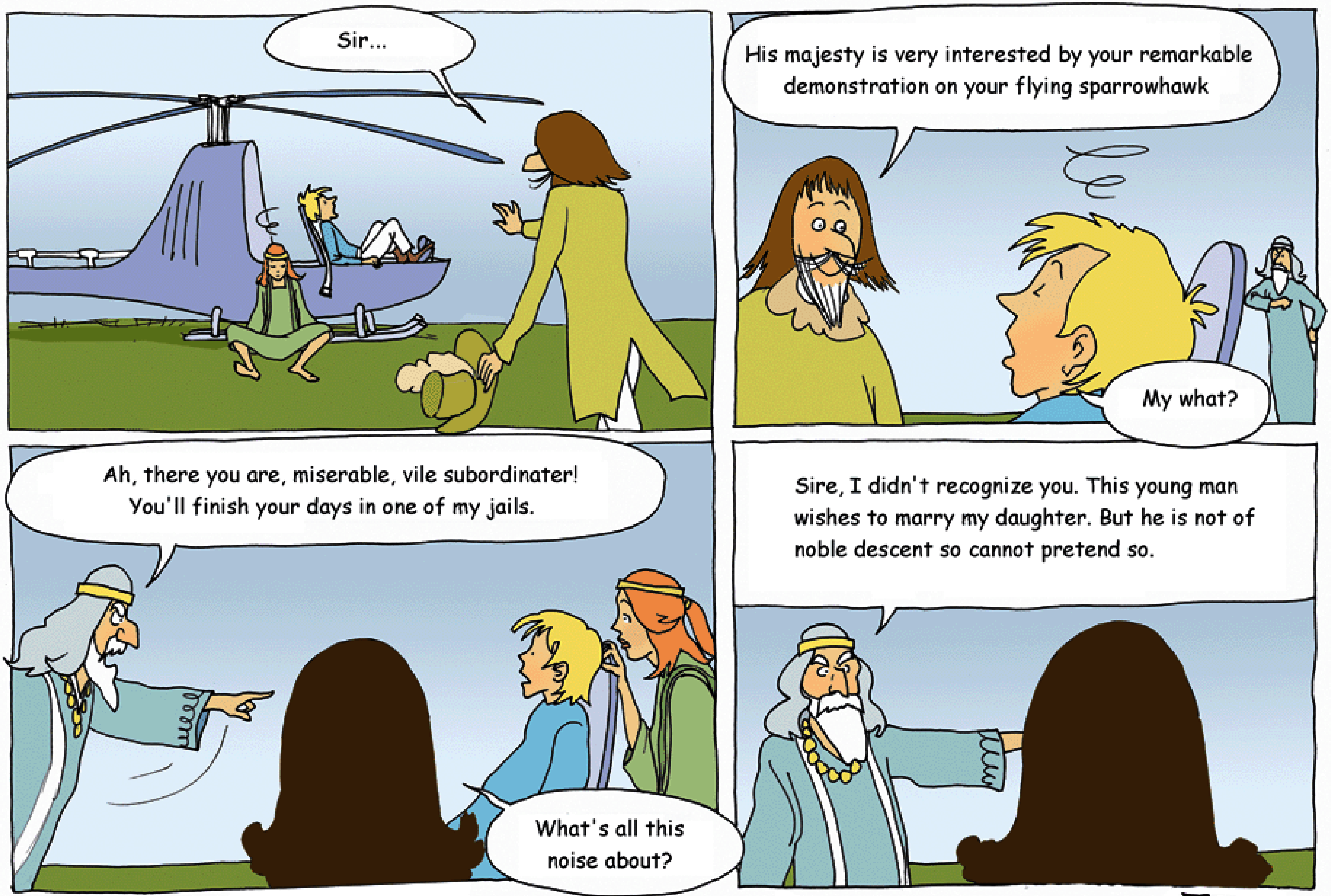


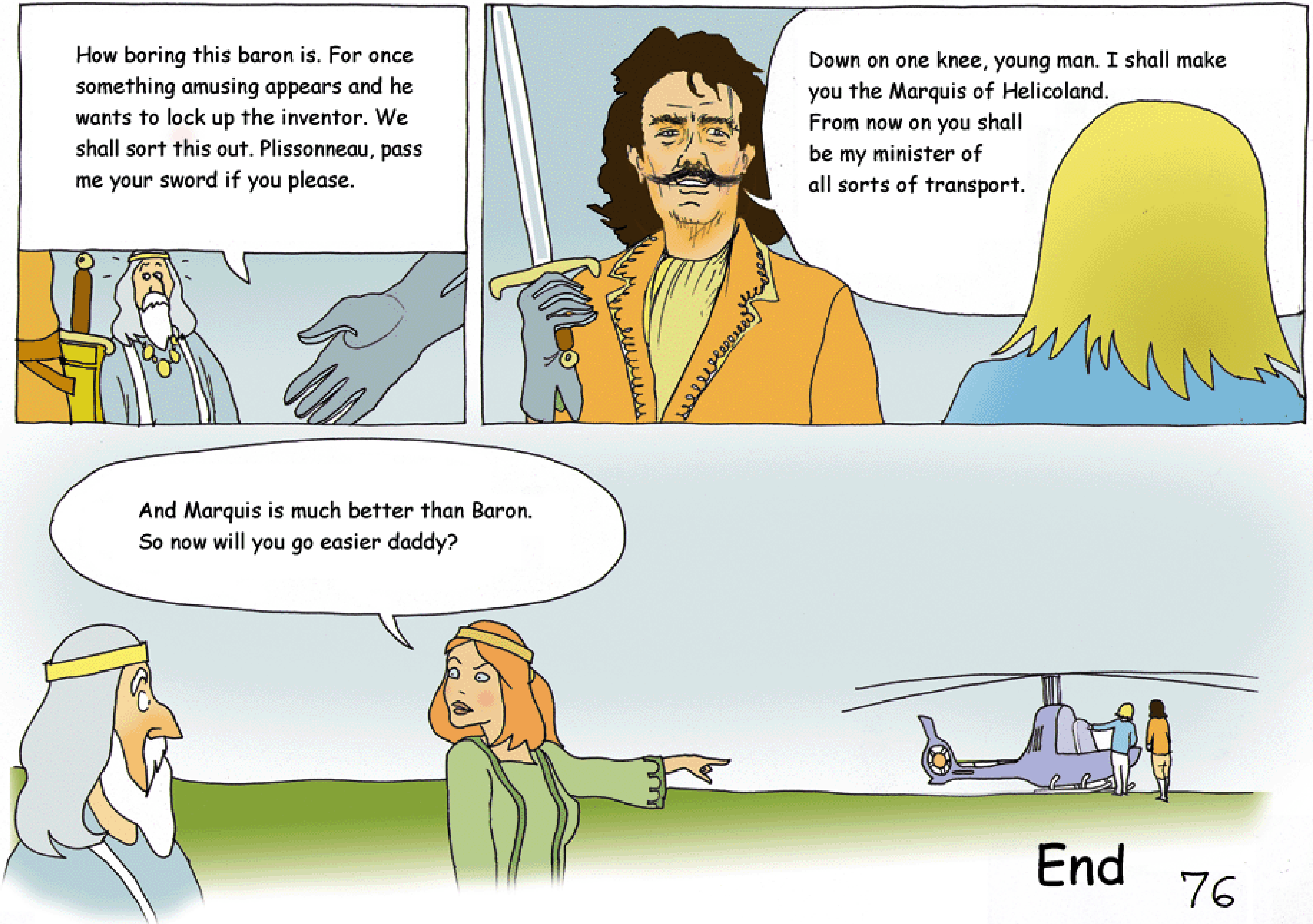
(*) $V_{(m/s)} = \sqrt{2gz} = \sqrt{20\,z_{(meters)}}$

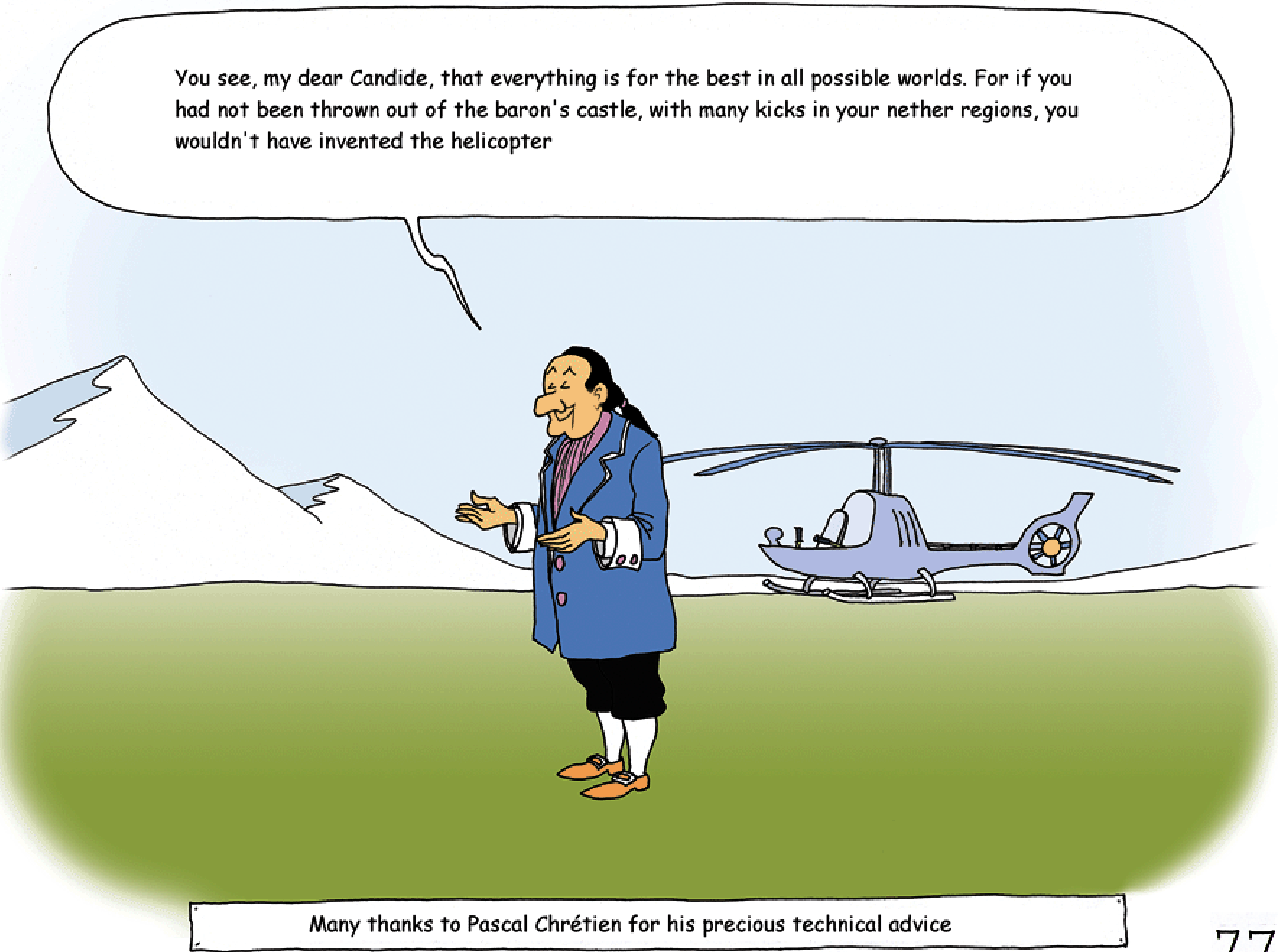
♥ Maximum value: around 1,5 for most of machines




FLARE
Rotor's motor part (autorotating)
V_x
I'll have to improvise ...
At ten meters up Candide pulls the joystick hard and maintains the collective pitch at minimum. The machine lifts up its nose and the blades are attacked with a stronger relative wind incidence, which increases the motor part of the autorotating rotor. It then converts the translation's kinetic energy into rotational energy. Then he pushed the joystick.
Then he pulls down the collective pitch lever. The airflow inverts. The rotor then goes from an "autogyro" regime to a "helicopter regime". By using the ground effect he uses the energy stocked by the rotor (*)
(*) This maneouvre consumes a lot of adrenaline


Sir...
His majesty is very interested by your remarkable demonstration on your flying sparrowhawk
My what?
Ah, there you are, miserable, vile subordinater! You'll finish your days in one of my jails.
What's all this noise about?
Sire, I didn't recognize you. This young man wishes to marry my daughter. But he is not of noble descent so cannot pretend so.


How boring this baron is. For once something amusing appears and he wants to lock up the inventor. We shall sort this out. Plissonneau, pass me your sword if you please.
Down on one knee, young man. I shall make you the Marquis of Helicoland. From now on you shall be my minister of all sorts of transport.
And Marquis is much better than Baron. So now will you go easier daddy?
End


You see, my dear Candide, that everything is for the best in all possible worlds. For if you had not been thrown out of the baron's castle, with many kicks in your nether regions, you wouldn't have invented the helicopter
Many thanks to Pascal Chrétien for his precious technical advice