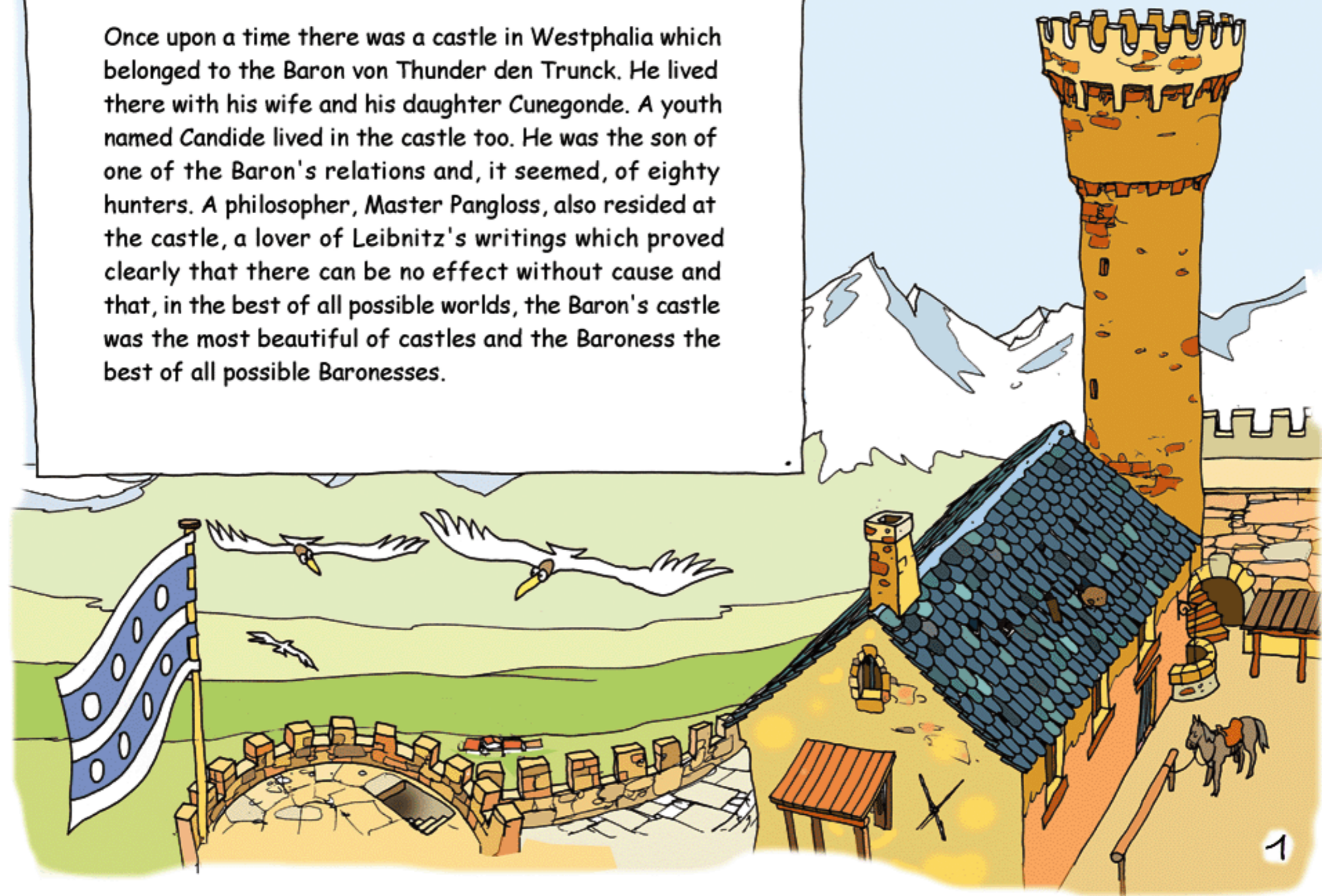


VERTICAL PASSION

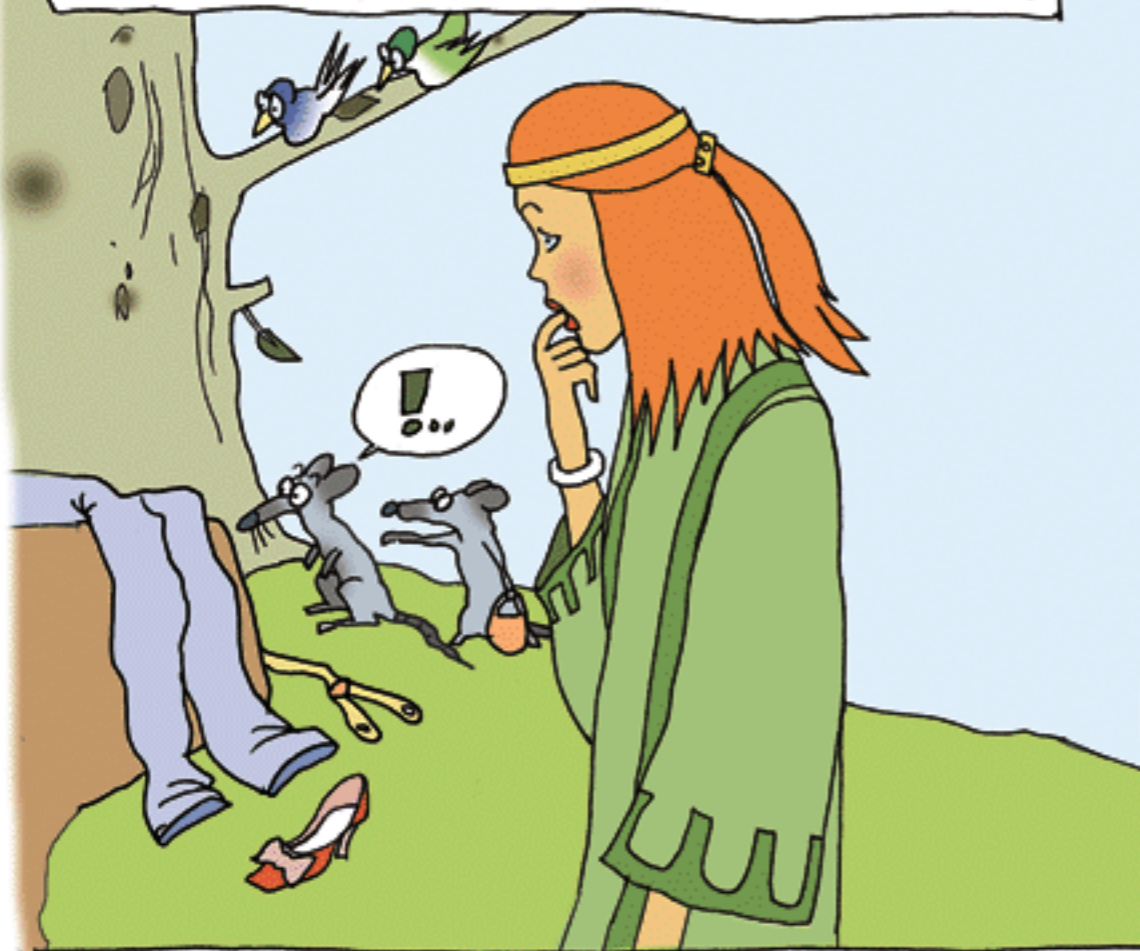
Jean-Pierre Petit



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.



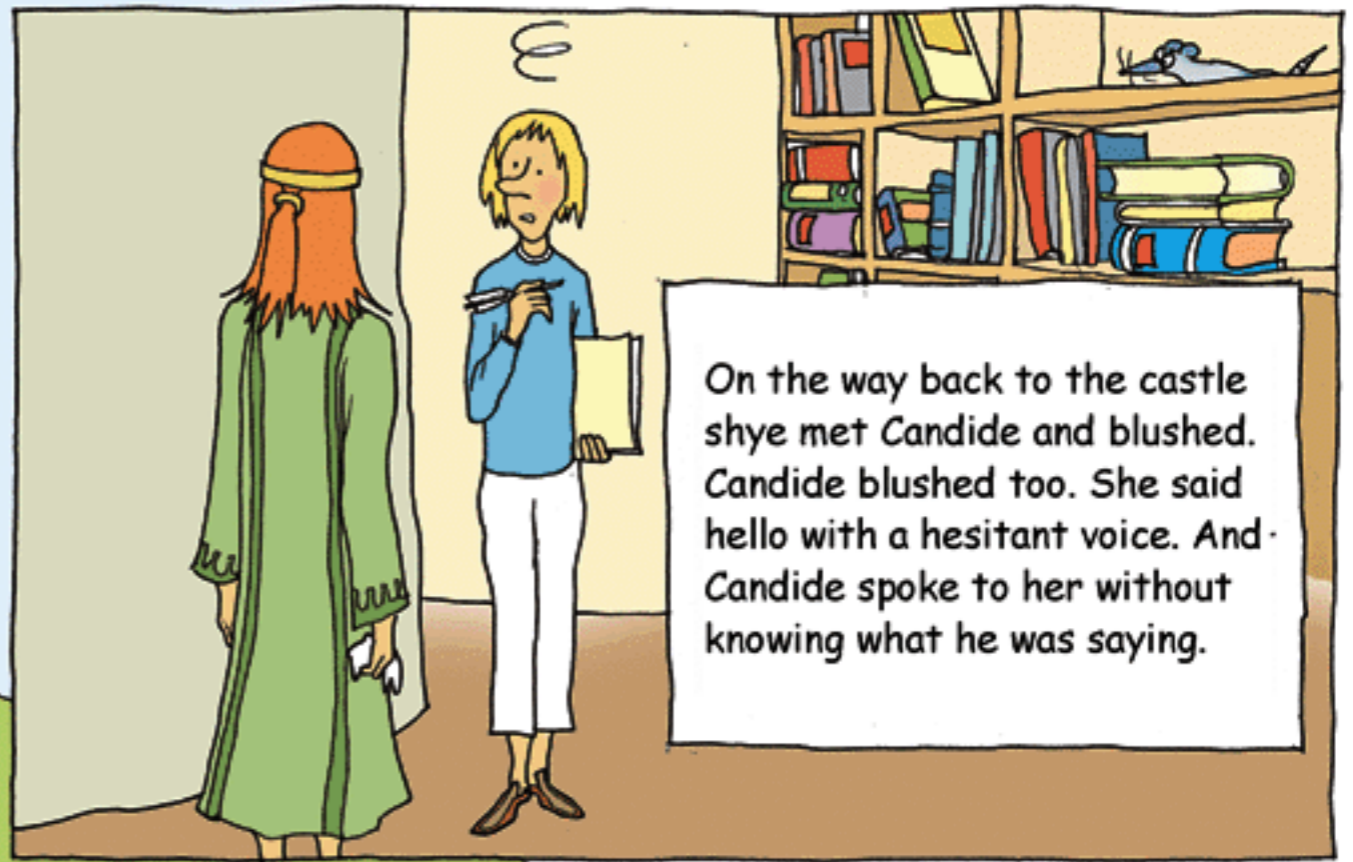
One day young Cunegonde, aged seventeen, saw professor Pangloss giving a lesson in experimental physics to Baroness's chambermaid in a wood near the castle. Having a special liking for science she observed the many experiments that she witnessed. (*)



She followed clearly the reasoning of the doctor, effects and causes, and went home very agitated and thoughtful, with a great desire for instruction.



On the way back to the castle she met Candide and blushed. Candide blushed too. She said hello with a hesitant voice. And Candide spoke to her without knowing what he was saying.





Cunegonde dropped her handkerchief. Candide bent down to pick it up. She did the same. Their hands touched, their knees trembled



their lips touched, their hands wandered. The Baron, passing that way, saw this scene, its effects and its causes (*).



The baron chased Candide away, kicking him in the backside (*)

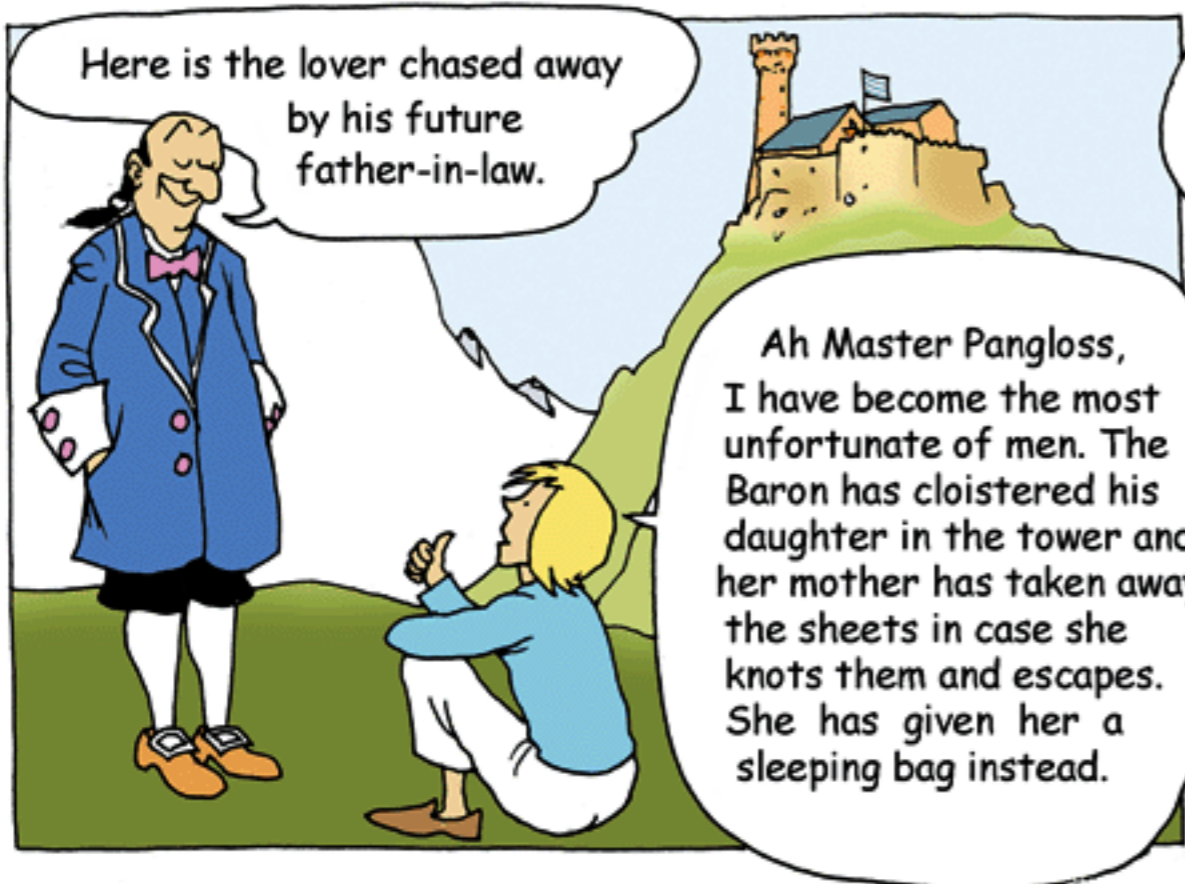


The Baroness told off Cunegonde and shut her up in a room at the top of the castle watchtower.



And everything was upset in the best of all possible castles.

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



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.

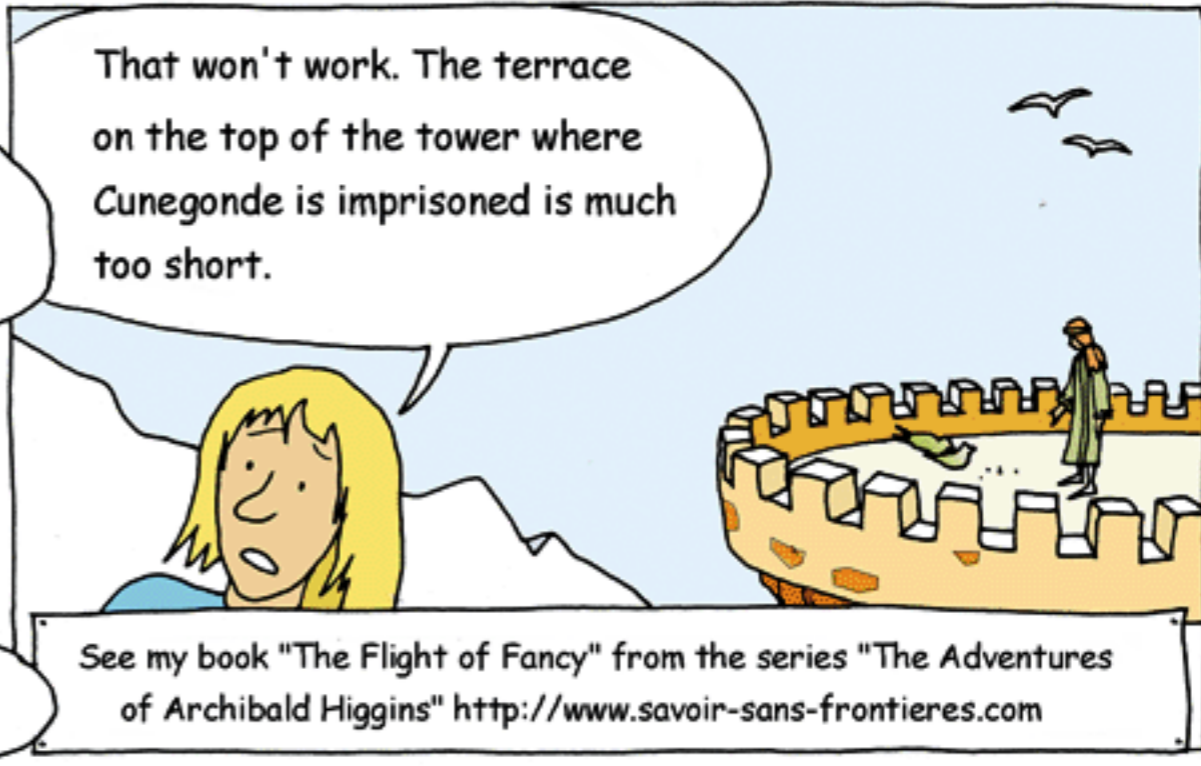
Maybe I can do something for you.



I have a flying machine: an aeroplane.

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>

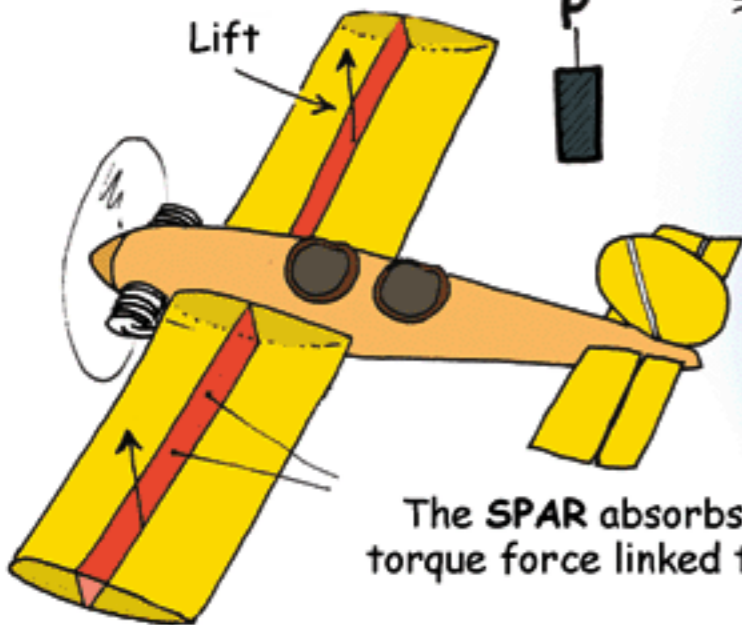
I should be able to reduce the distance needed by approaching at a lower speed. The lift on the wings is proportional to the incidence?. By nosing up the plane I should be able to fly a lot more slowly.



Like on crane jibs.



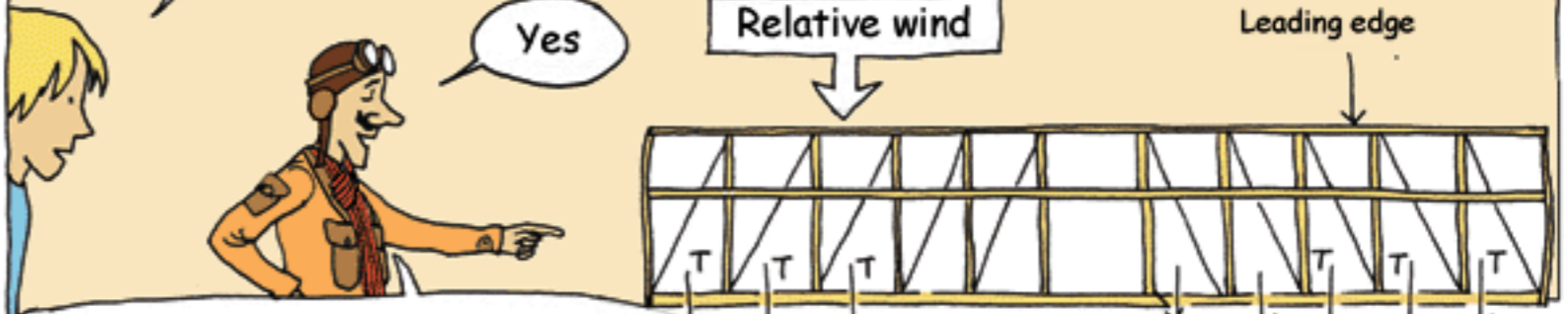
The bars work as **TRACTION**



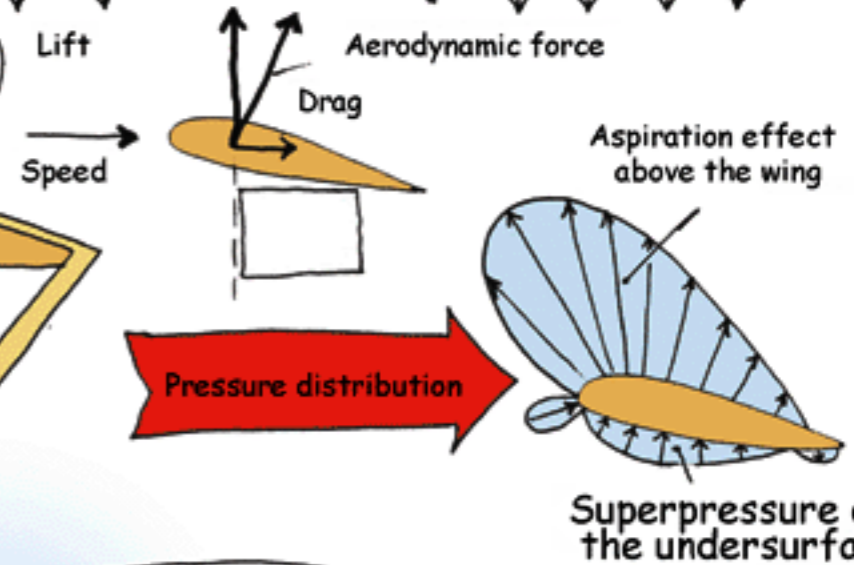
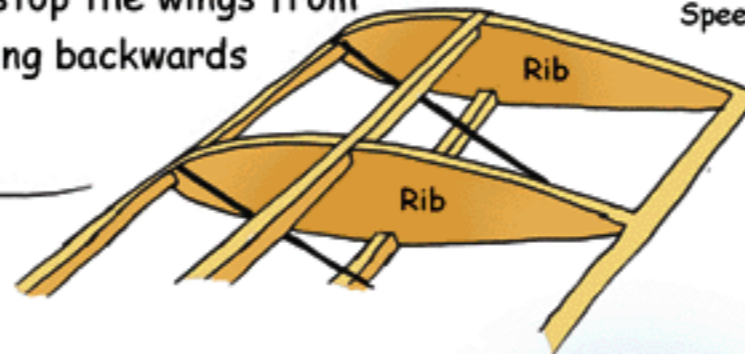
The **SPAR** absorbs the torque force linked to **LIFT**.

So it's this wing that allows you to remain in the air?

Yes



I've added stiffening cables which absorb the strong drag forces and stop the wings from folding backwards



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

KRAAAAK!

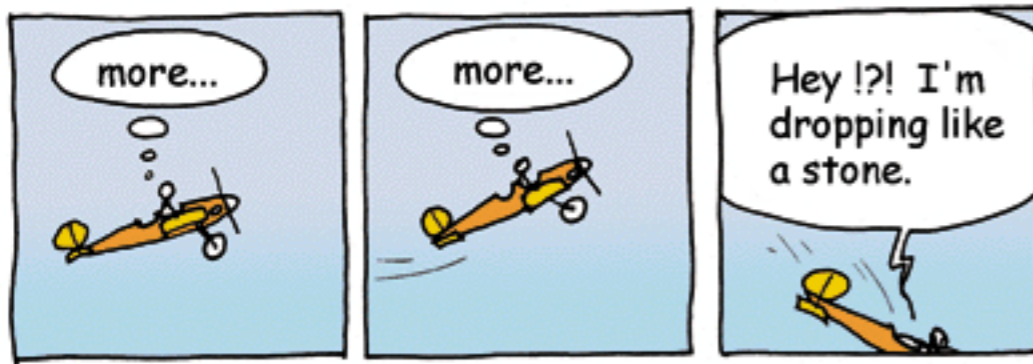
Suddenly the wings snap and fold towards the front!

!!!

OK, it's all sorted out. It just needed a second series of stiffeners to stop the wings folding forwards.

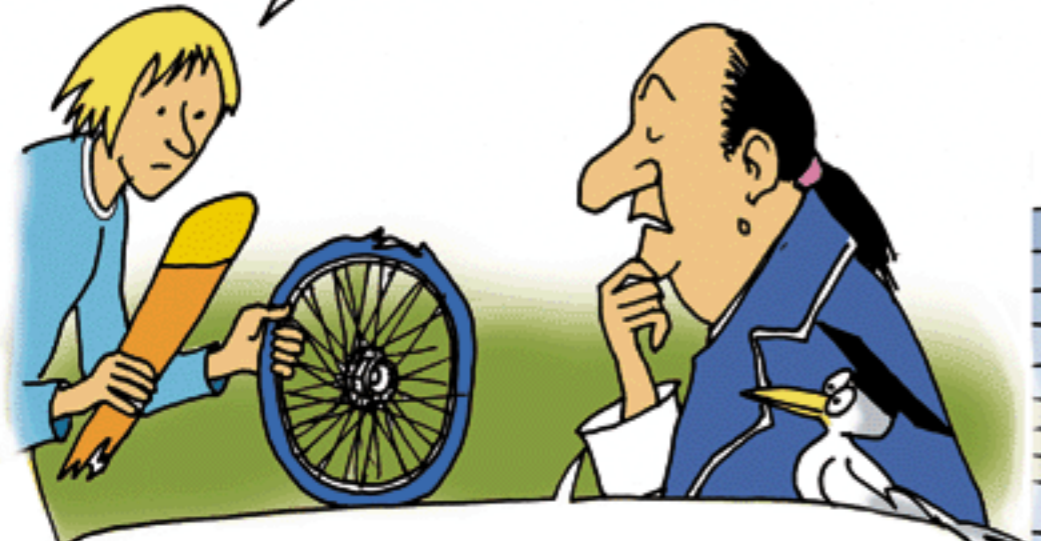
The plane is now correctly strengthened. I'll tilt it slowly.

At least, it should nose up, otherwise I'll want to know why.



STALLING

Well I won't be able to free Cunegonde with this machine. In fact I wonder if this thing has any future at all.



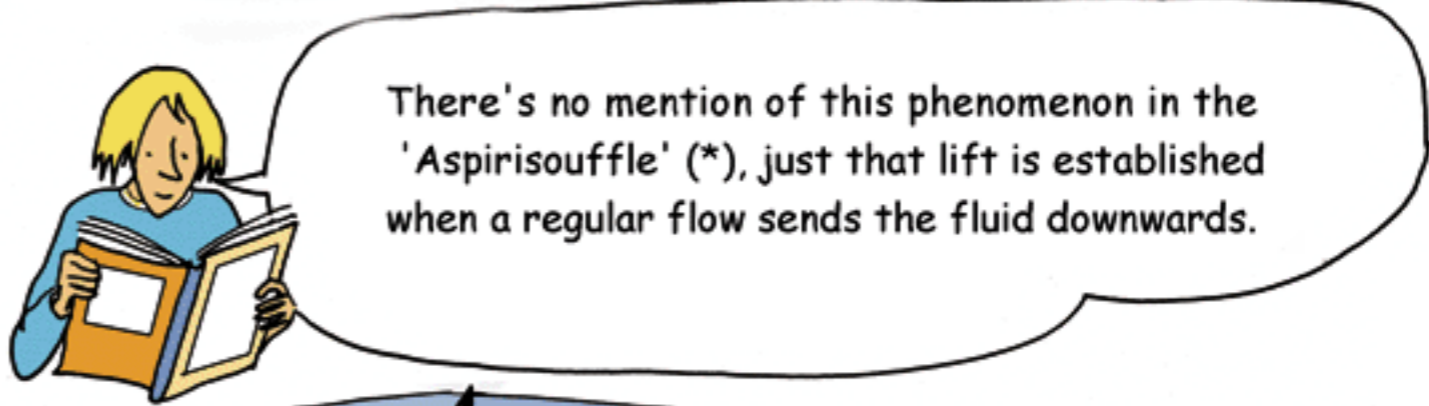
As there is no effect without cause we need to discover a good reason for this sudden loss of lift.



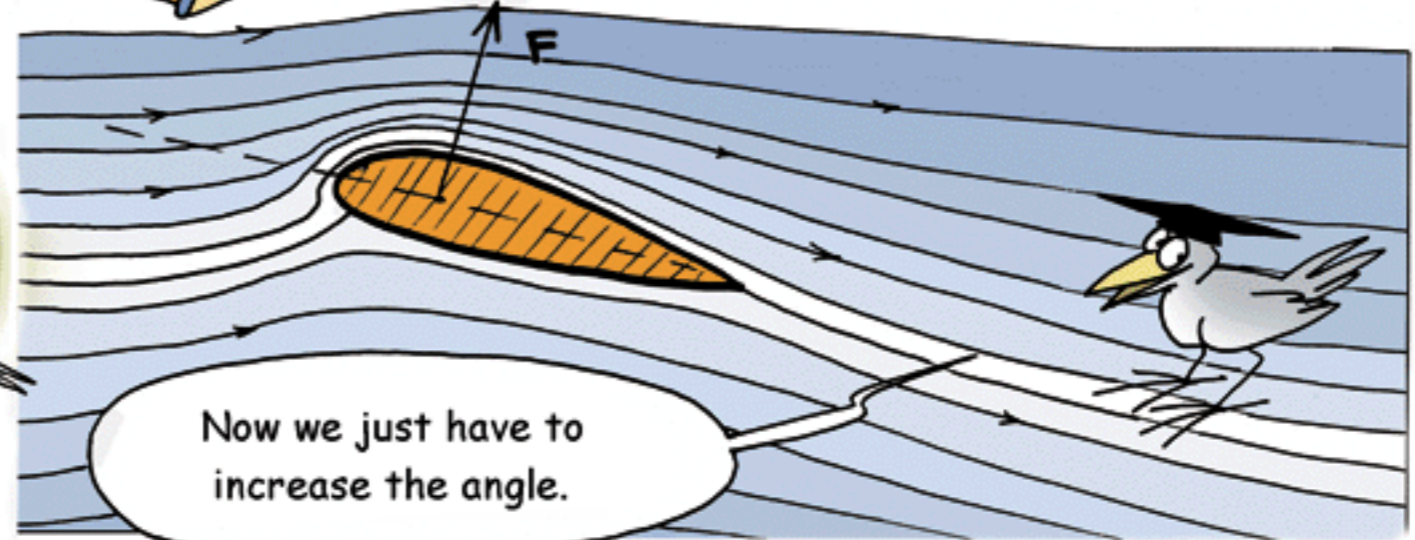
This time you were really lucky that there was haystuck below you.

What happened ?

I don't know. At a certain angle I lost all lift !?!

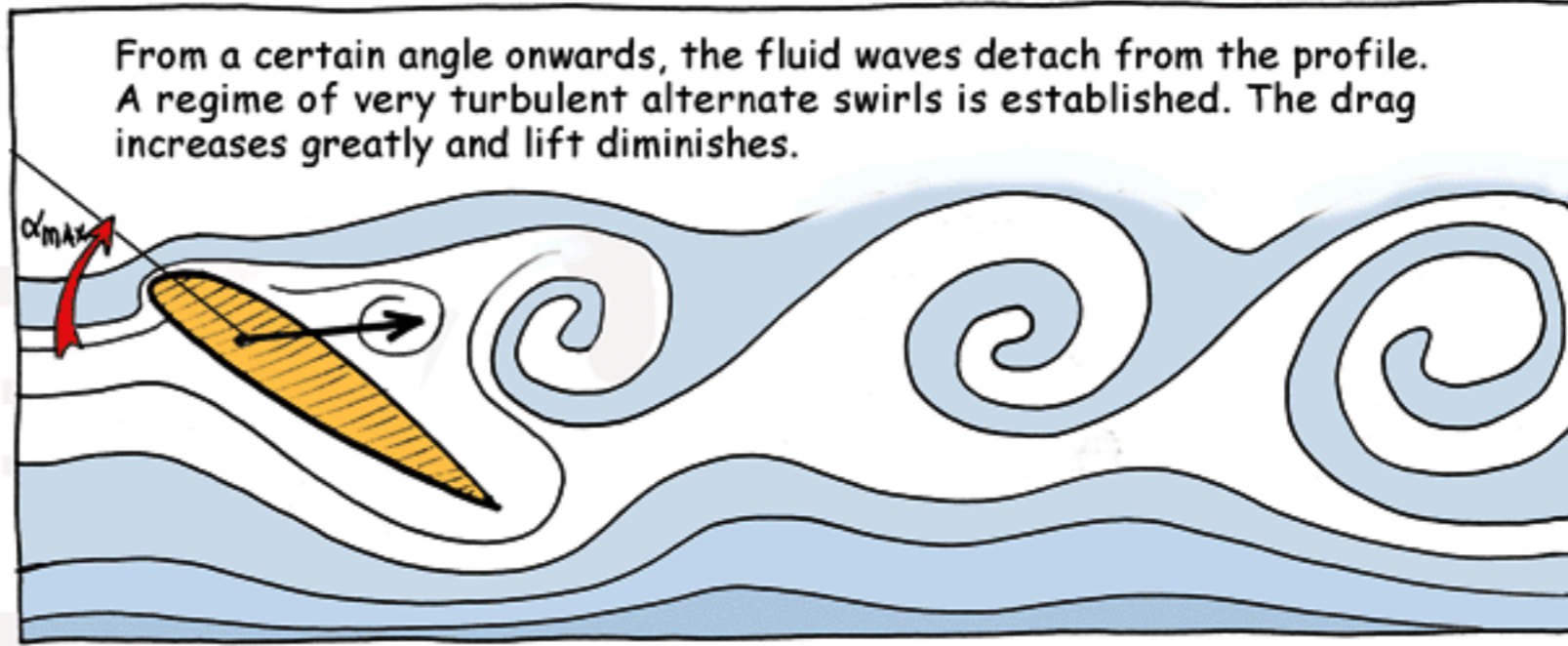
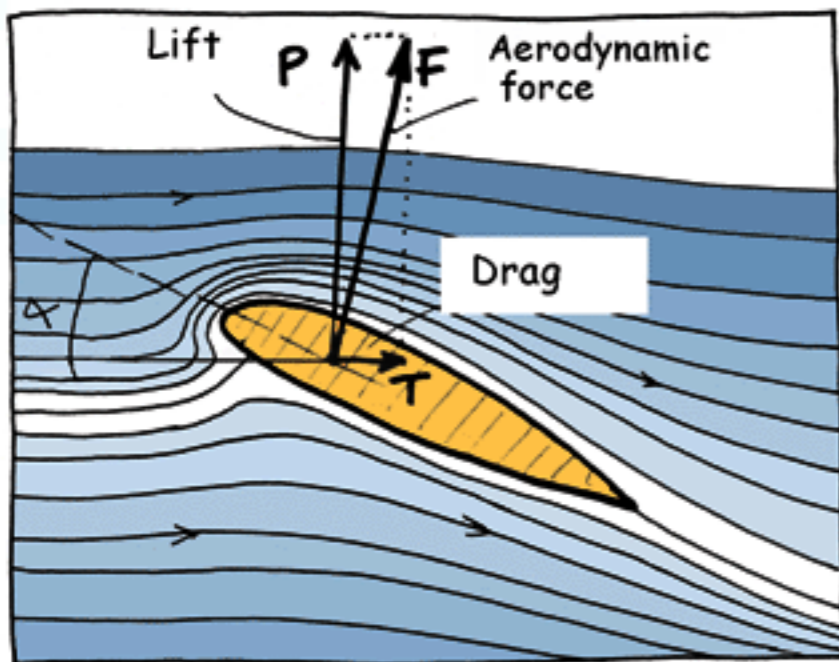


There's no mention of this phenomenon in the 'Aspirisouffle' (*), just that lift is established when a regular flow sends the fluid downwards.



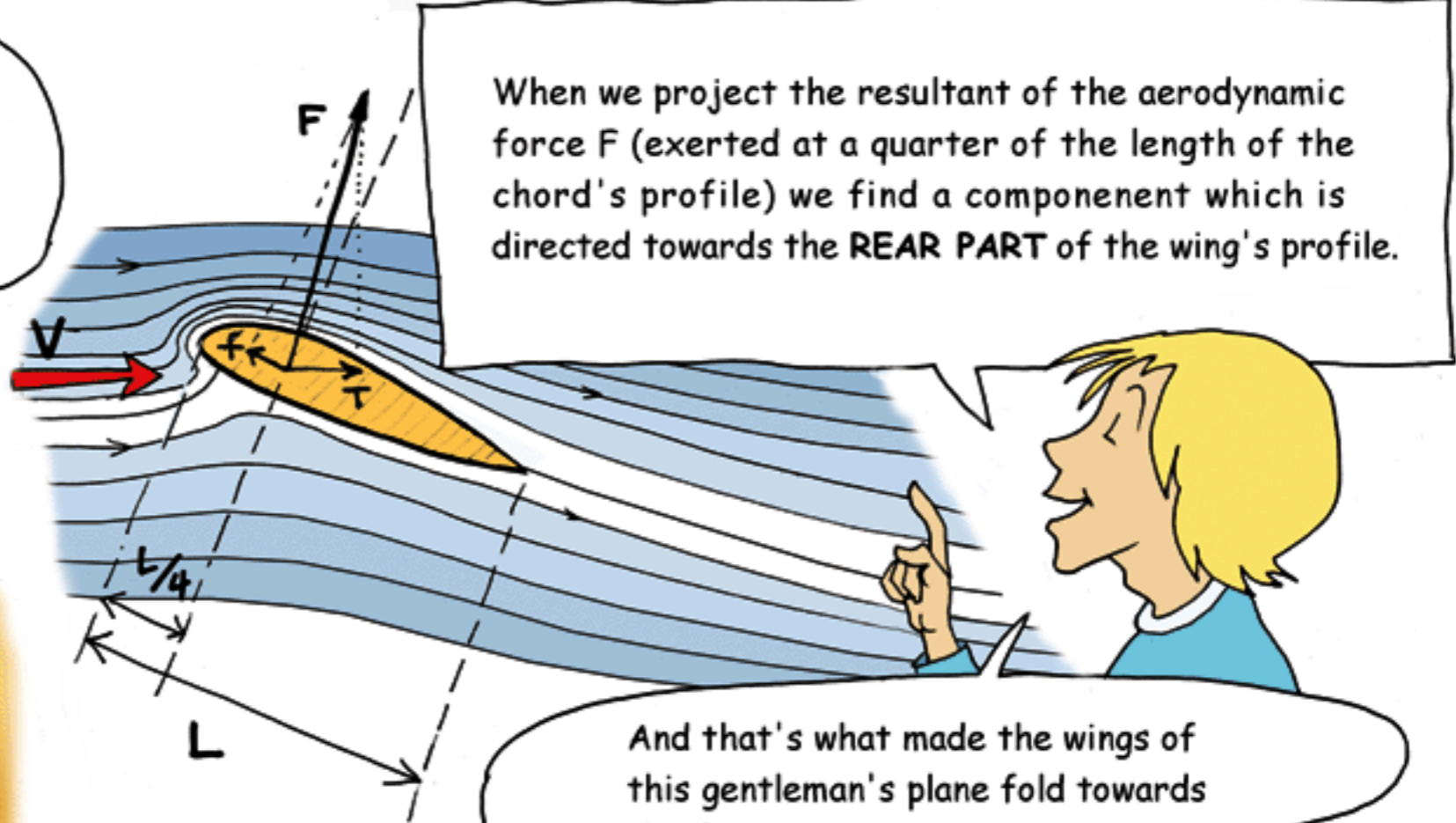
Now we just have to increase the angle.

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



When I looked at the flow map corresponding to high incidence, I noticed something.

What?



And that's what made the wings of this gentleman's plane fold towards the front.

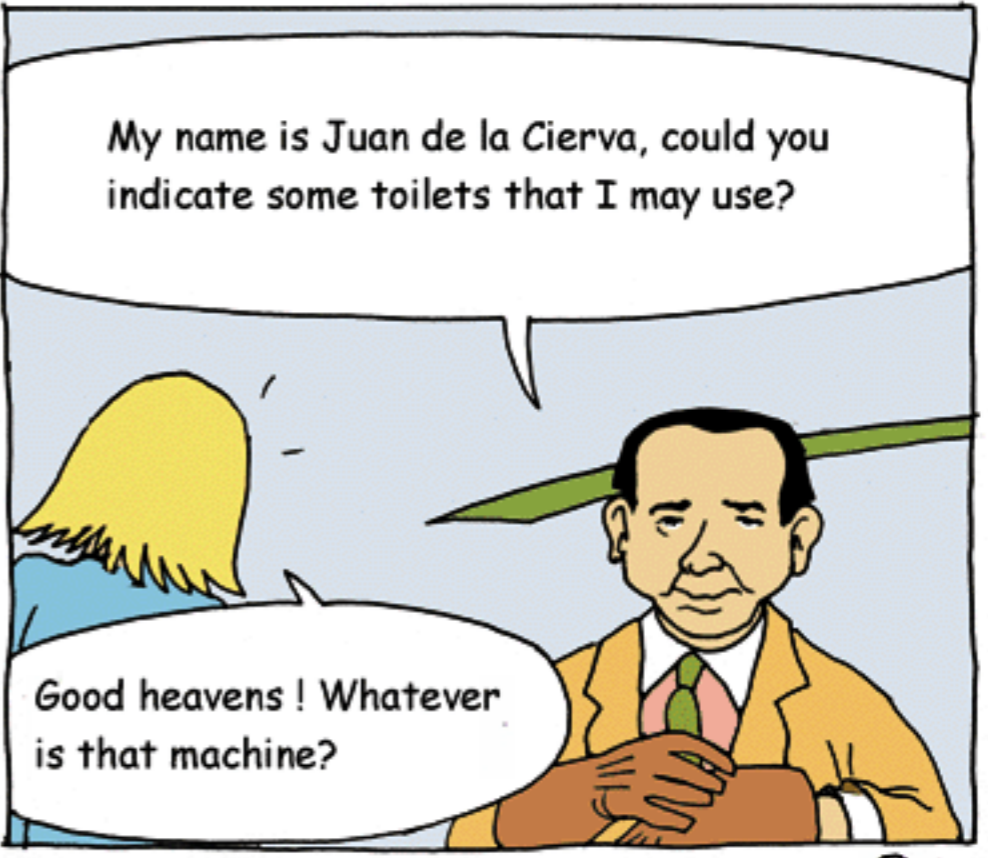
In the meantime Cunegonde wrote letter after letter to Candide



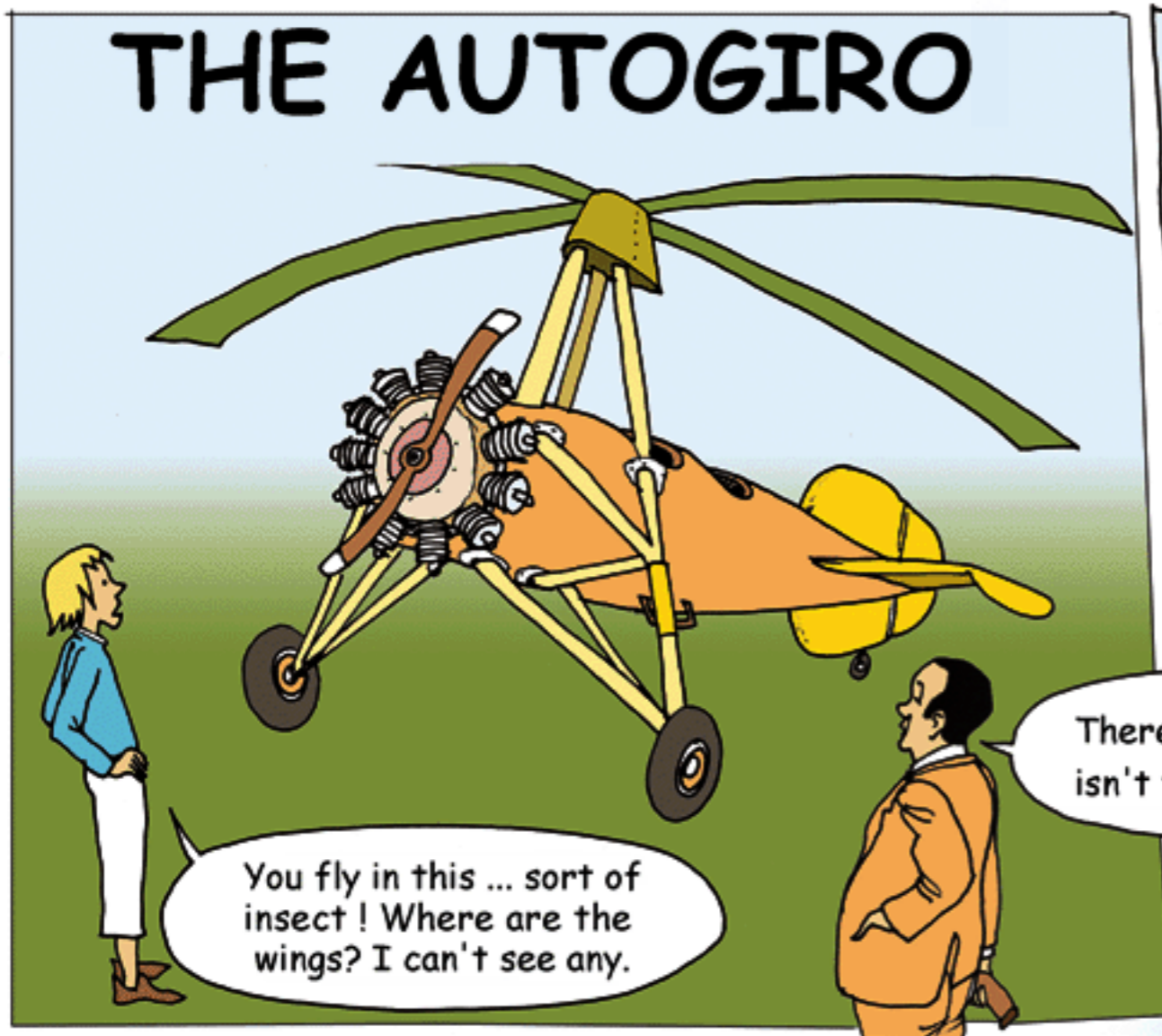
but her words were so inflamed that her missives burnt up before they reached the ground.



A balloon? No, that won't work. It's almost certain I'd miss the tower.



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?

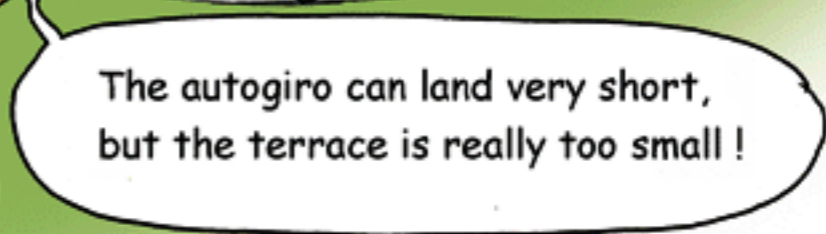
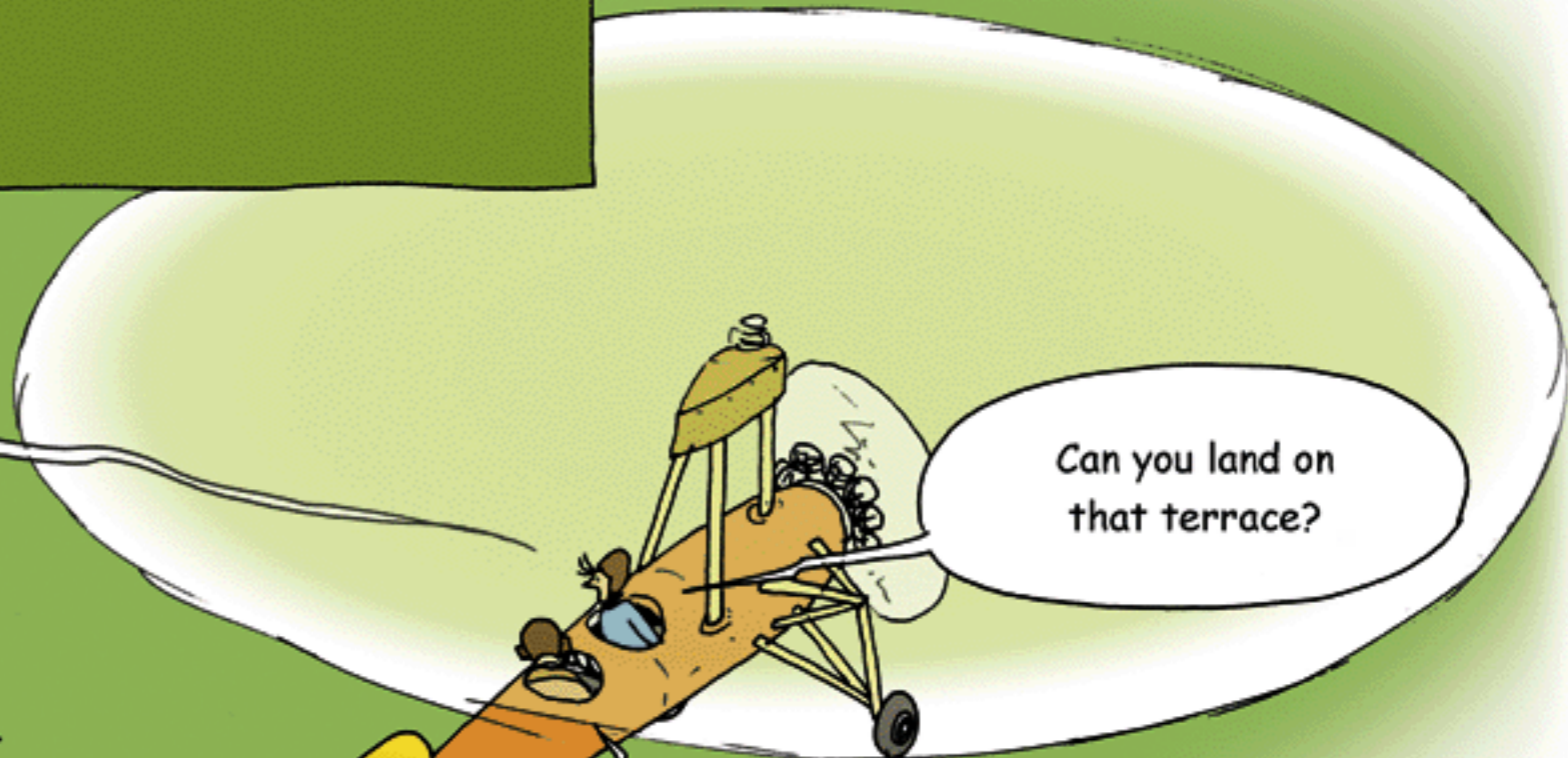
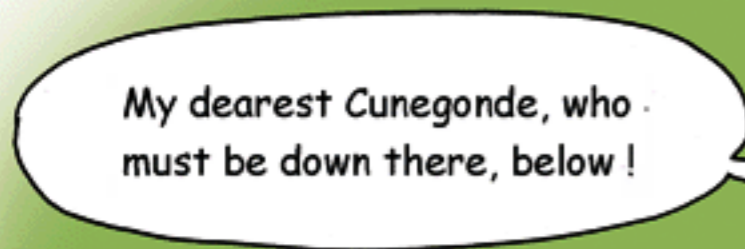
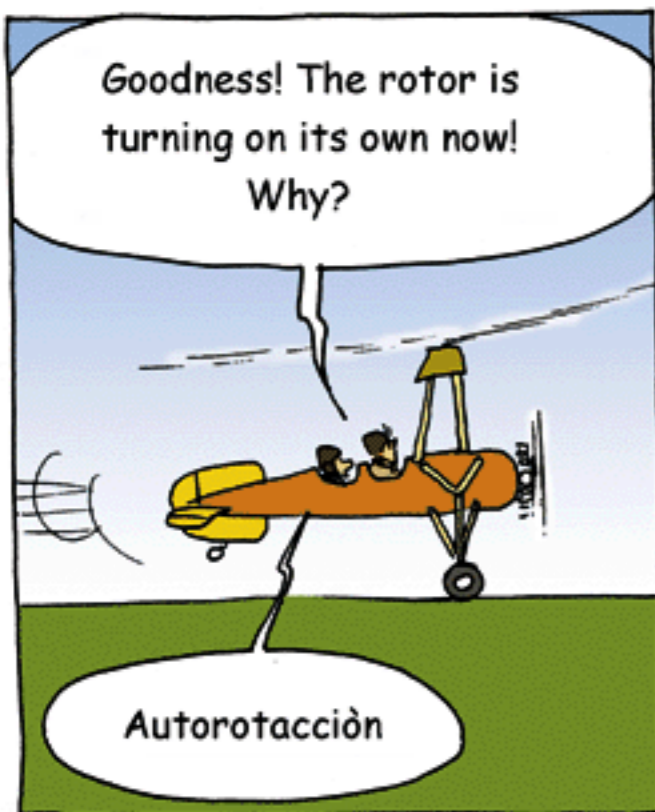
An autogiro, do you want to try it?

You mean that I have to ensure our lift by hand?

Could you make the rotor turn a bit?

The... Ah... how?

No ...



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.

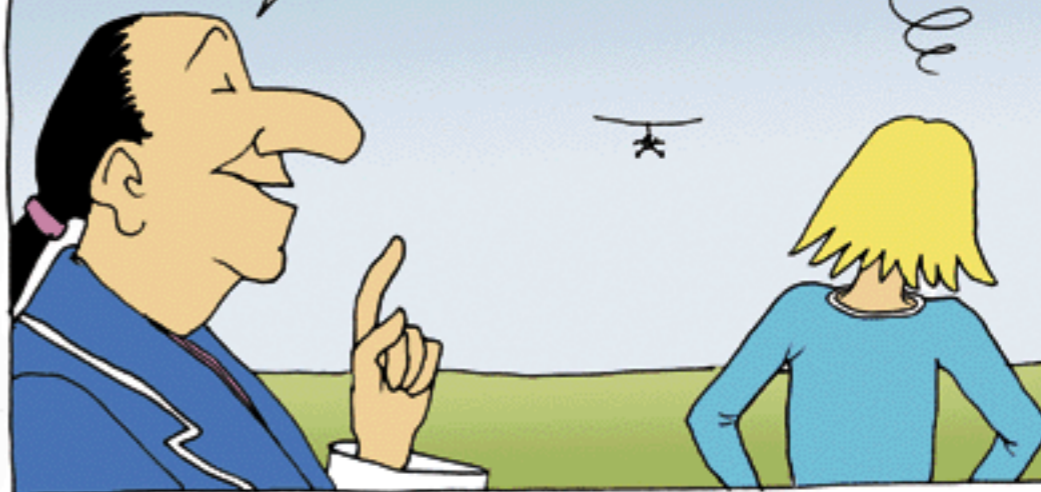


It's that him taking off in the distance, over there?

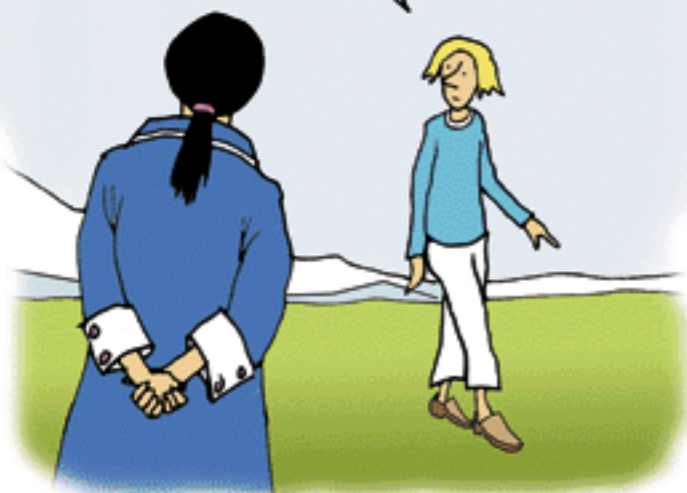
Oh misfortune! He's taking all his secrets with him. What is the mysterious force that turns the rotor?



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.



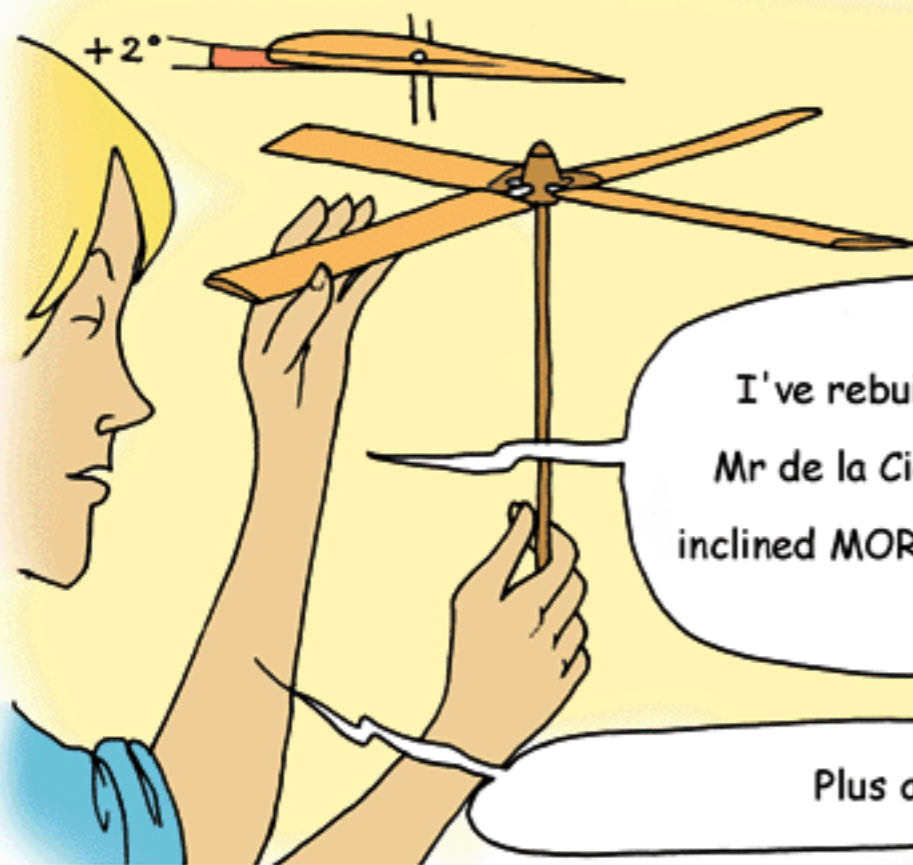
Your reasoning is most sound master, but I would like to know more...



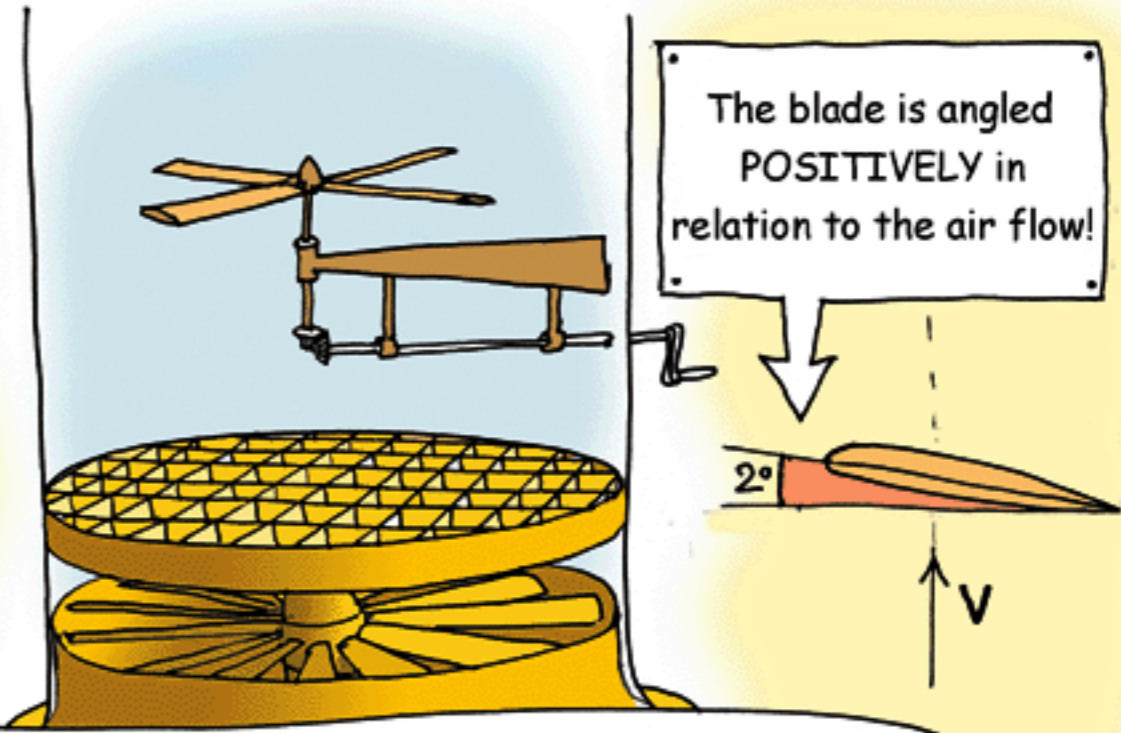
What's Candide doing?



I think he's going to recreate the air blower that led Mr de la Cierva to discover the reason for this astonishing phenomenon.

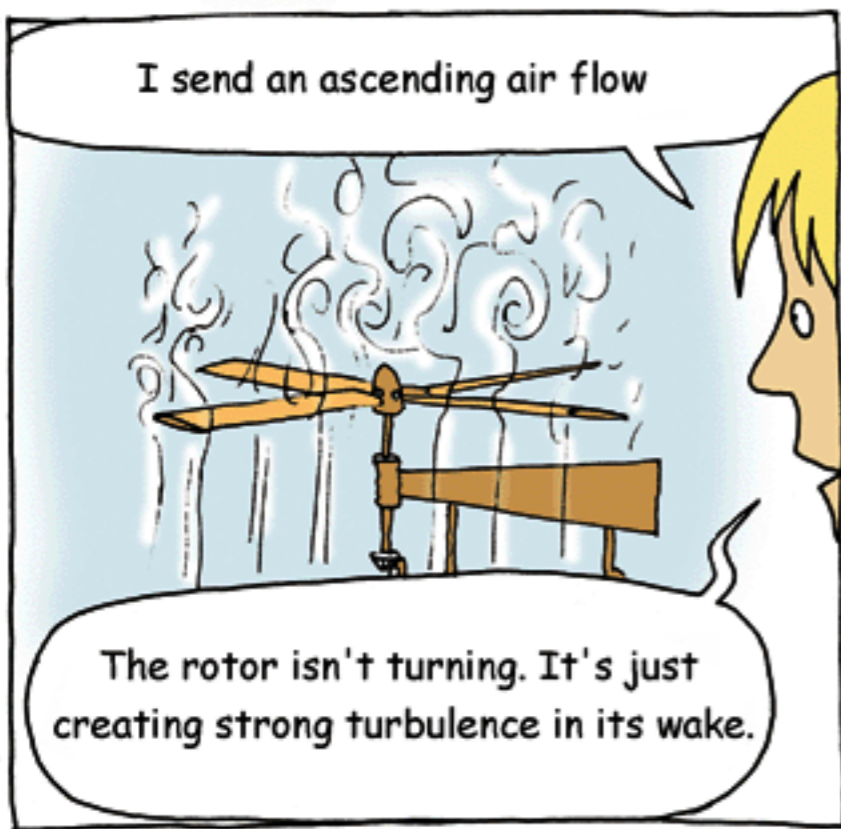


I've rebuilt the rotor of Mr de la Cierva, with blades inclined MORE than two degrees.



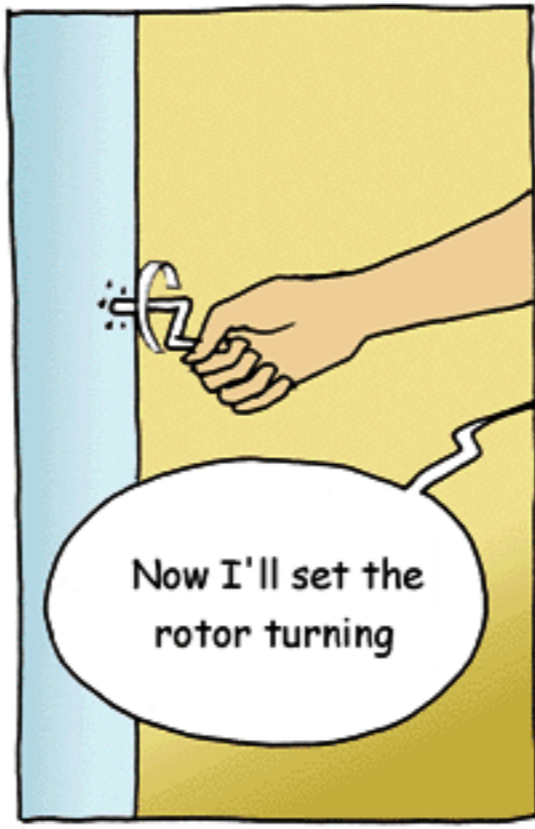
The blade is angled POSITIVELY in relation to the air flow!

Plus a vertical air-blower, a calming grid and a smoke emitter.

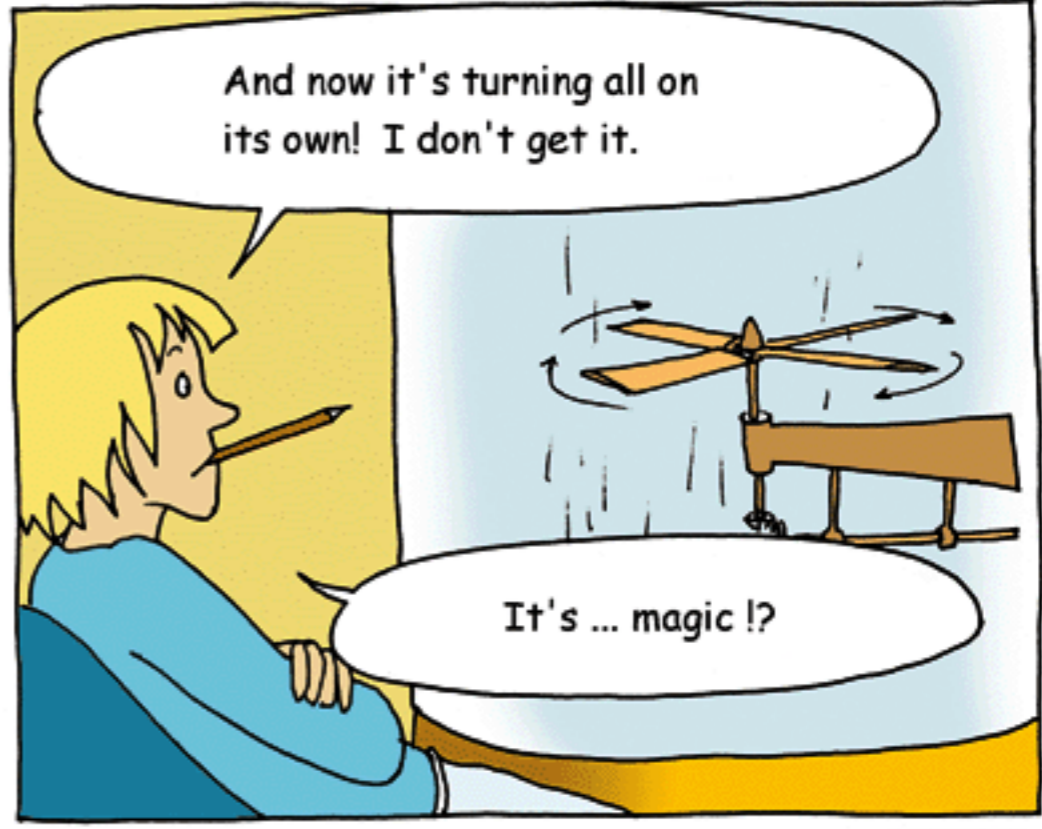


I send an ascending air flow

The rotor isn't turning. It's just creating strong turbulence in its wake.



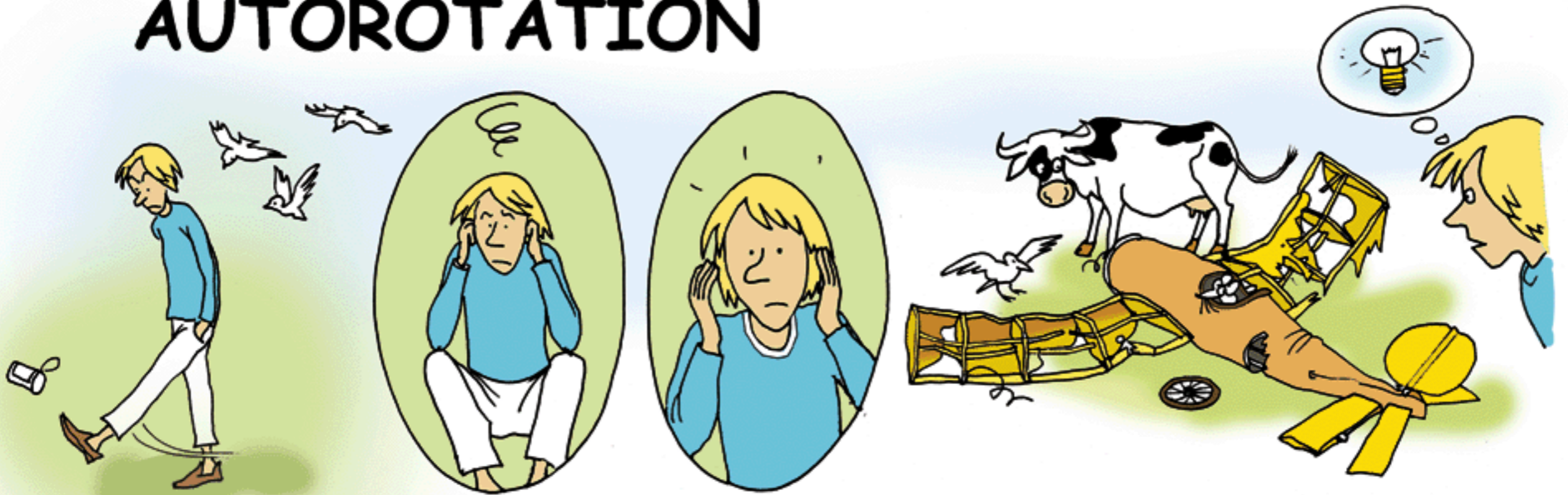
Now I'll set the rotor turning



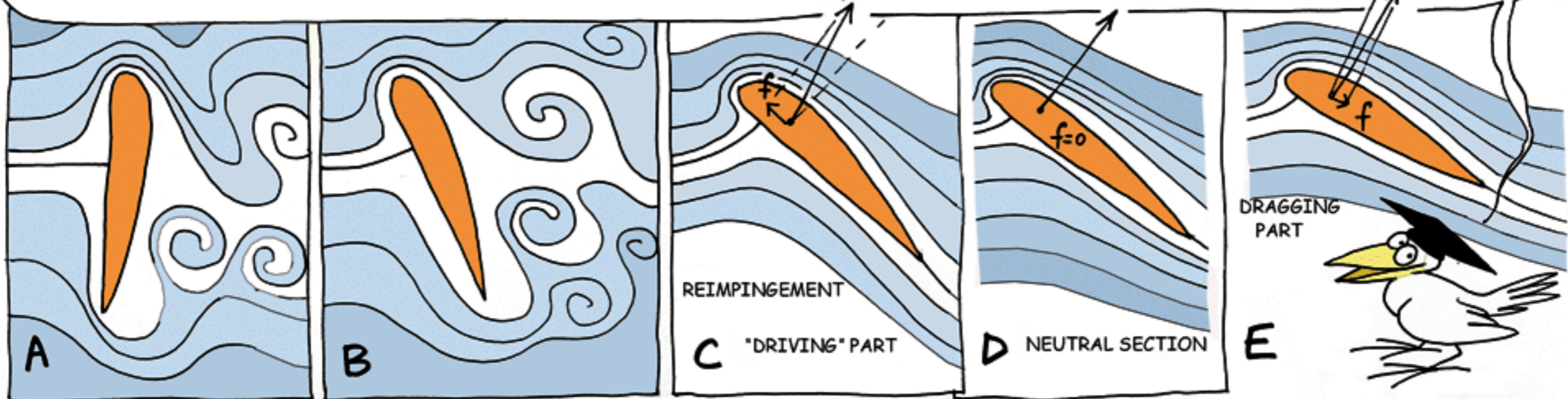
And now it's turning all on its own! I don't get it.

It's ... magic !?

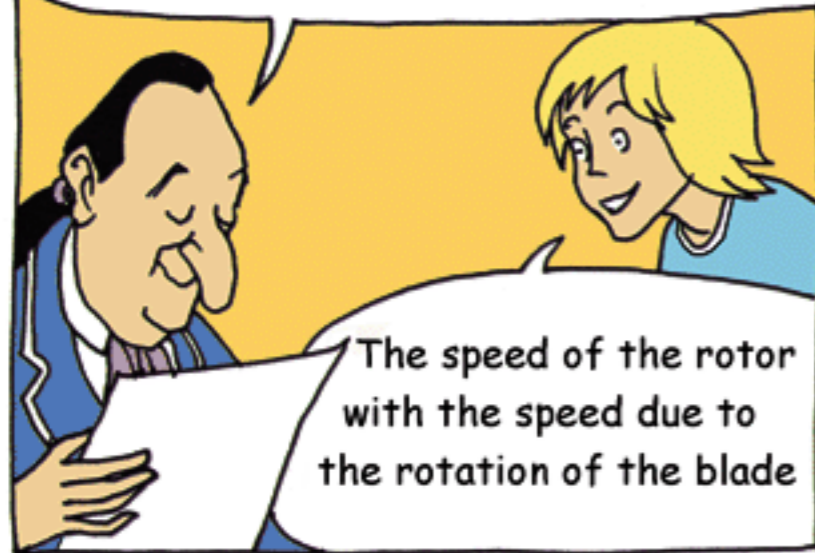
AUTOROTATION



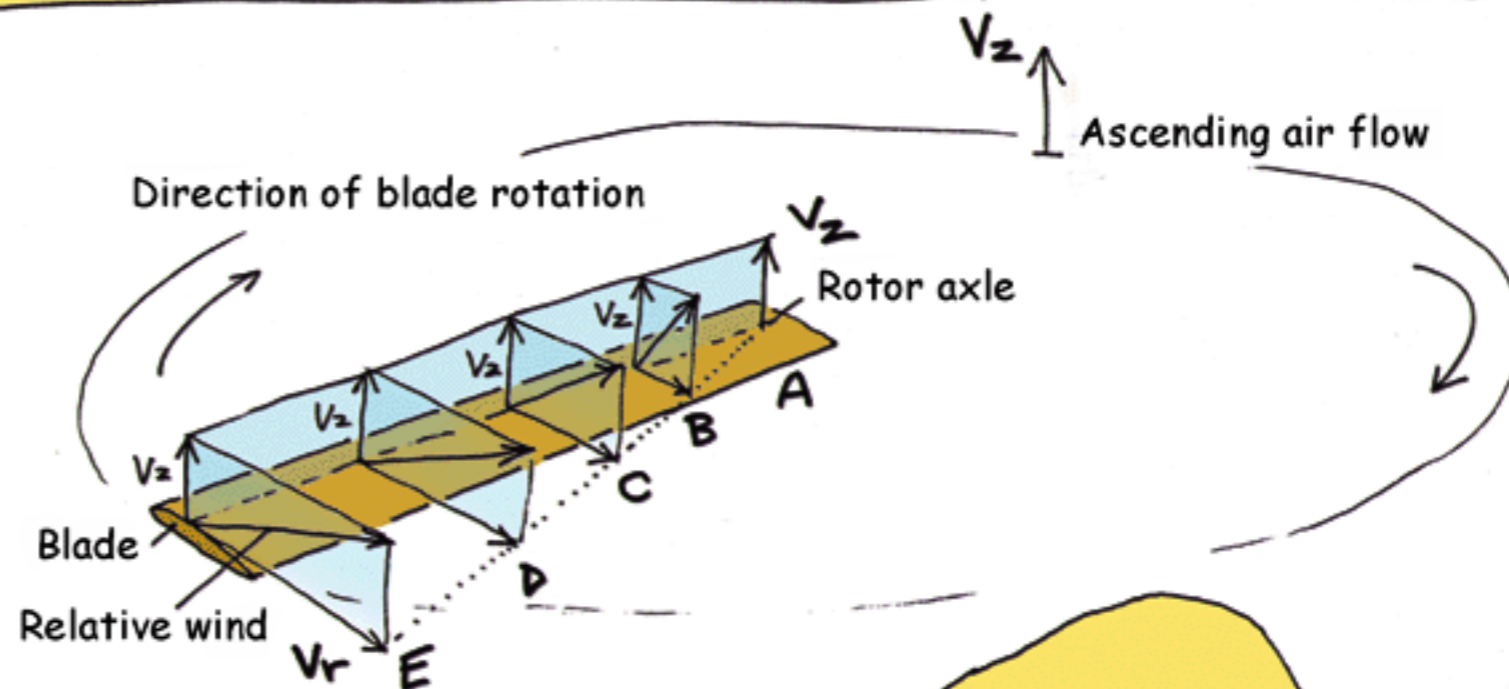
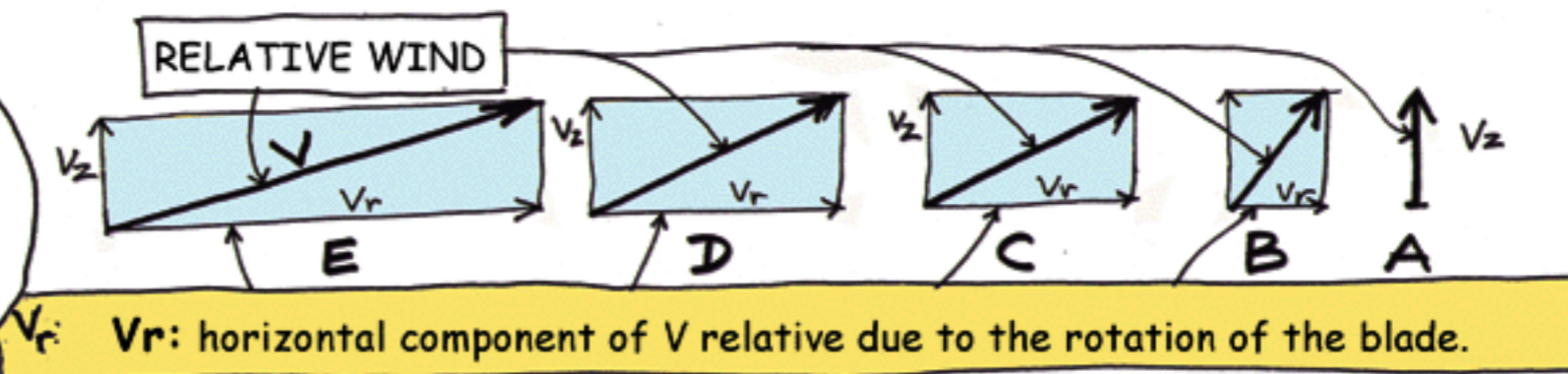
When the incidence of the blade is reduced in relation to RELATIVE WIND direction, the flow reimpinges (figure C). The aerodynamic force (component f) tends to drag the blade. In D this force is cancelled out and then inverted in E. The F component then brakes the blade's movement.



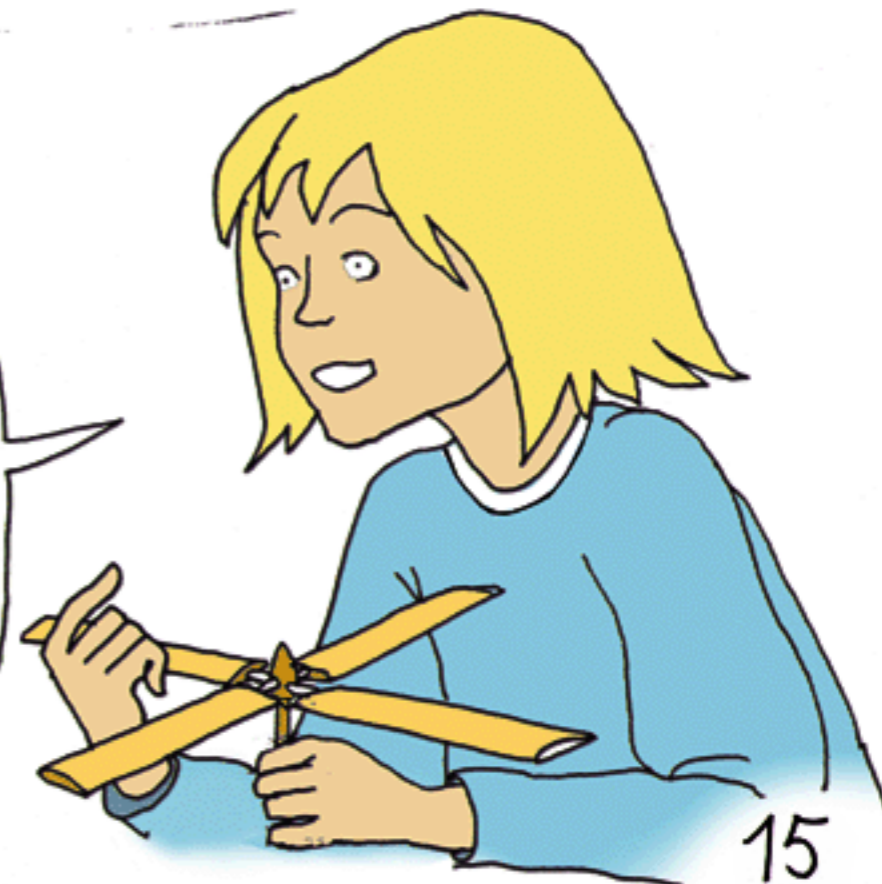
Yes I understand my dear Candide, but where does this change of direction, which you call the **RELATIVE WIND**, come from?



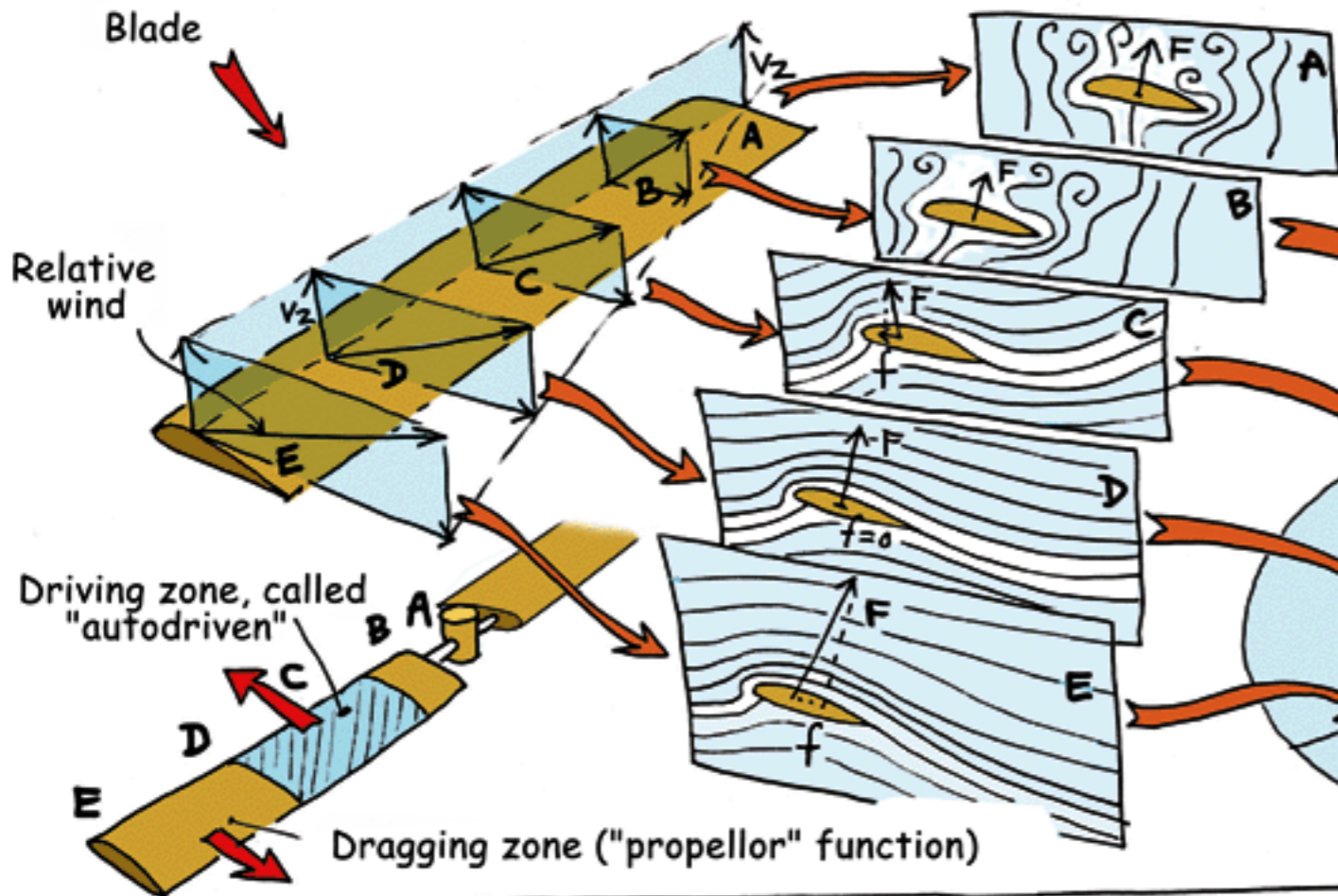
The speed of the rotor with the speed due to the rotation of the blade



The rotor is immersed in an ascending airflow which corresponds to a speed V_z . This combines with the speed induced by the rotating movement of the blade V_r , 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.



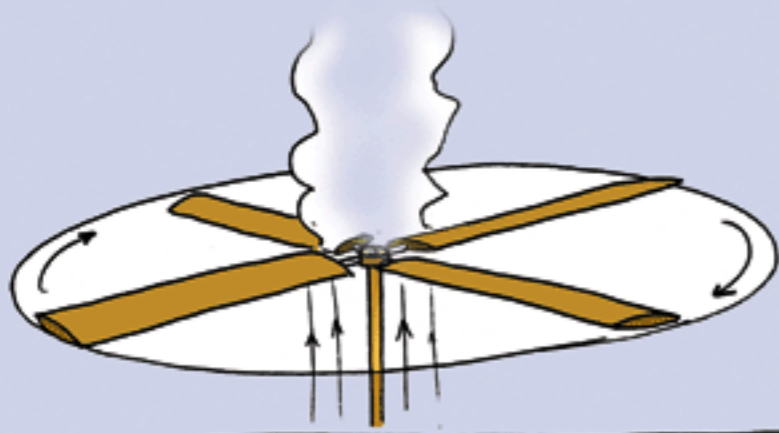
The flows vary greatly according to the way the **RELATIVE WIND** attacks the blade. To visualise it I fixed a thin tube onto the blade that sent out smoke as it turned. These are the results I obtained.



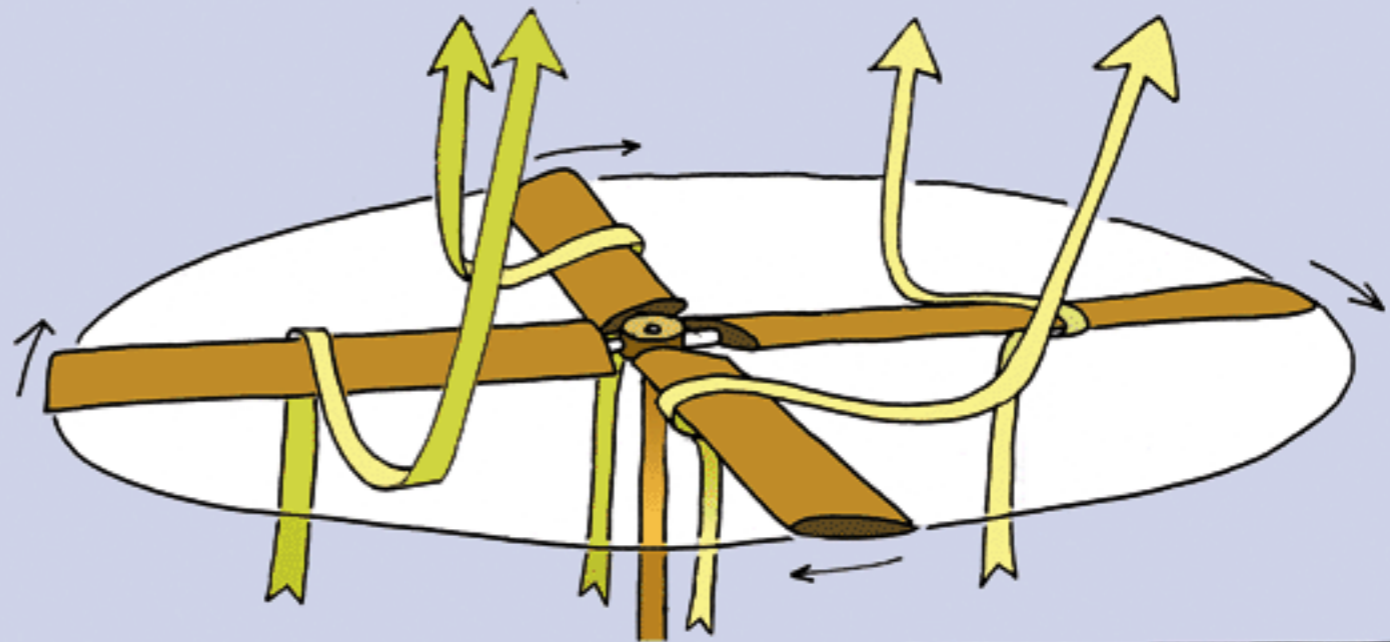
In A and B the flow has come 'unstuck'. The blade created strong turbulence. In C the flow is reattached to the profile. Aerodynamic force tends to pull the blade towards the front (driving zone, "autorotating", greyed)

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.

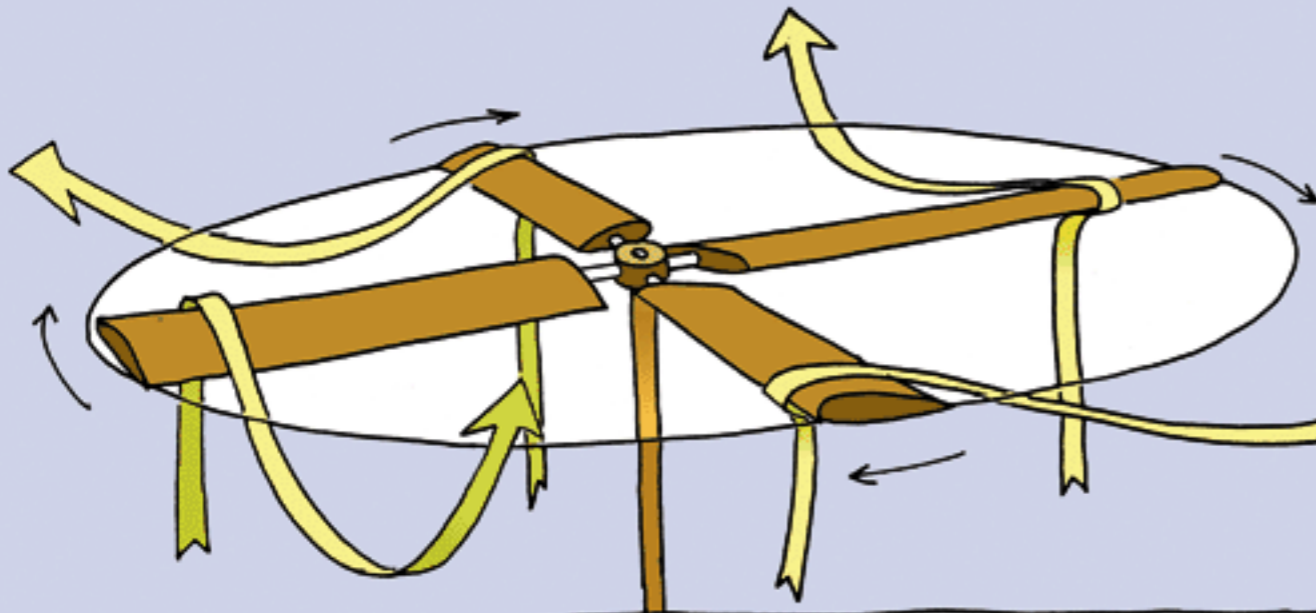
All that was experimented in a wind-tunnel by Juan de la Cierva



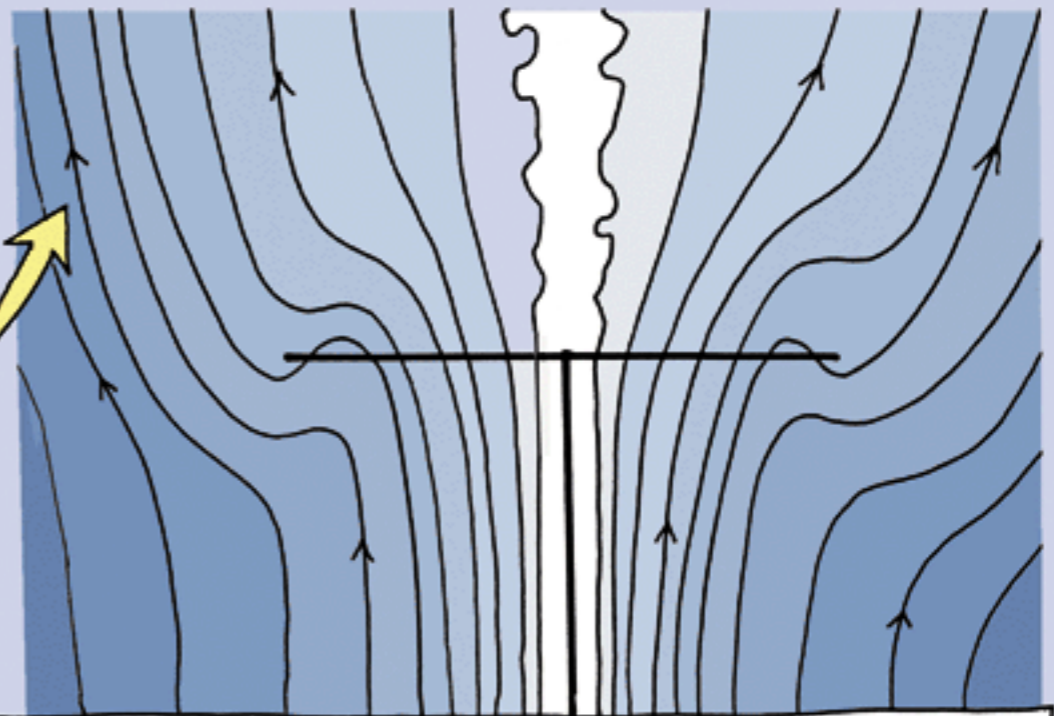
Above the central part ("detached" flow), there is a strong turbulent wake



Here the flow is reattached to the blade's edge

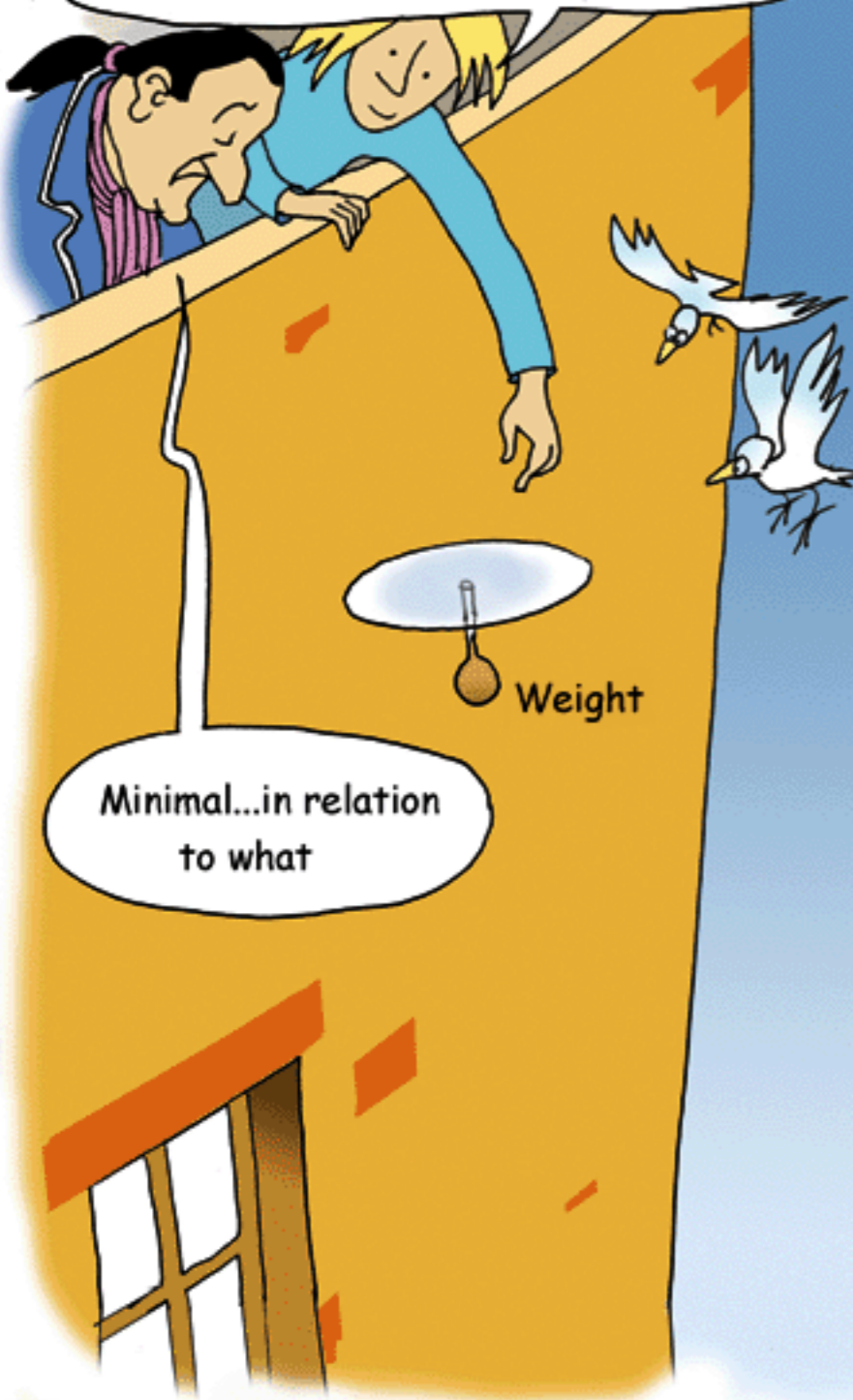


On the periphery, the impulse communicated to the air mass, directed downwards (**INDUCED SPEED**) is sufficient to push the air out beyond the disc area formed by the sweep of the blades.



This gives the rather strange airflow shown above.

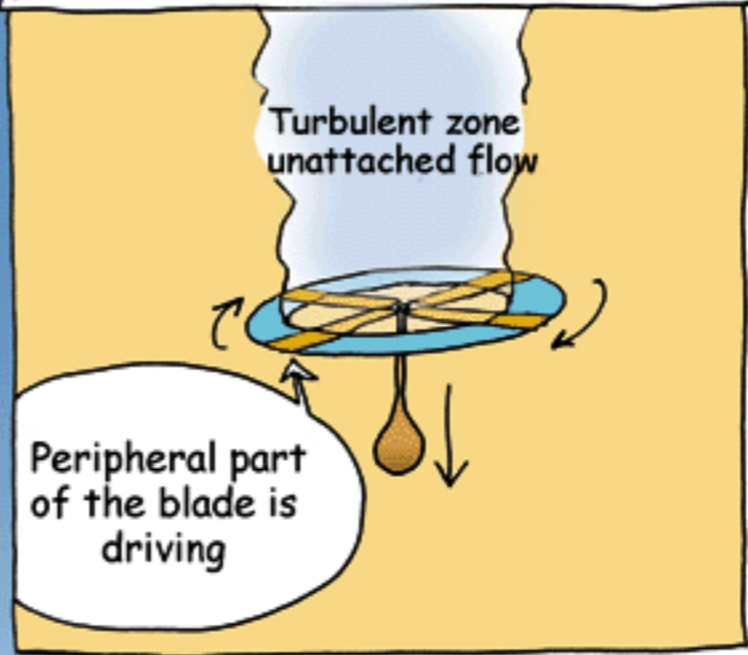
Look master Pangloss, I let go of this little model from the window after having given it a minimal impulsen



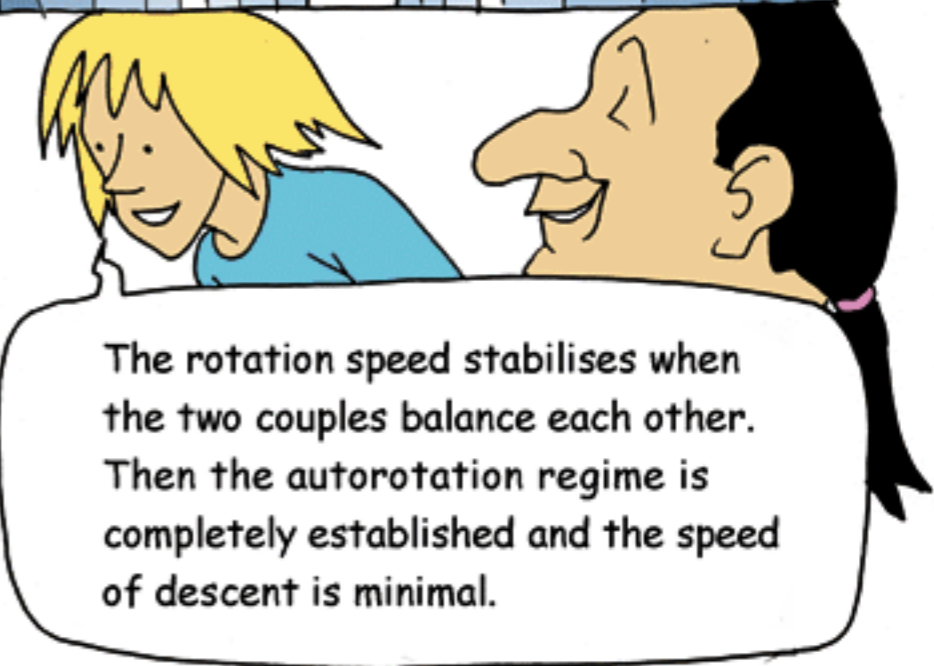
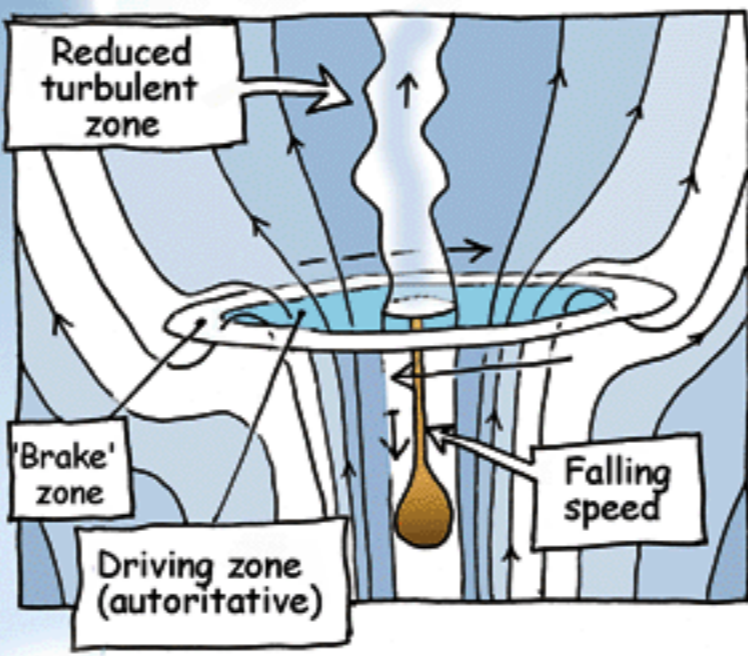
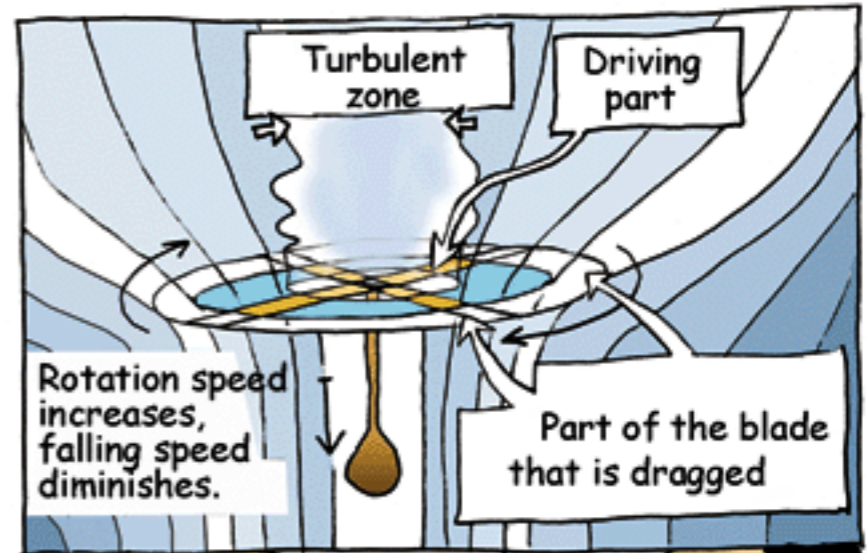
Weight

Minimal...in relation to what

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.



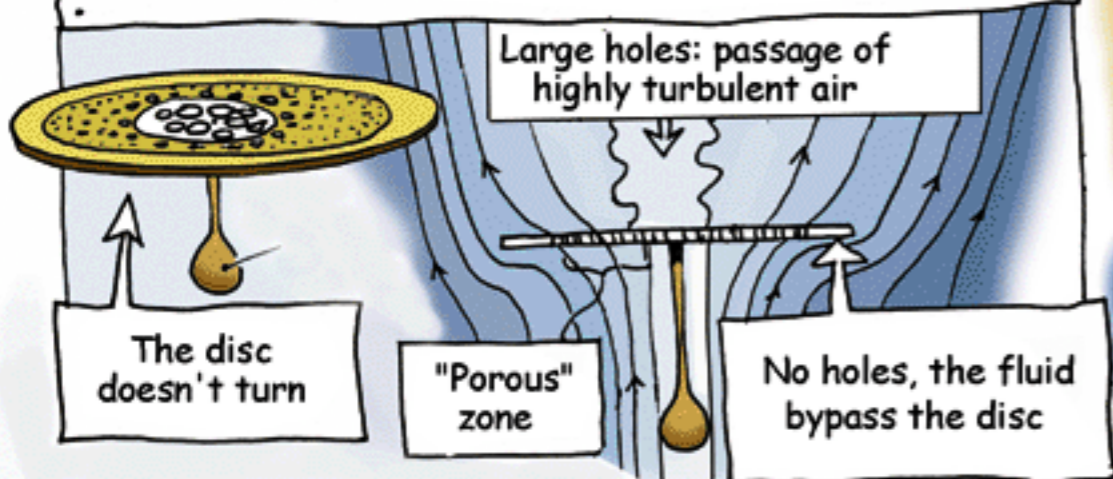
The turbulent part of the flow ("dragging") diminishes with the increase in rotation speed. A "dragging" part then appears towards the end of the blade.



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



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.

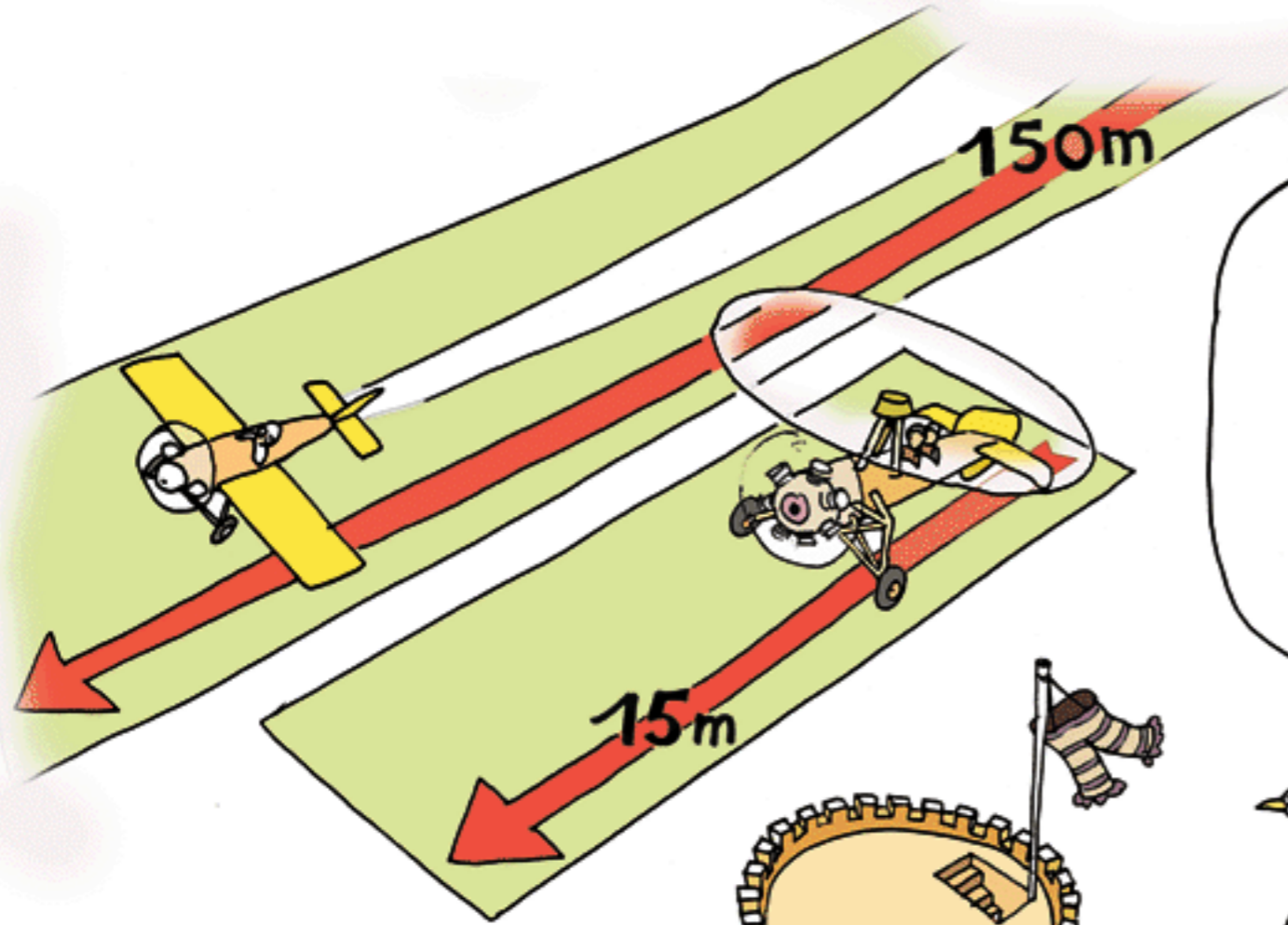
And the autogiro?

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.

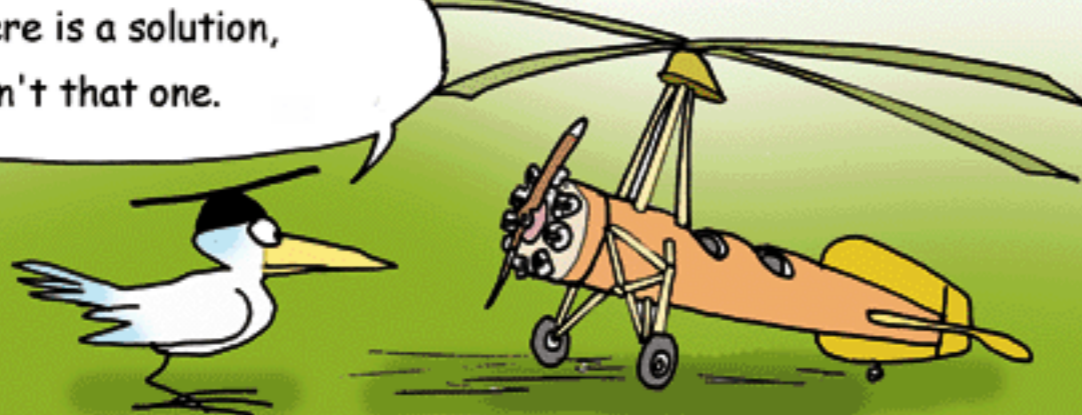
(*) e pur si muove (Galileo)



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?

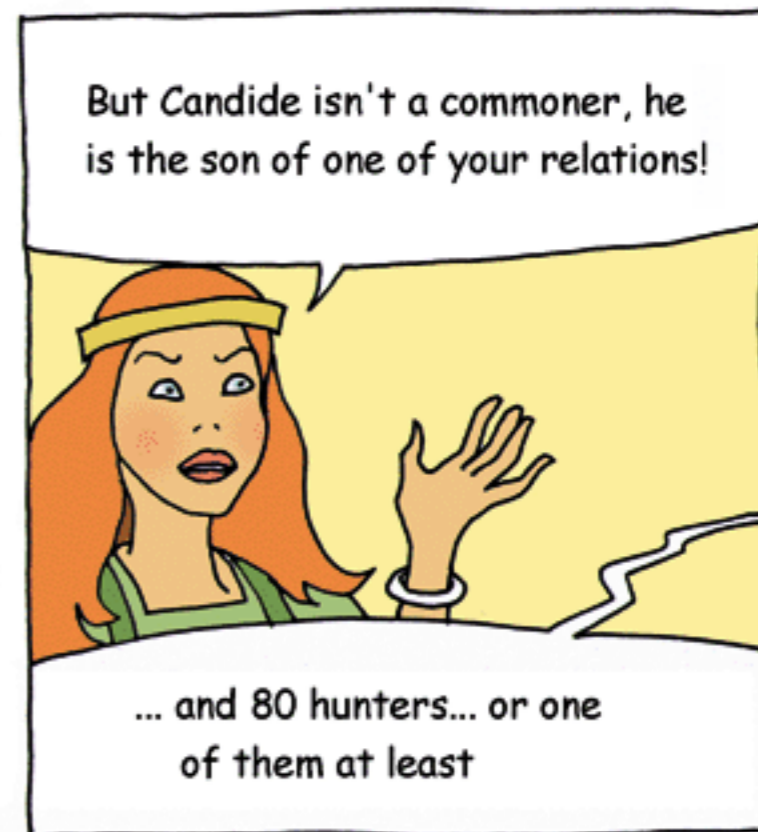
You don't understand anything about fashion my dear.



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

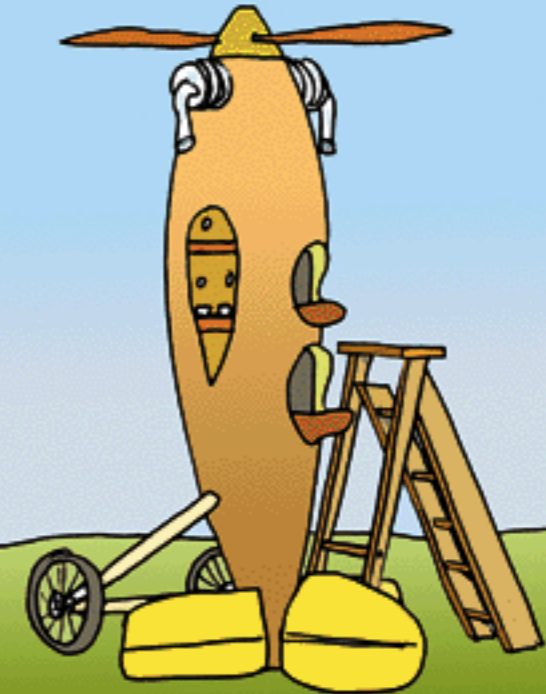
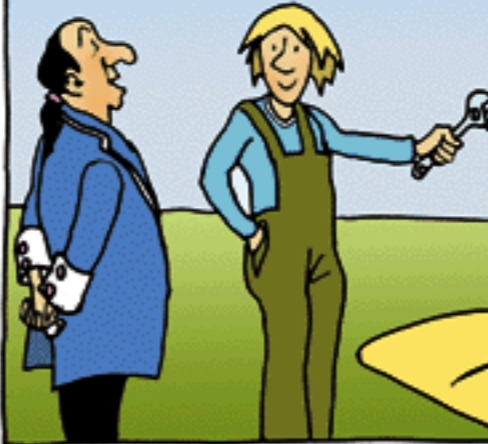


Hmmm... I think when it comes to diplomacy we aren't quite there yet.

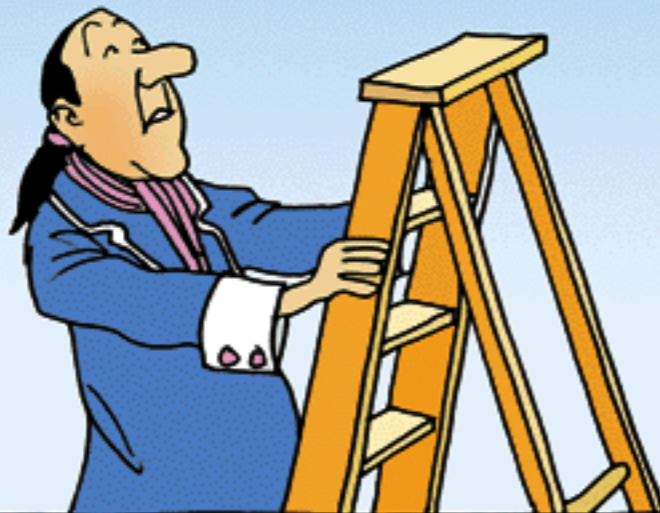
In fact the aeroplane pilot wasn't wrong to want to nose up his machine. The best thing would be to change his tractive propellor into a system of lift. Then, while we're at it, we might as well remove the wings completely.



Well professor, what do you think of that?



You can take the ladder away, I'm going to give it full throttle

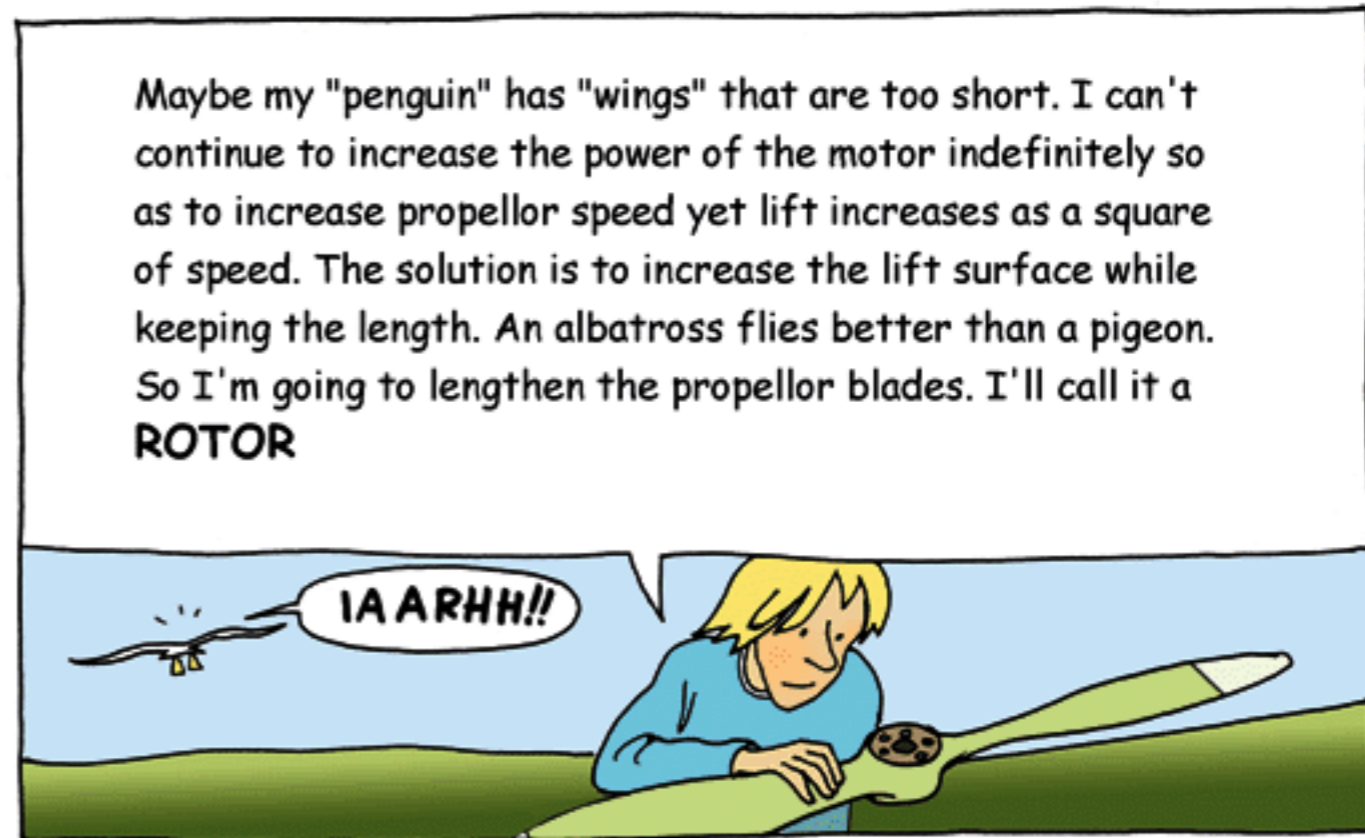
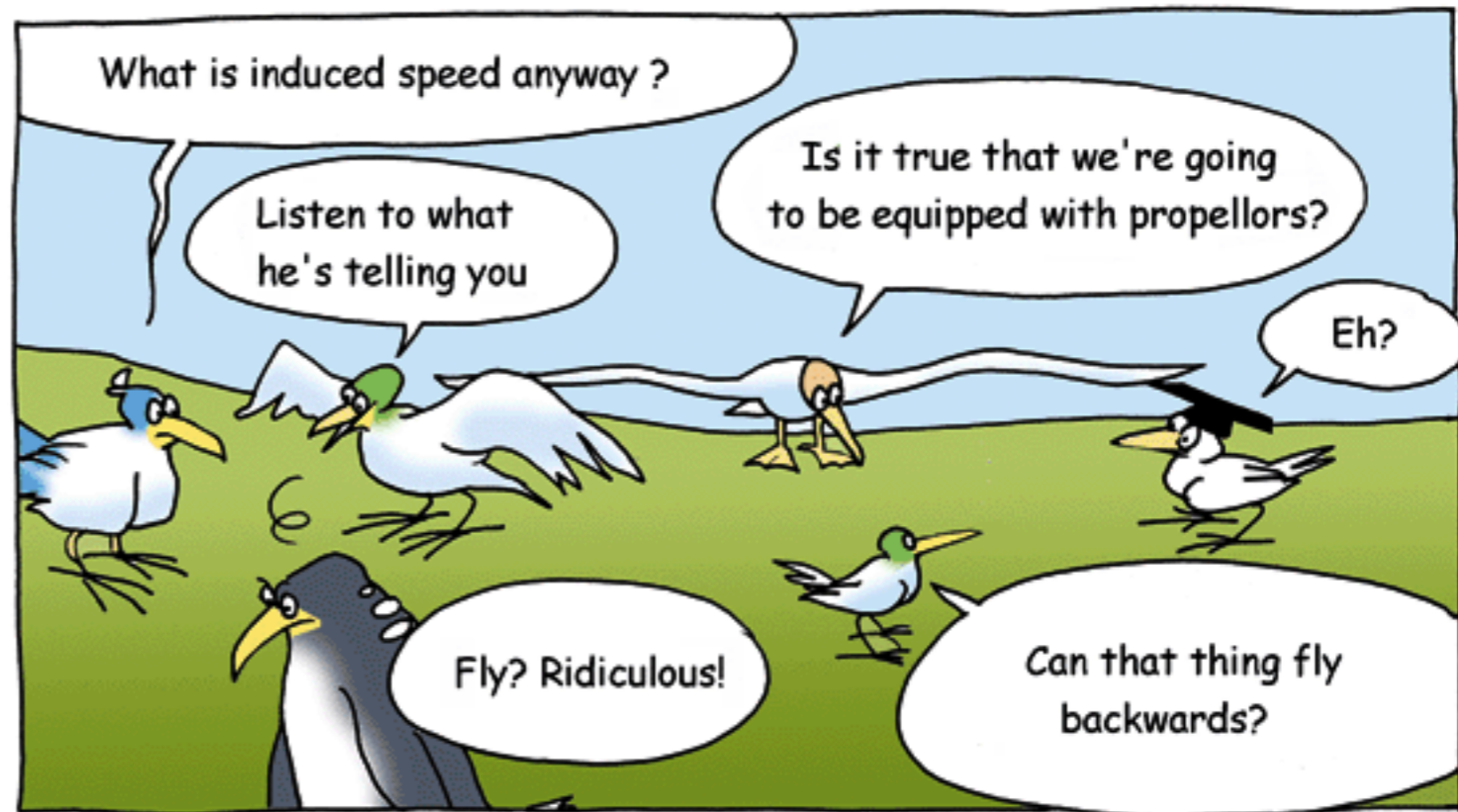


WROOAR

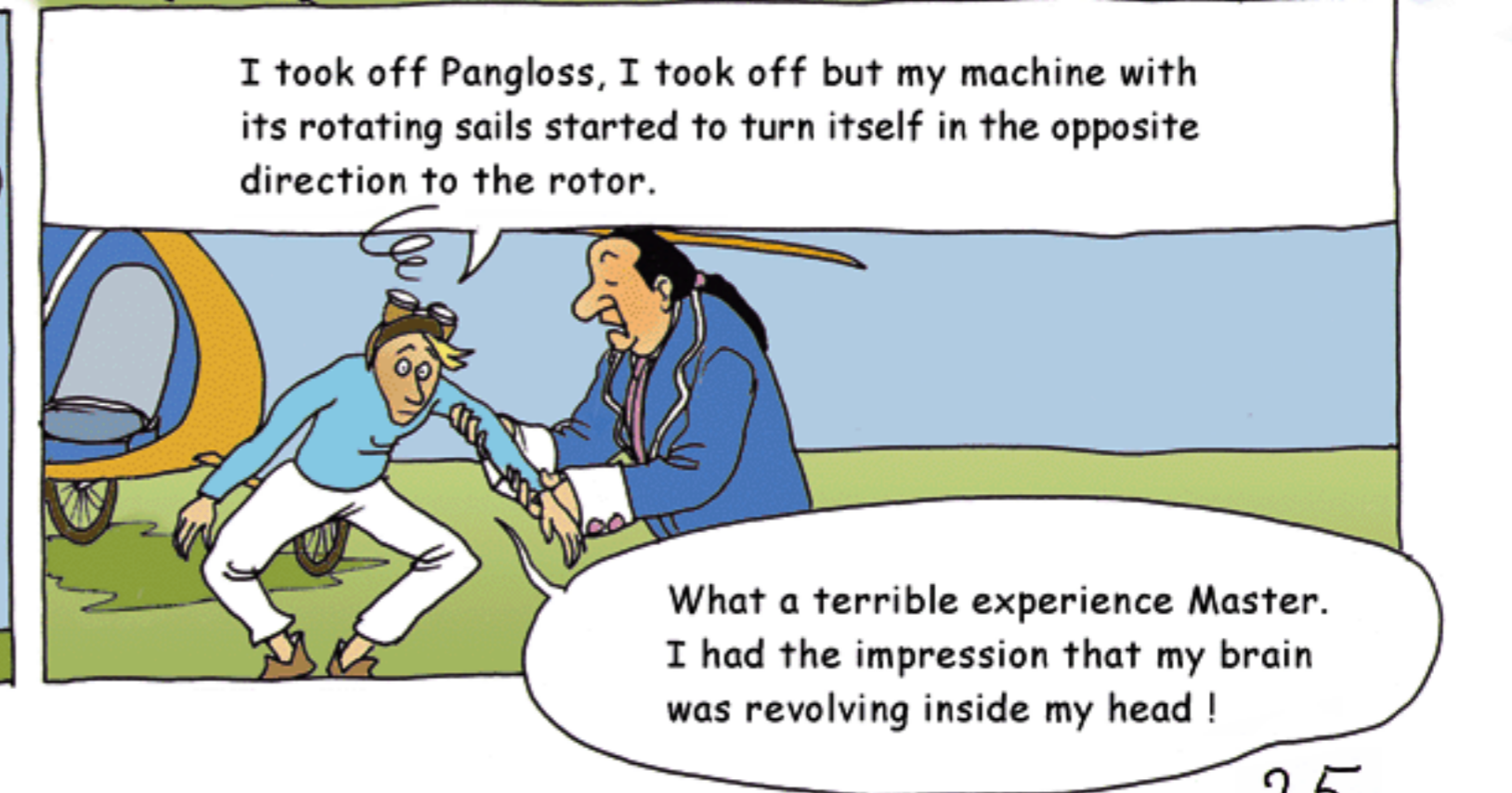
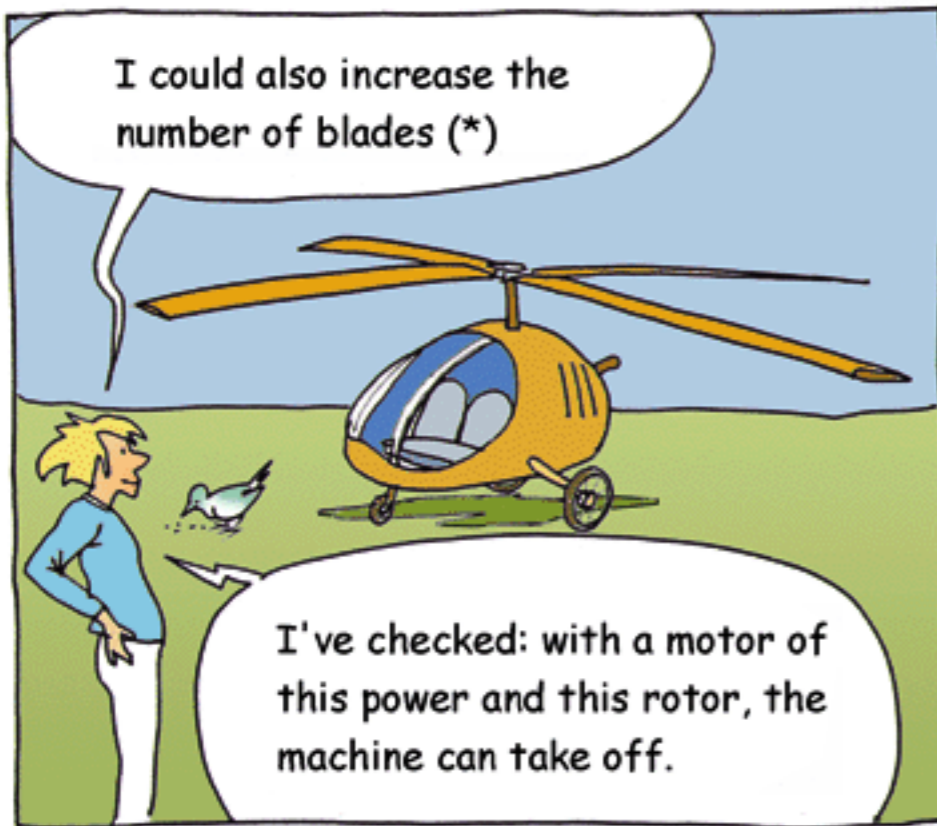
NOTHING !?!



Don't hurt yourself. I'll bring the ladder back.



TORQUE



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



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

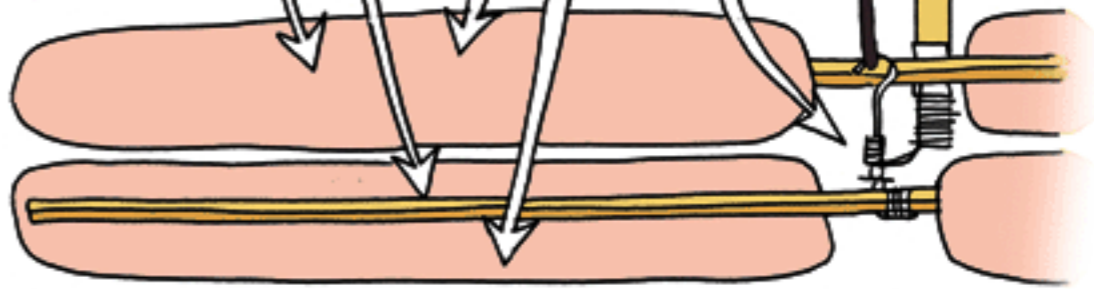
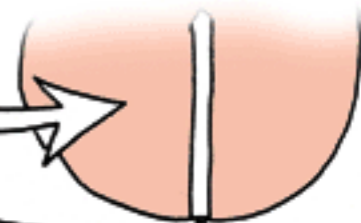
Elastic

2 square balsa rods, 3x3

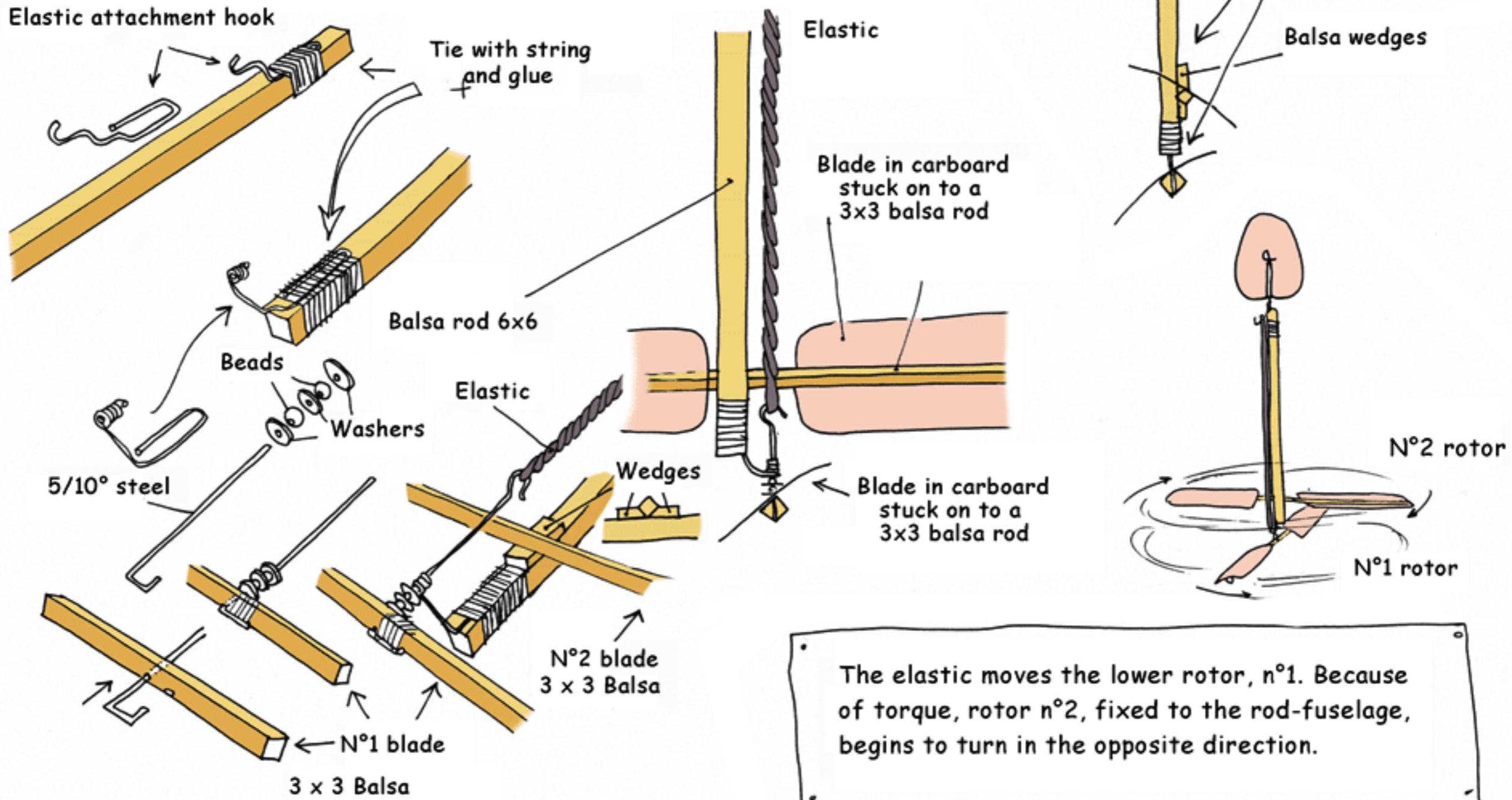
beads

4 blades in thin cardboard

+ washers



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

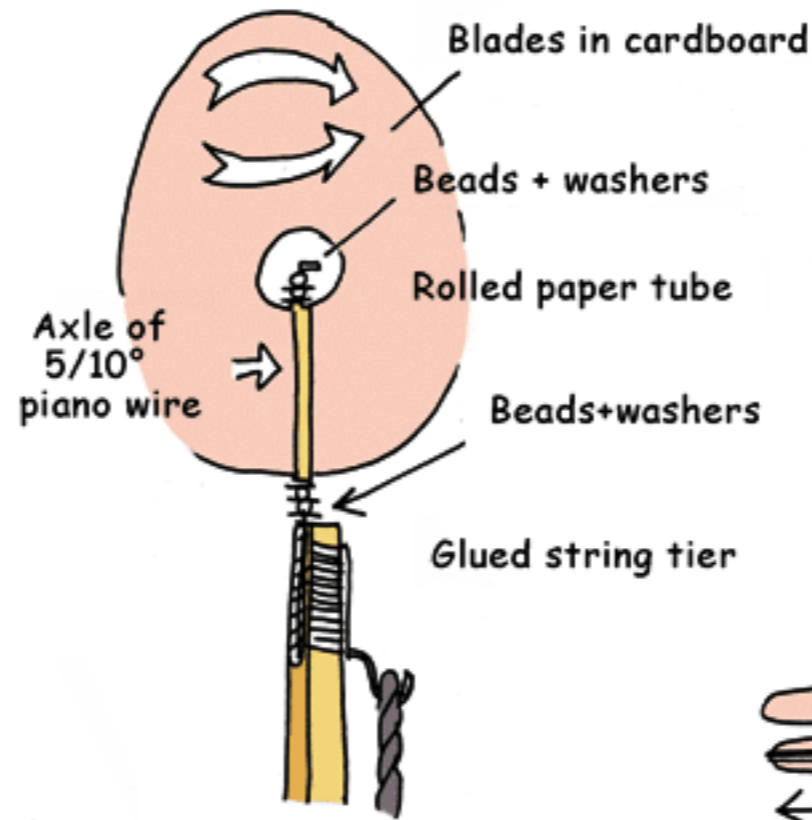


The elastic moves the lower rotor, n°1. Because of torque, rotor n°2, fixed to the rod-fuselage, begins to turn in the opposite direction.

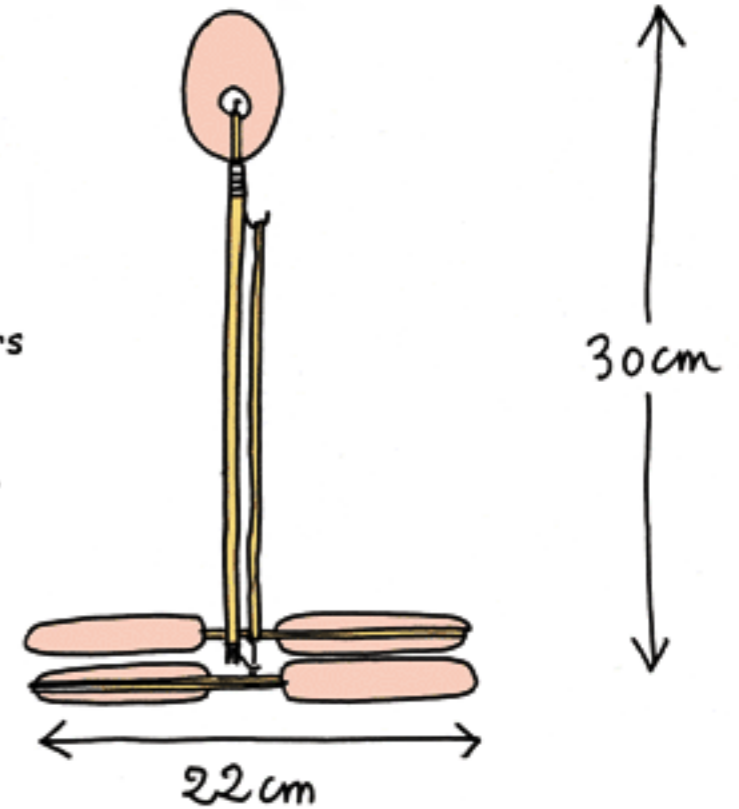
Construction of the upper blade which makes the machine autostable



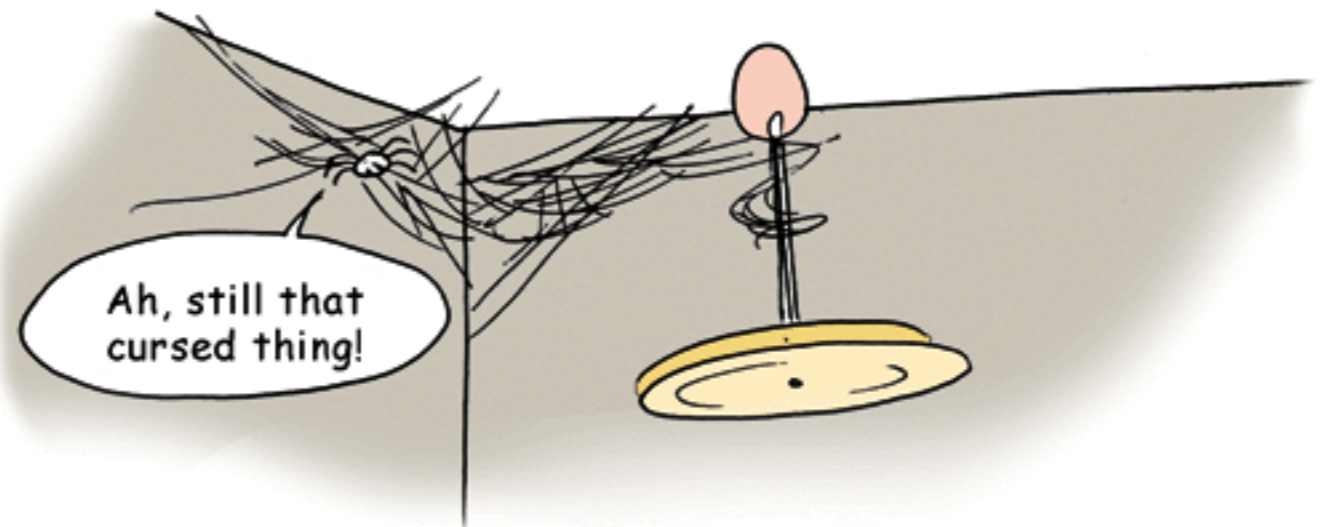
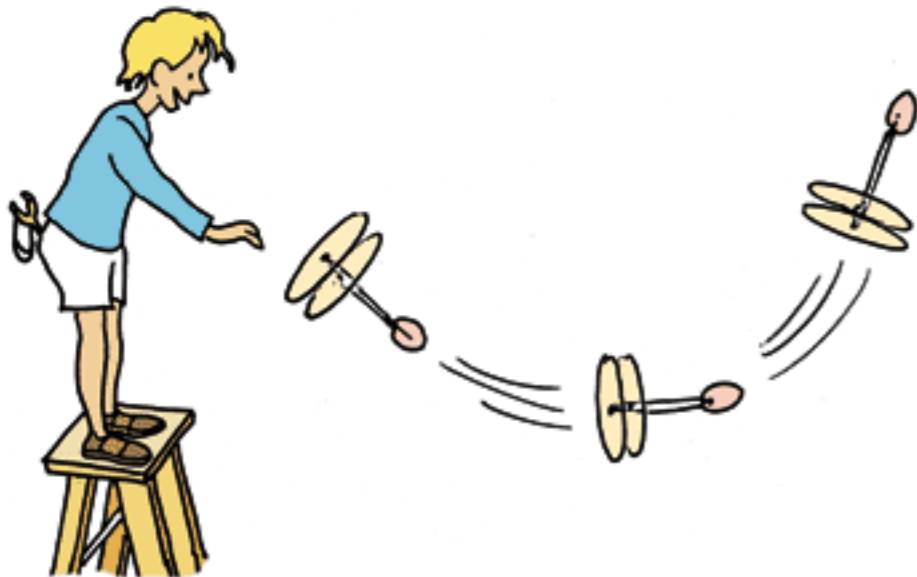
Roll a strip of paper around a big pin, add a bit of glue so as to make a small diameter tube.



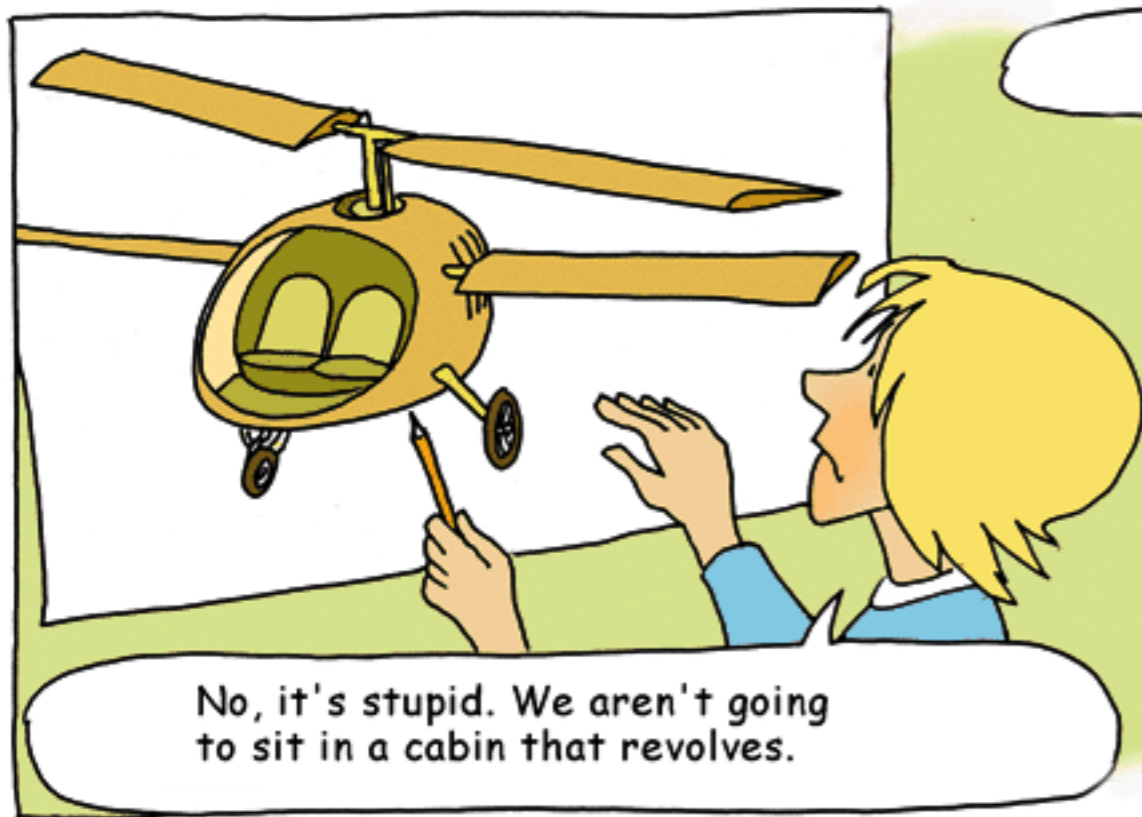
Proportions



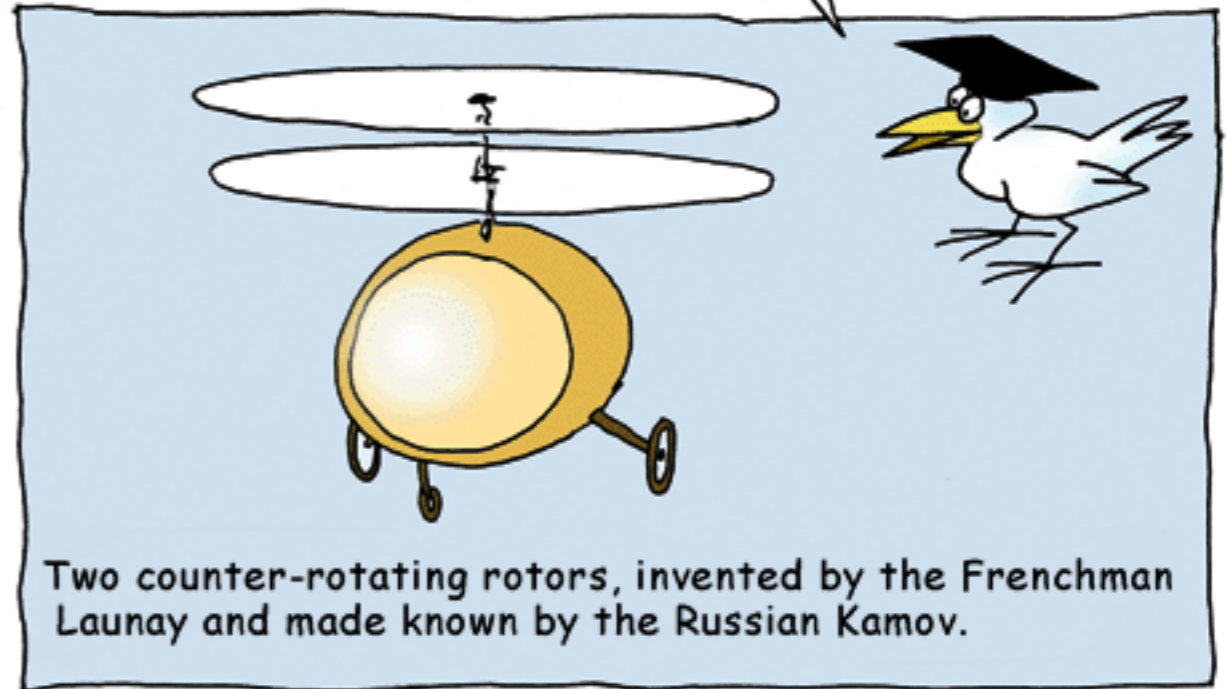
When the helicopter tilts it goes off to the side. The effort of the upper blade straightens it immediately. Left on its own, it goes up swaying from side to side (*)



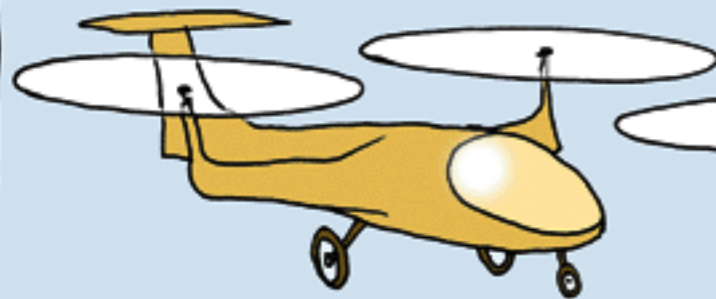
(*) When I was a child I used this to get rid of the spiders' webs on the ceiling of the Château de Thiors, in the Deux-Sevres (France).



Candide thought about various solutions.

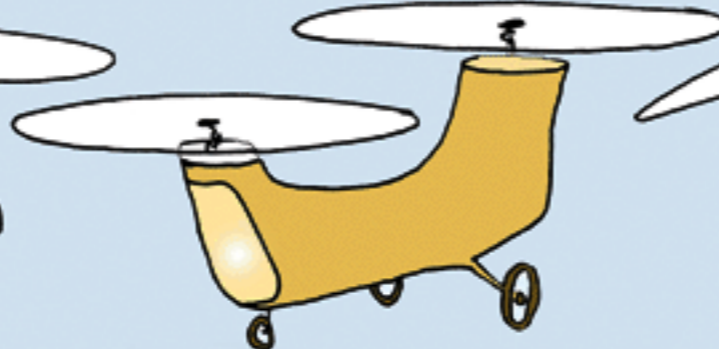


Lateral rotors



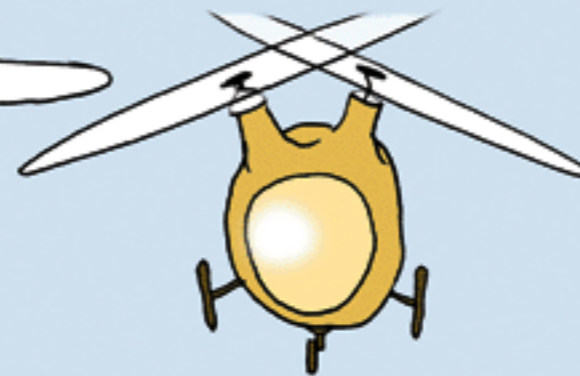
invented by the Englishman Cayley, continued by the German Focke

Tandem rotors



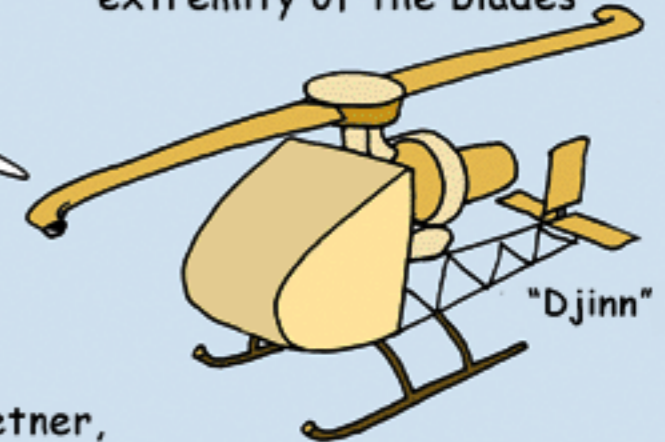
invented by the Frenchman Cornu, developed by Piasecki

Cogged rotors



by the German Fletner, developed by Kaman.

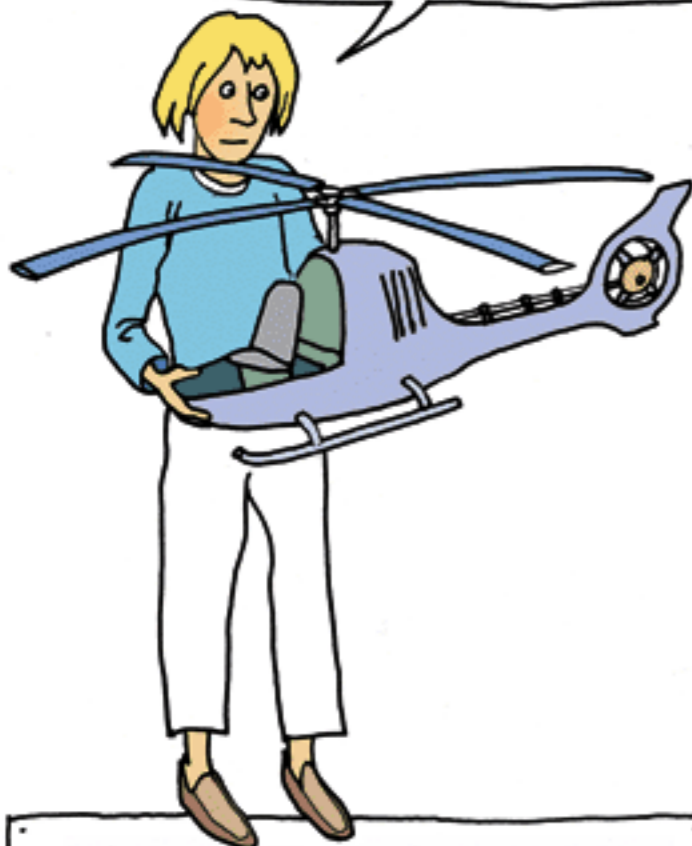
Ejection of gaz at the extremity of the blades



The Frenchman Morain "Djinn"

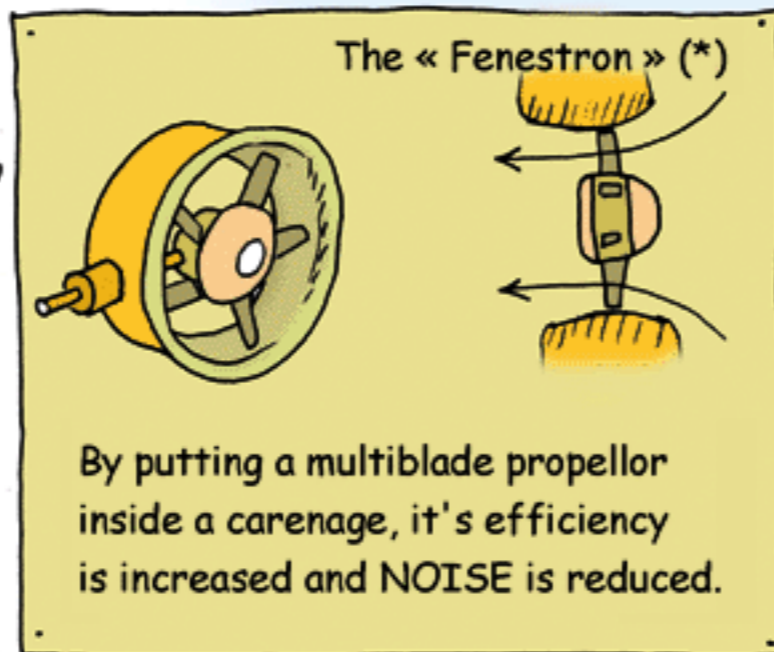
Yves le Bec has written a book illustrated with fine drawings entitled « la véritable histoire de l'hélicoptère, de 1486 à 2005 », published by Les Editions Jean Ducret S.A. CH-1022 Chavannes-près-Renens. ISBN 2-8399-0100-5. In it you'll find all the types of helicopter imagined by man.

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.

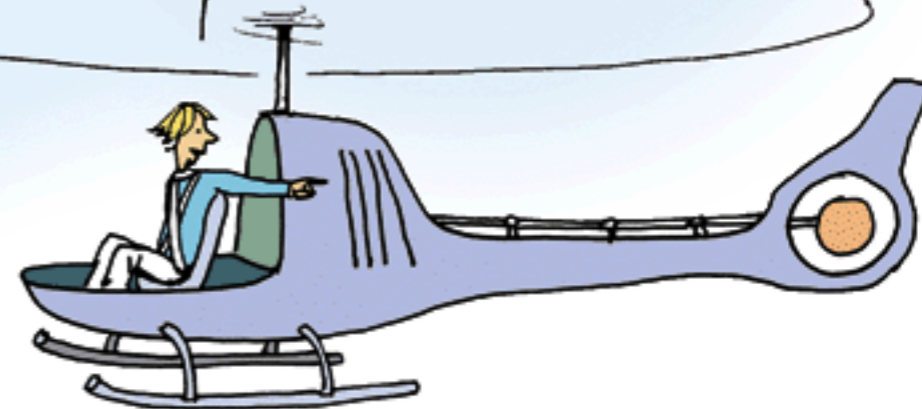


The antitorque tail rotor was invented by the Russian Yuriev and developed by Sikorsky.

(*) The "fenestron" was introduced by the Frenchman Mouille.



Pangloss, I've done it!



Come back immediately, if not you'll be cut up in a million pieces.

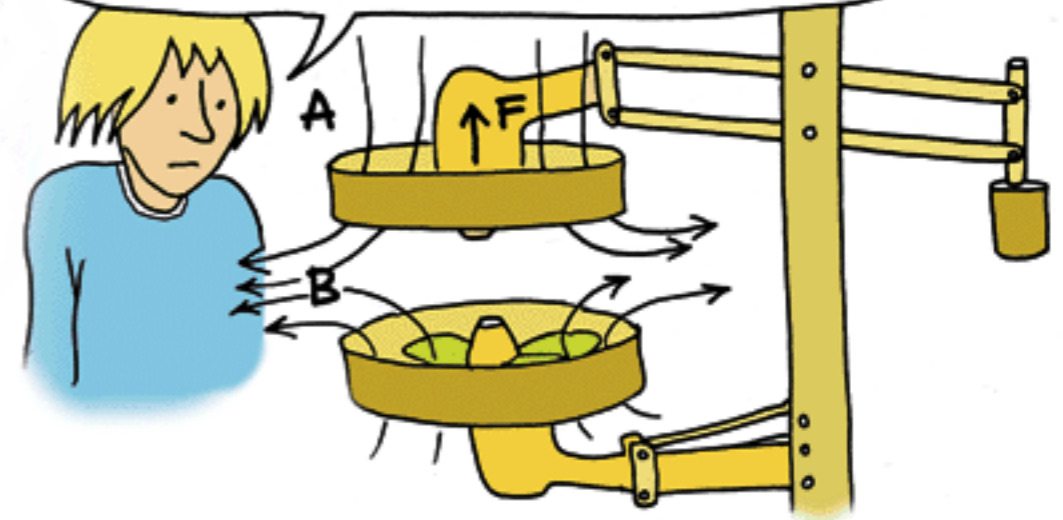
This shows that all is for the best in the best of all aeronautics.

GROUND EFFECT

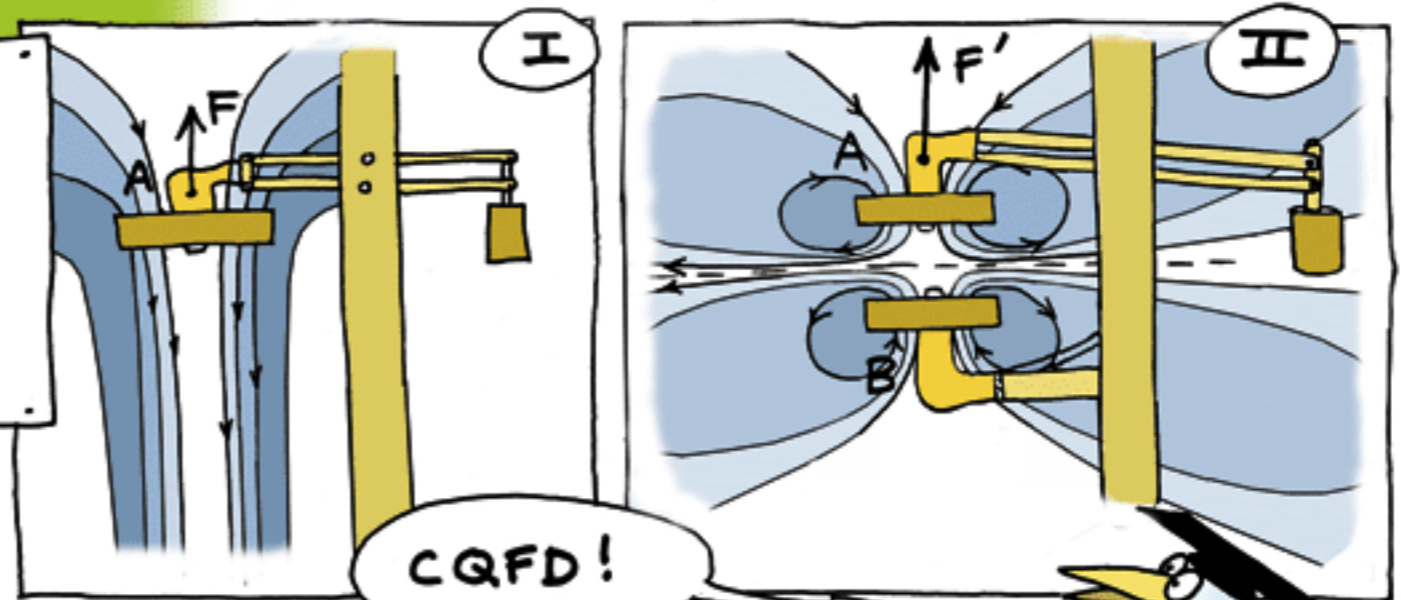
It's odd but near the ground I manage to fly with a lot less power (*)



This machine is nothing more than a nice big fan. I'm going to work with two, putting them face to face.



At equal power, the force of ascension exerted on the fan A is greater when it is running facing fan B, which pushes air in the opposite direction, than if fan A was running alone.



The flow 2 is the same as it would be if fan A was facing the ground

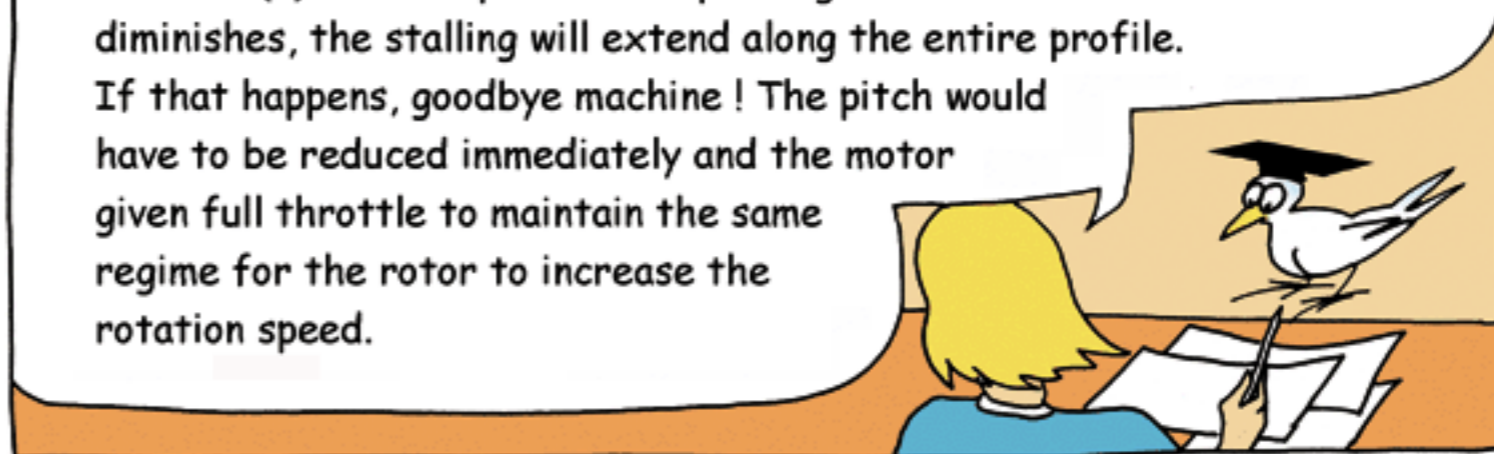
(*) The ground effect becomes important when the rotor is at a distance from the ground equal or inferior to half its diameter.

INCREASING RPM

My rotor has a fixed pitch. What value to choose? The greater the pitch, a high blade angle, the greater the **DRAG**, which brakes the rotation of the blade.



If, for some reason, my motor loses power, this drag will slow its rotation (*). If the speed corresponding to **RELATIVE WIND** diminishes, the stalling will extend along the entire profile. If that happens, goodbye machine! The pitch would have to be reduced immediately and the motor given full throttle to maintain the same regime for the rotor to increase the rotation speed.



What did he say?

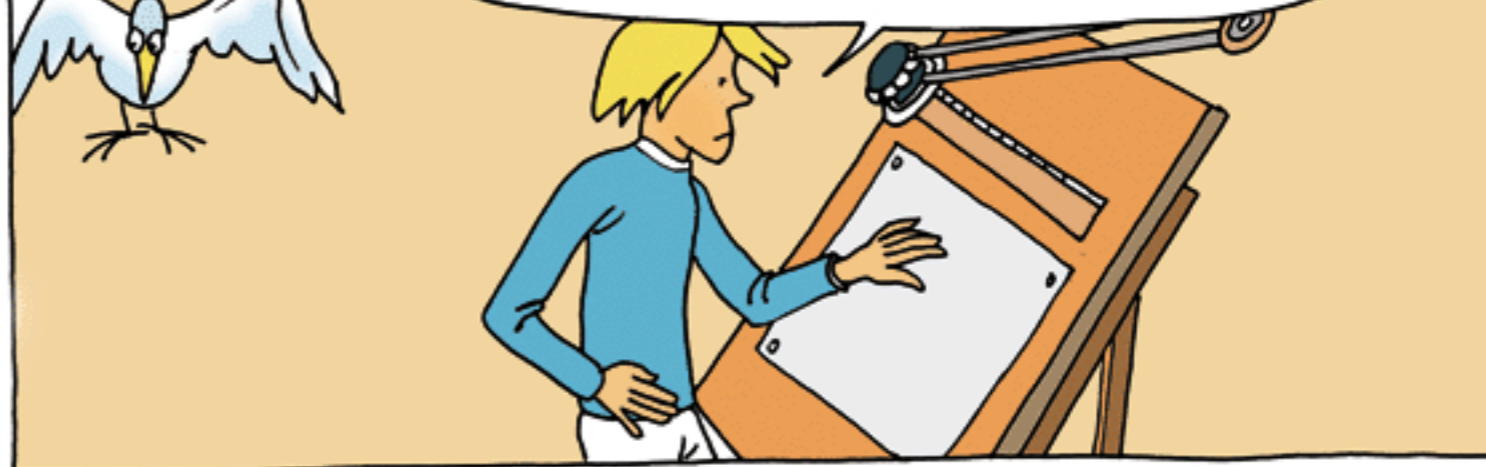


It's not your business, as far as I know you don't have revolving sails?

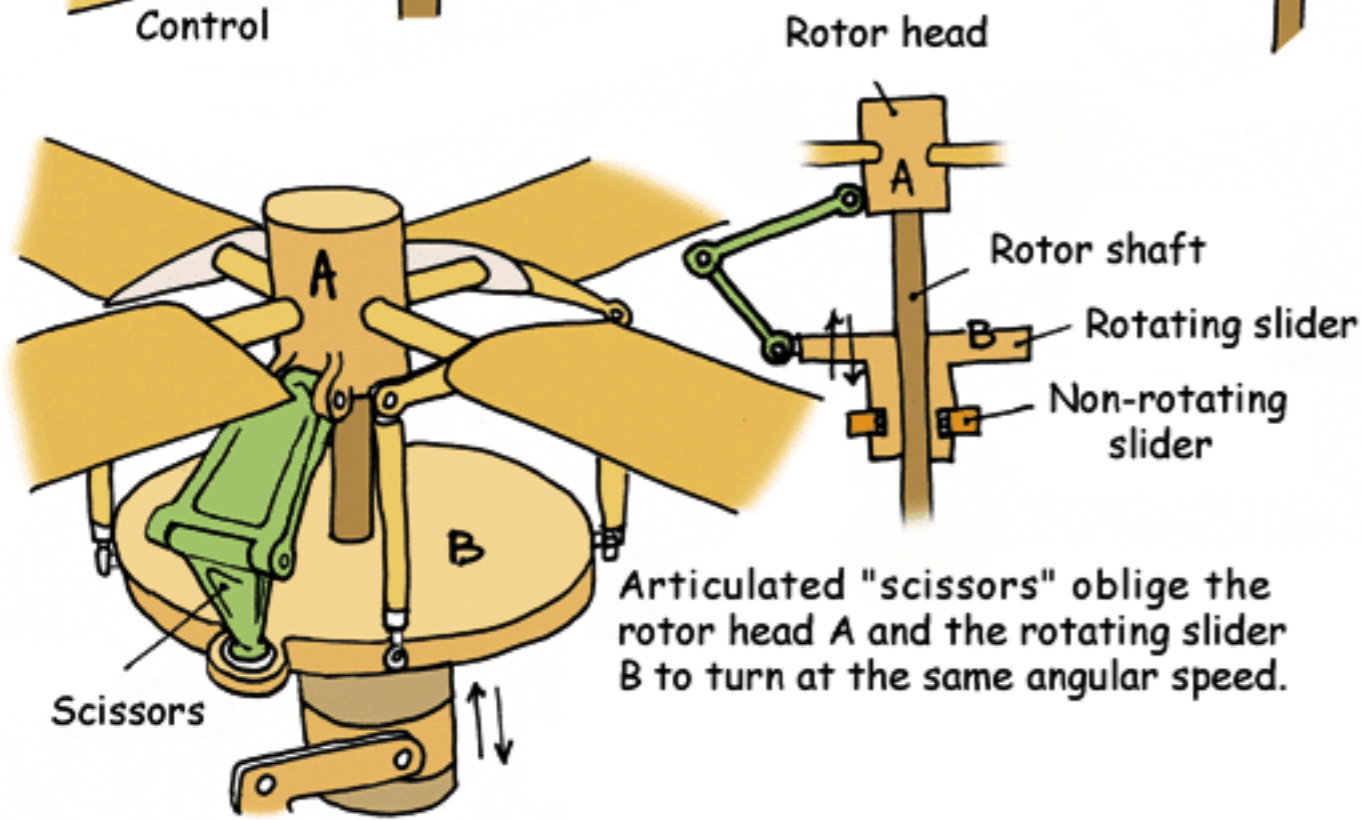
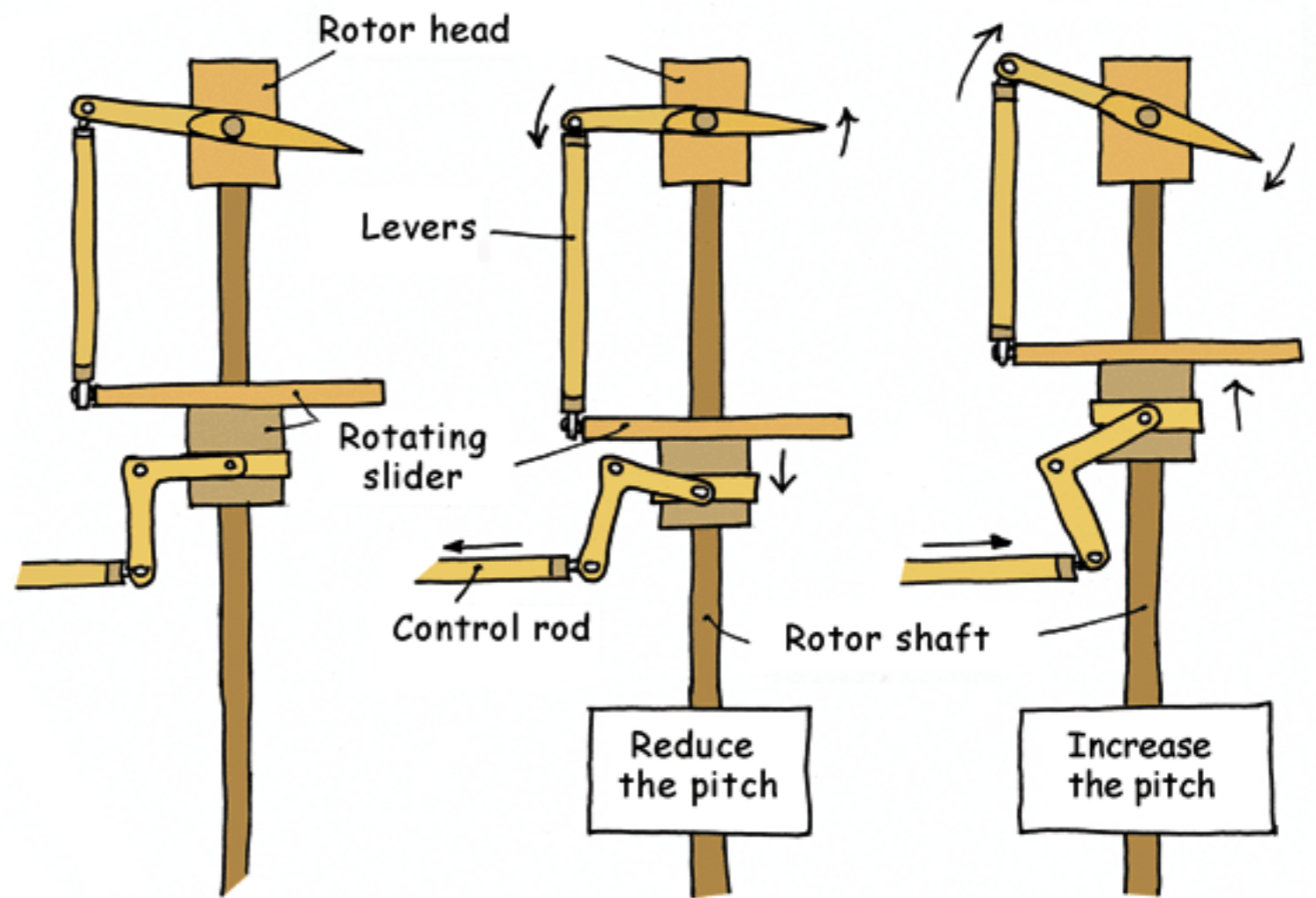
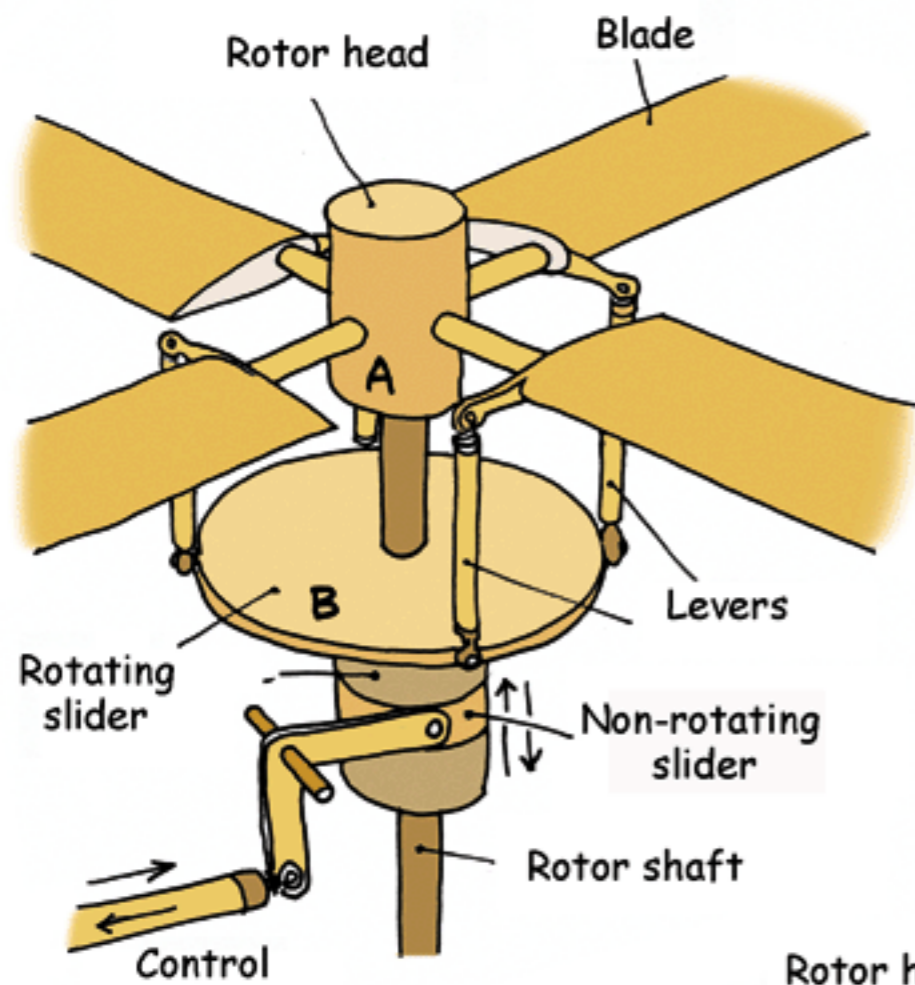
Erm...no. I don't think so.



I need a way to be able to adjust the pitch when in flight, that is to say the angles of attack of the blades.



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



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.

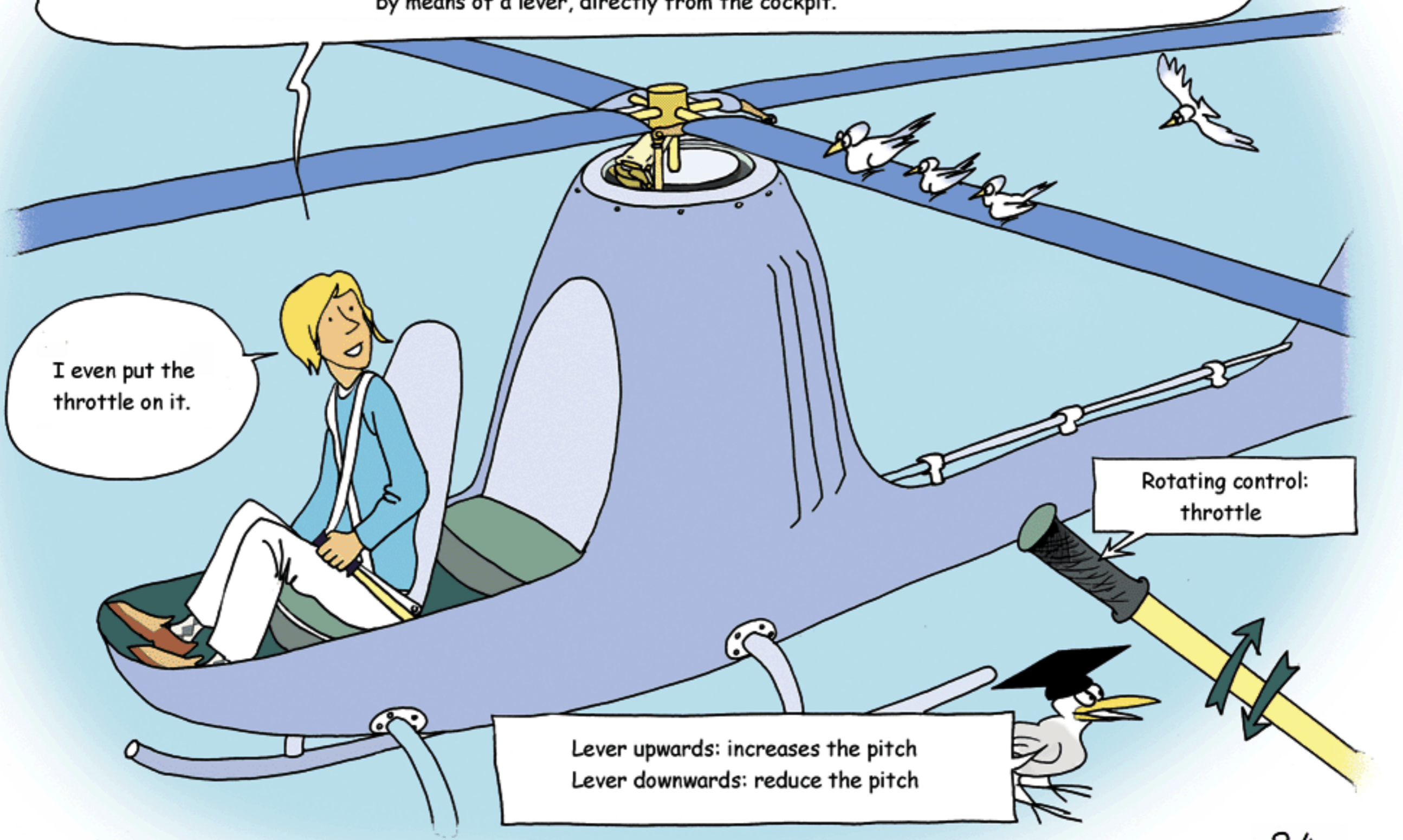
The Management.

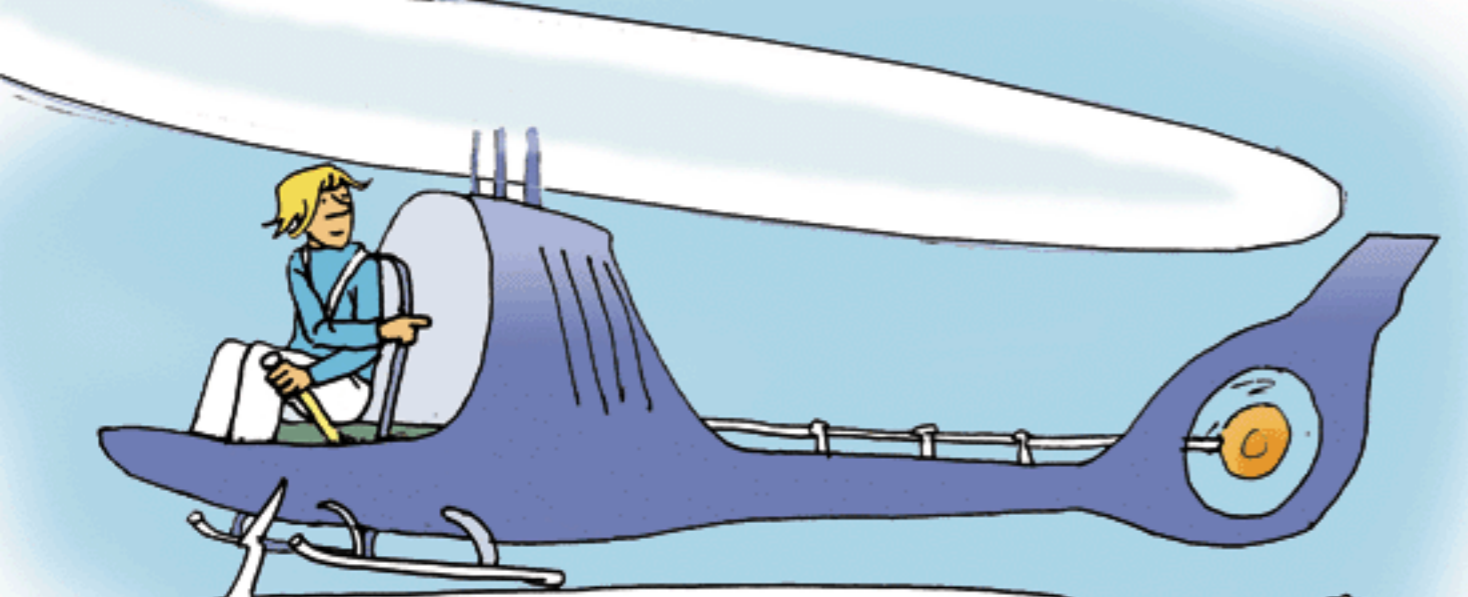
I adapted a control linkage which allowed me to vary the general pitch at will by means of a lever, directly from the cockpit.

I even put the throttle on it.

Rotating control:
throttle

Lever upwards: increases the pitch
Lever downwards: reduce the pitch

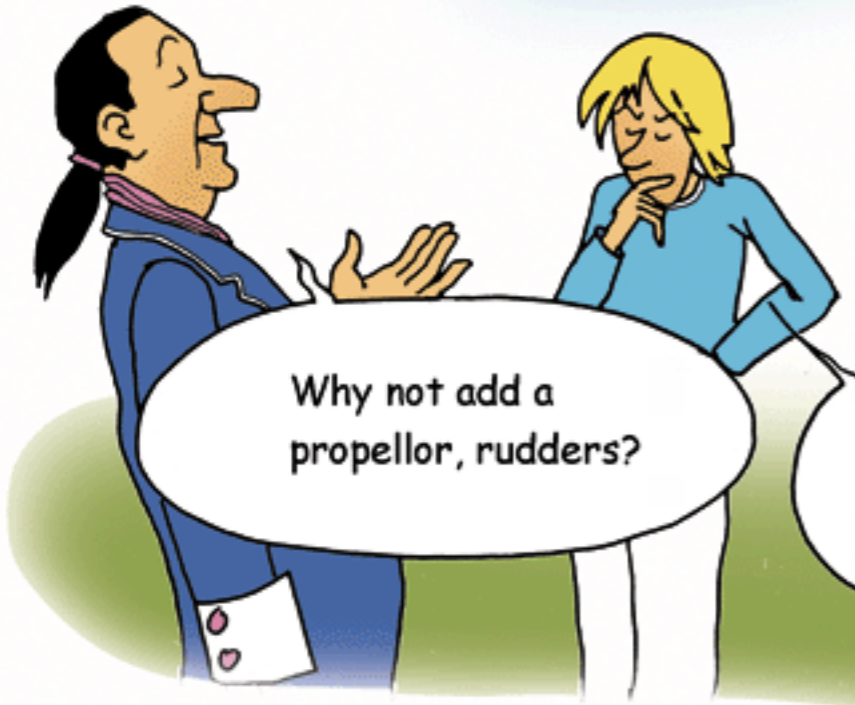
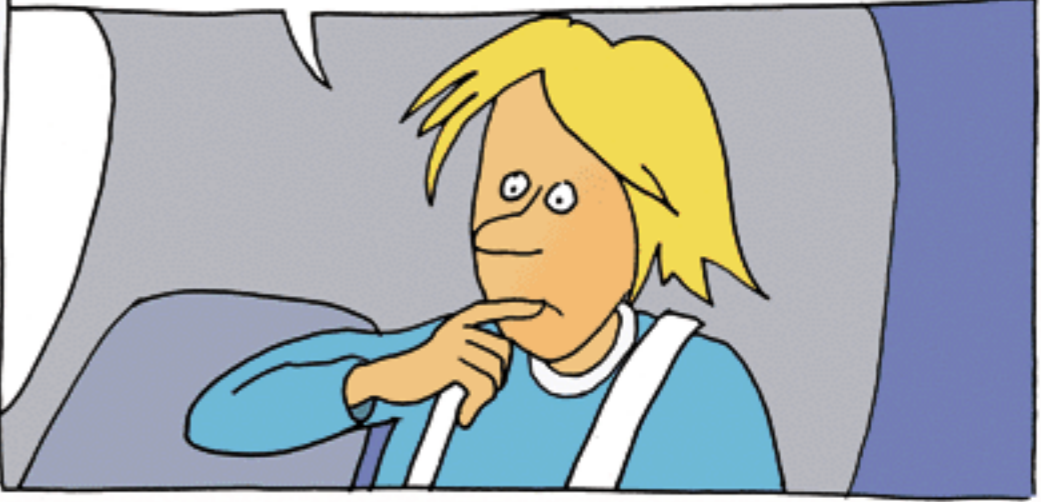




So I adapted the same system to the tail rotor, antitorque, so as to avoid changes of direction when I changed the general pitch, and I added a foot control, a pedal, that lets me hover.

What, I can't hear anything...

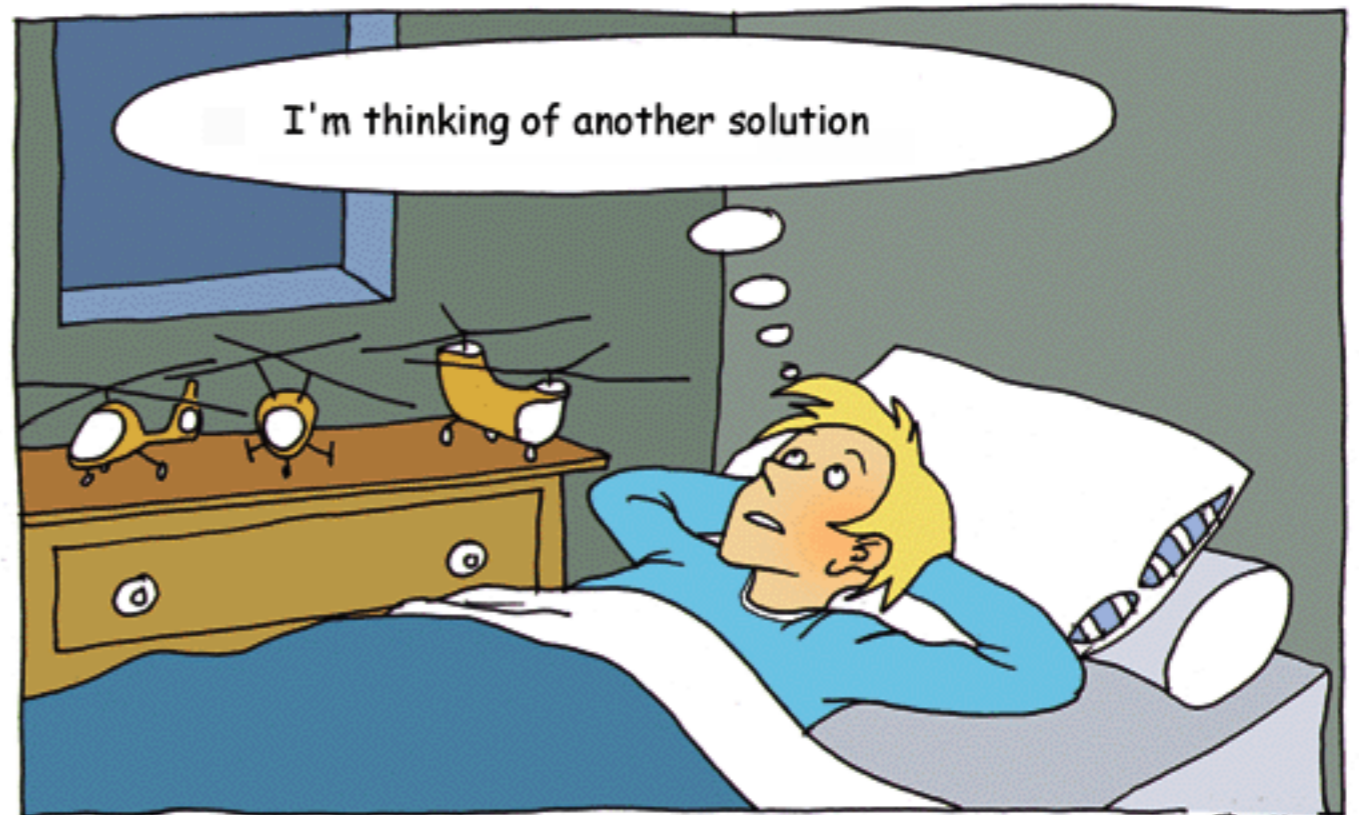
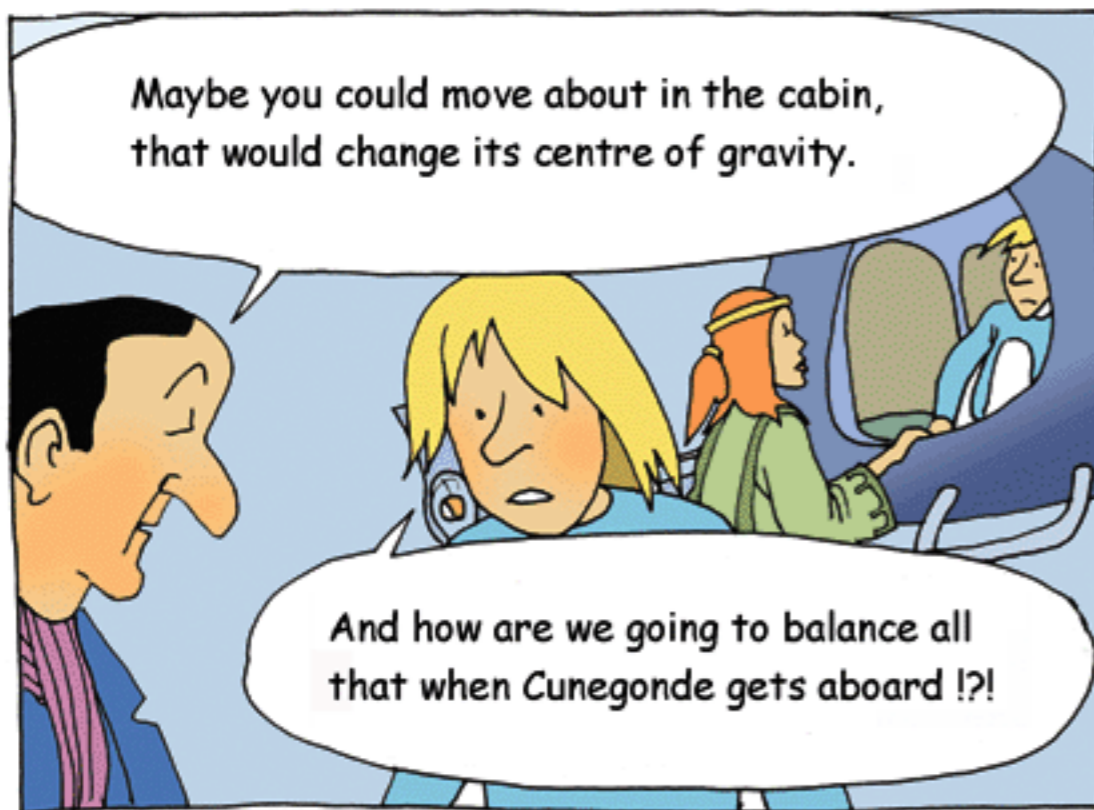
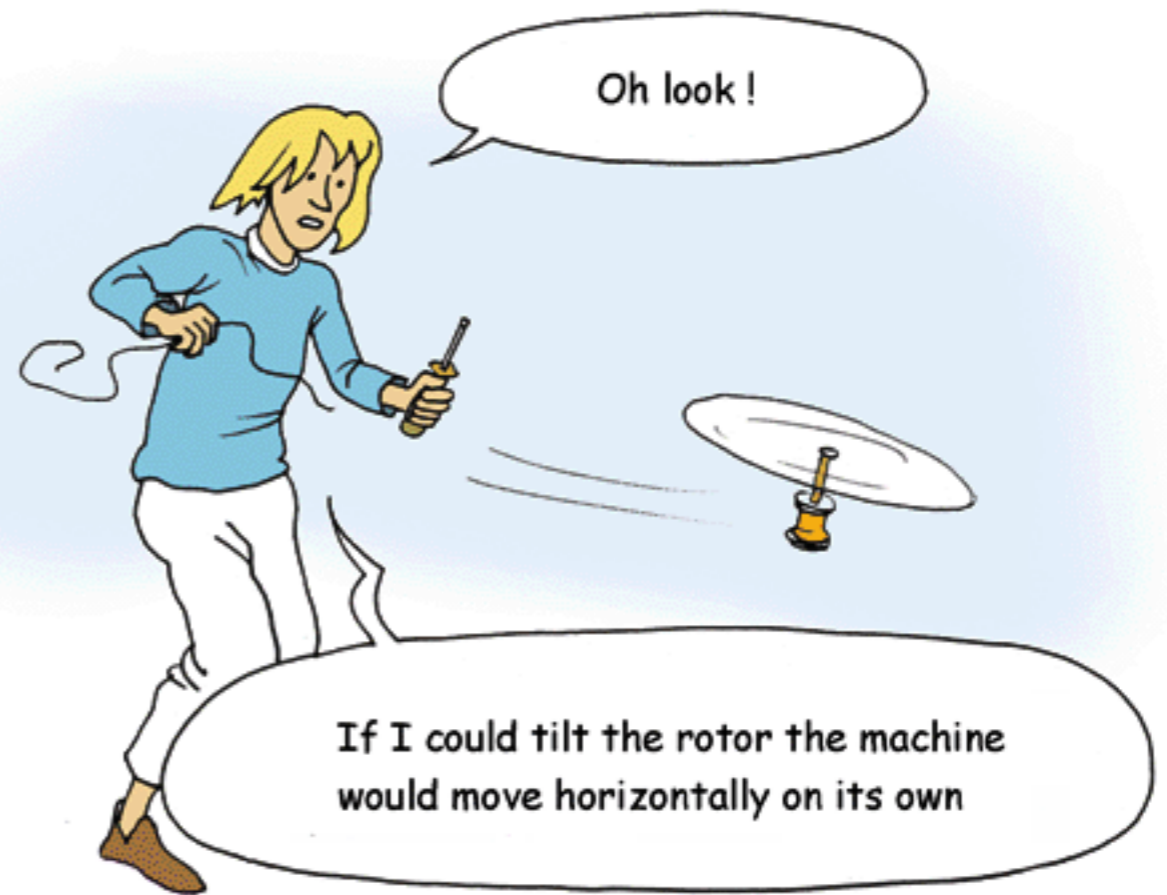
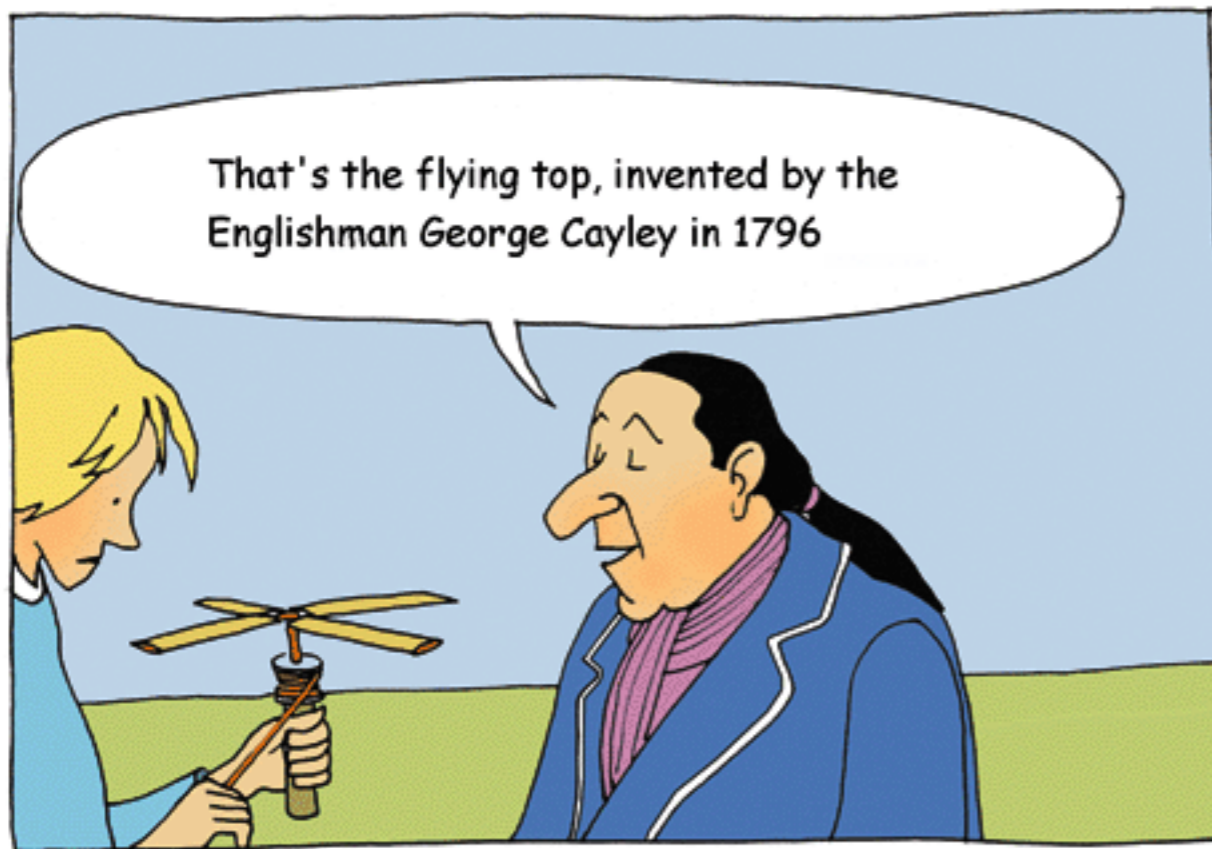
OK, so I've made this flying machine, capable of carrying Cunegonde and me. I can go up, down or hover as I wish. Just one question left, how do I advance?



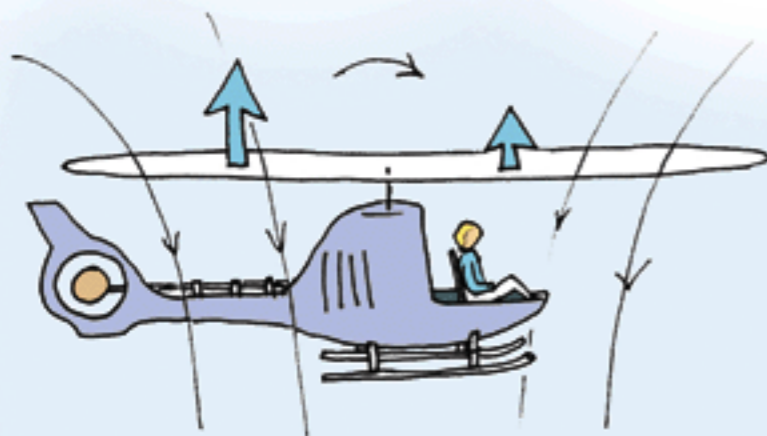
Why not add a propellor, rudders?

Hmm, all that seems very complicated

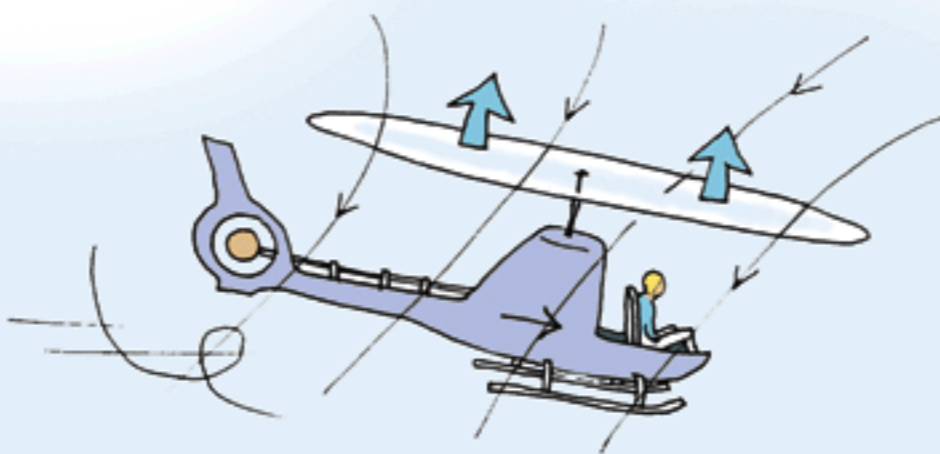




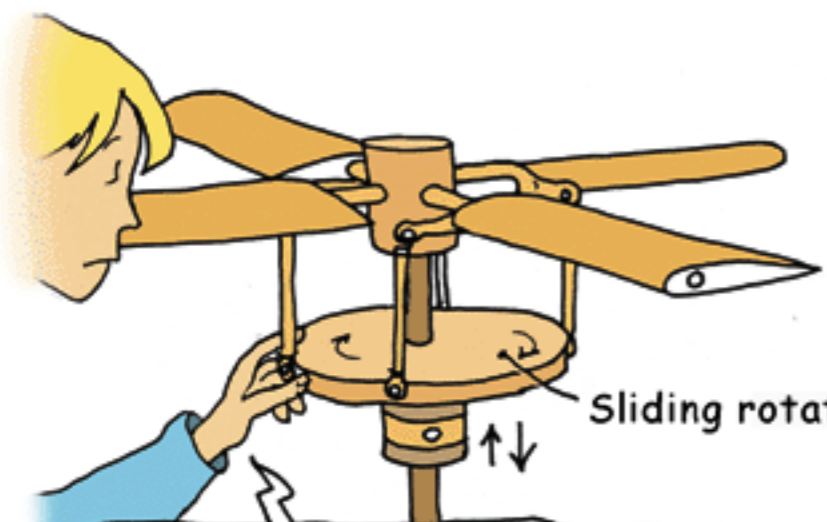
Stationary



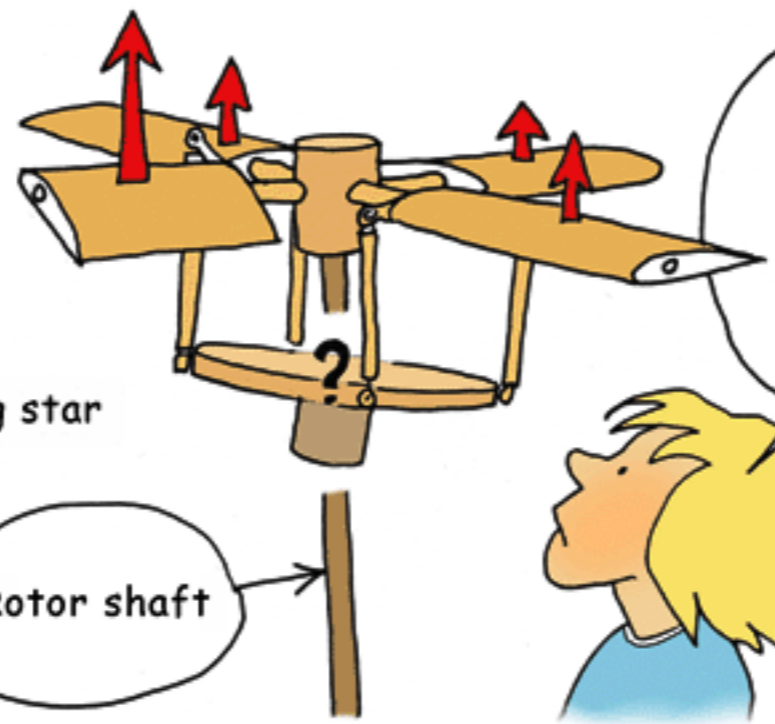
Translation



If I could increase the lift of the rotor's blades when these are towards the back and increase it when they are towards the front, using **CYCLIC PITCH VARIATION**, that would make the machine tilt and start a **TRANSLATION** movement.



Sliding rotating star



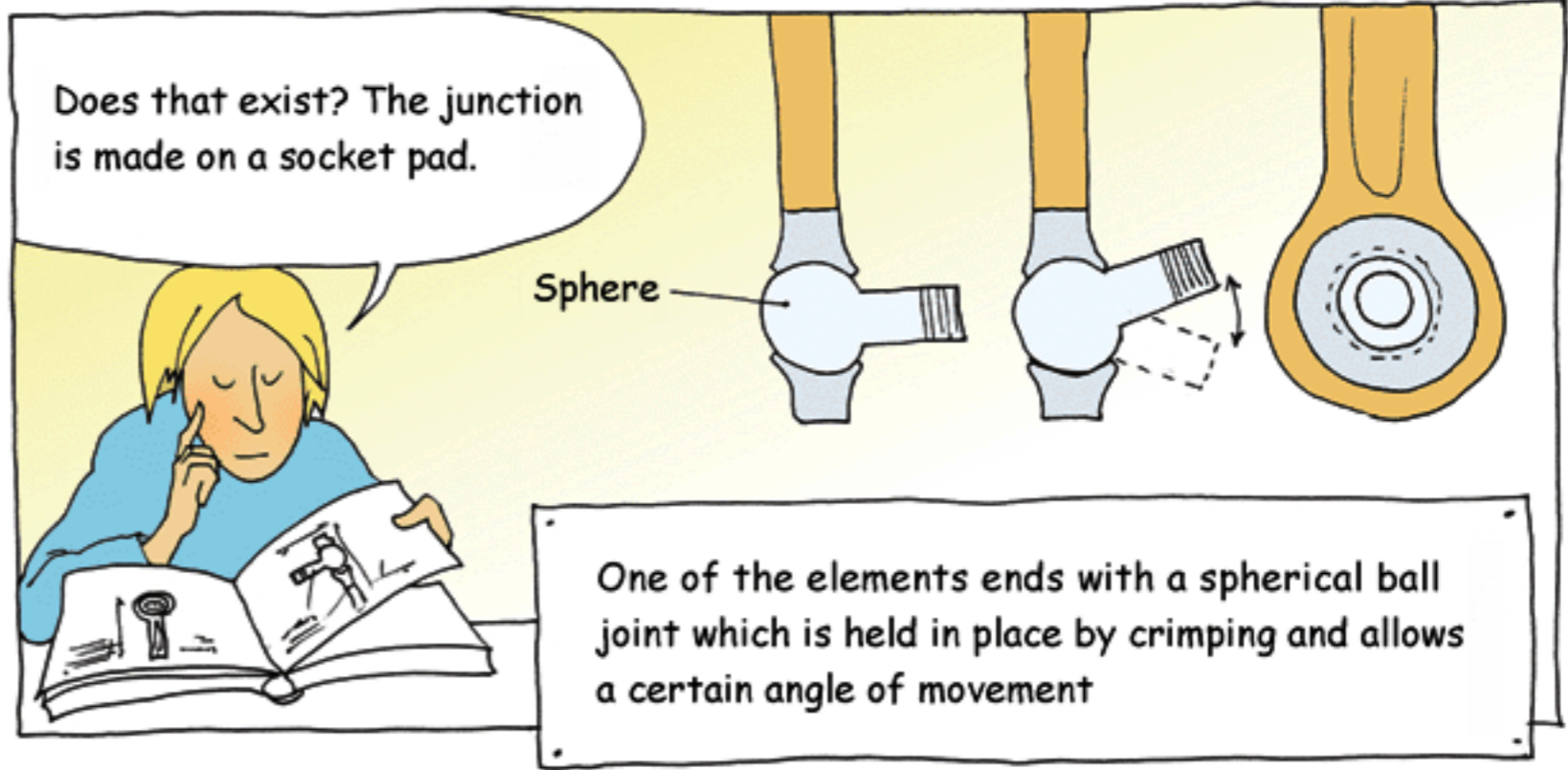
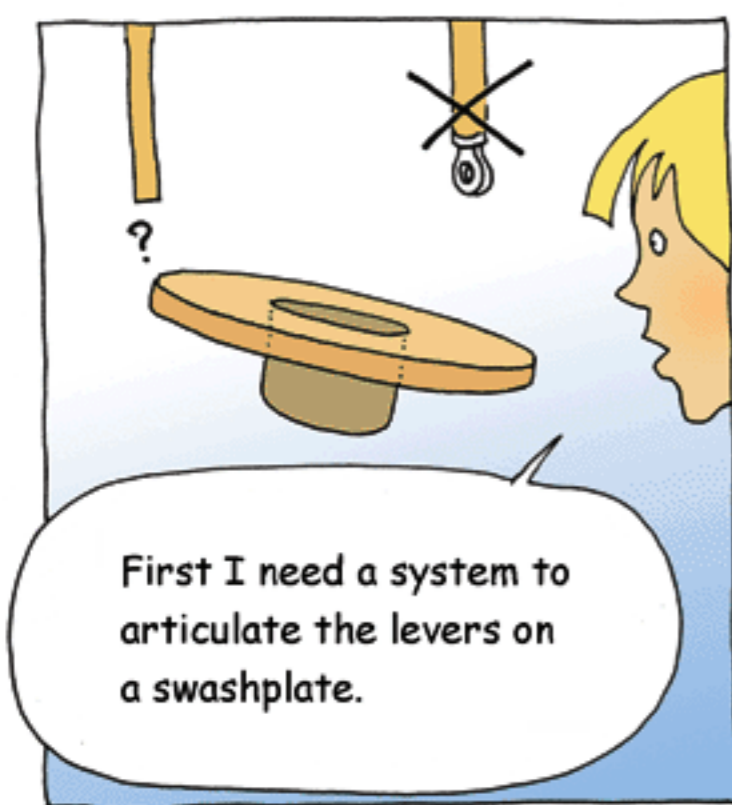
Rotor shaft

If I could make it that this star was inclined, while still turning, I could create this cyclic blade pitch variation (*). But how do I link and control all this mess !?!

The pitch of the blades is given by the position of the rotating star which slides on the rotor shaft.



(*) 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.



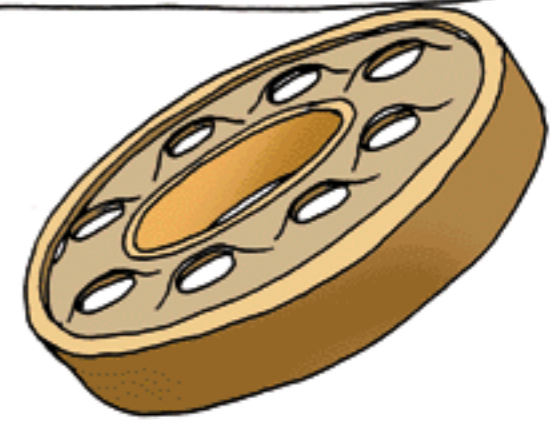
The ball-bearing is an important element.



But how do you get these blasted balls in?



When the rings are separated we can put in a certain number of balls.

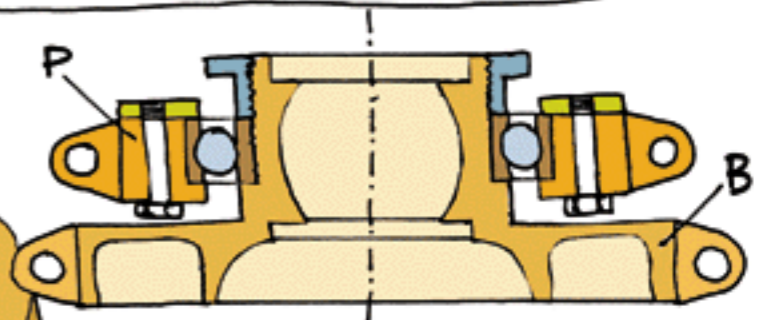
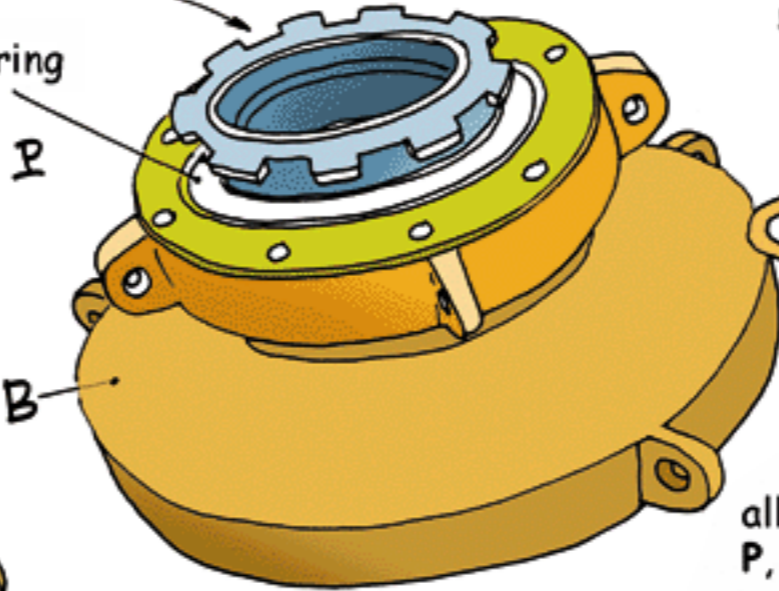
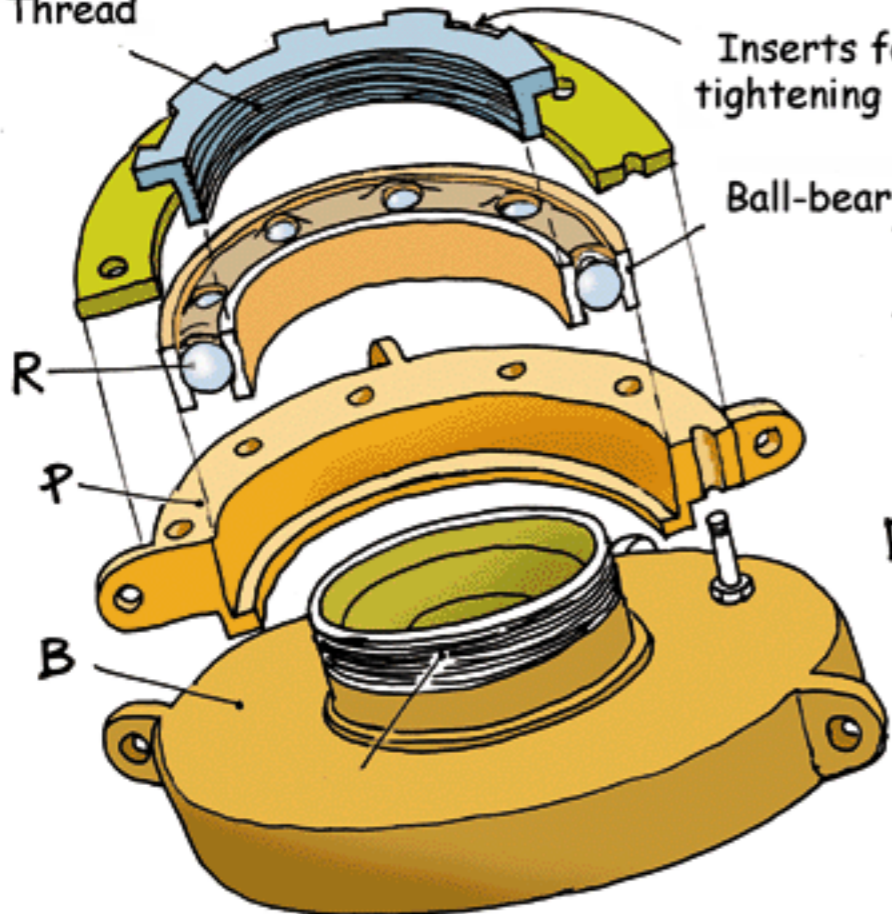


These are held in place by a cage made of two elements which are then welded, crimped and glued

Thread

Inserts for tightening key

Ball-bearing



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.

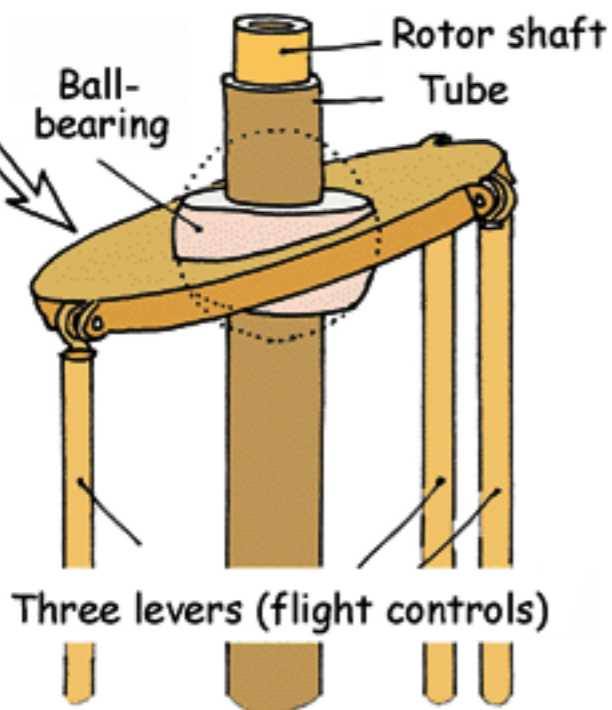


To make something work straight that is off kilter, the solution is a **BALL-BEARING**

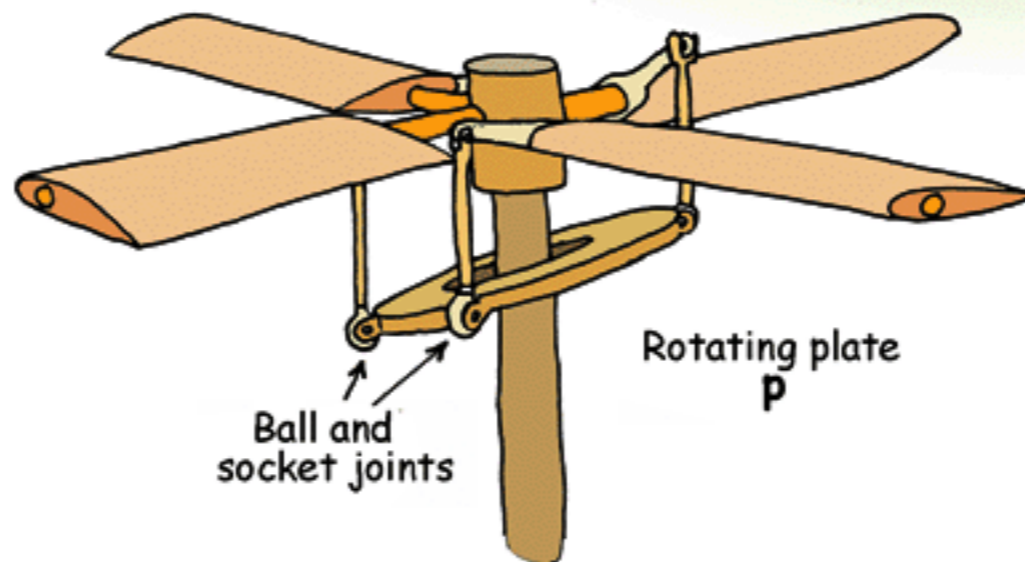


A ball-bearing that slides on the tube inside which the **ROTOR SHAFT** turns

Plate **B**, non-rotative, whose orientation is set by the flight control lever, will pivot on this ball-bearing



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.



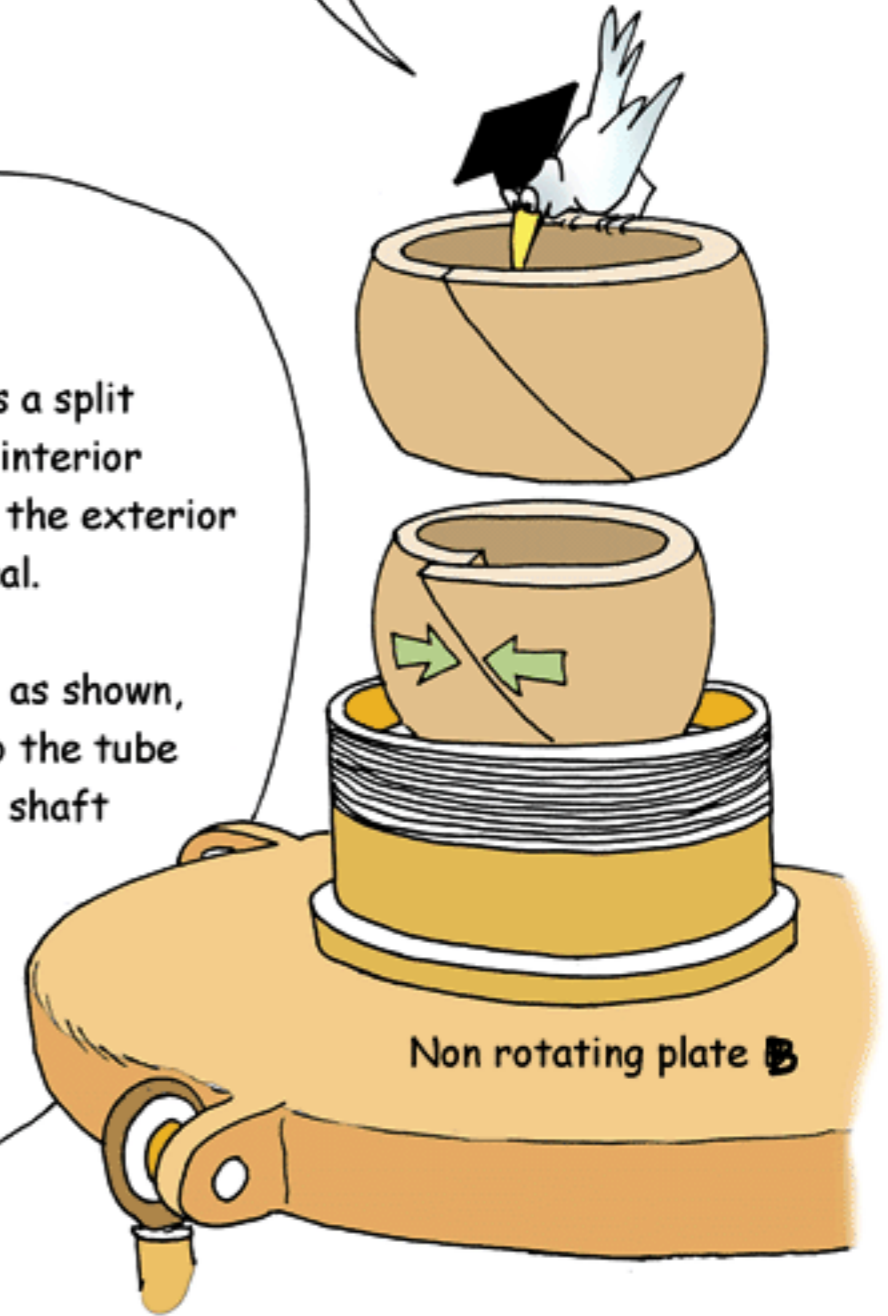
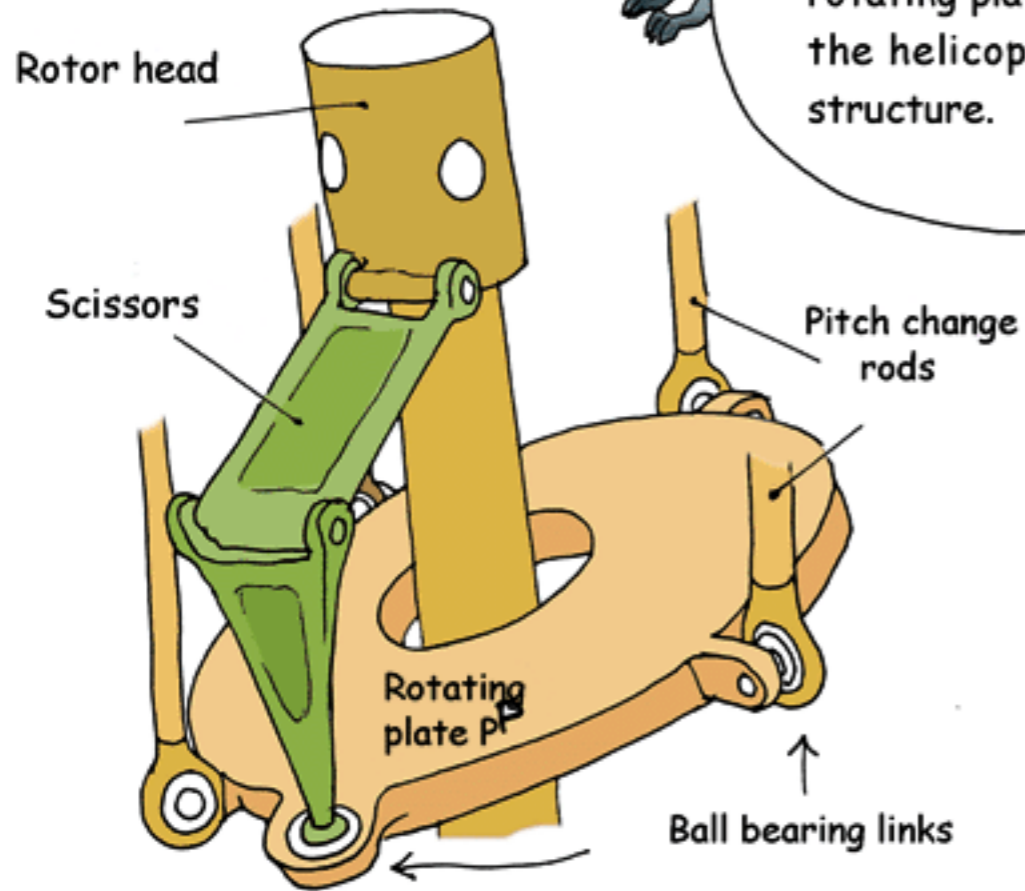
A few problems remain to be solved before we finish this study of the swash plate. First, how to fix the rotating star P to the rotor head. Are we going to use fragile levers for this?

Second question: How to place the ball bearing into its socket on plate B?

No, we'll use scissors. And we'll use the same type of system between the rotating plate B and the helicopter's structure.

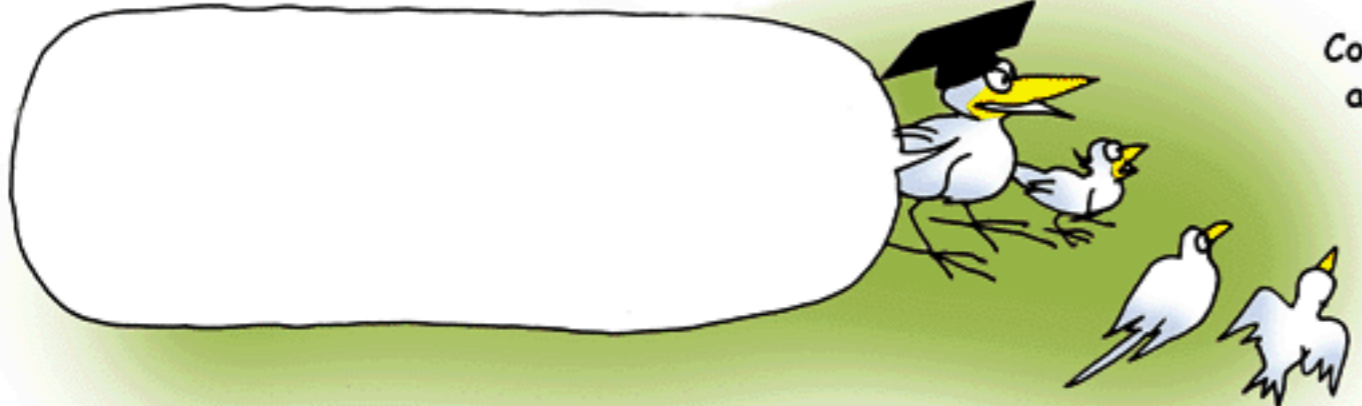
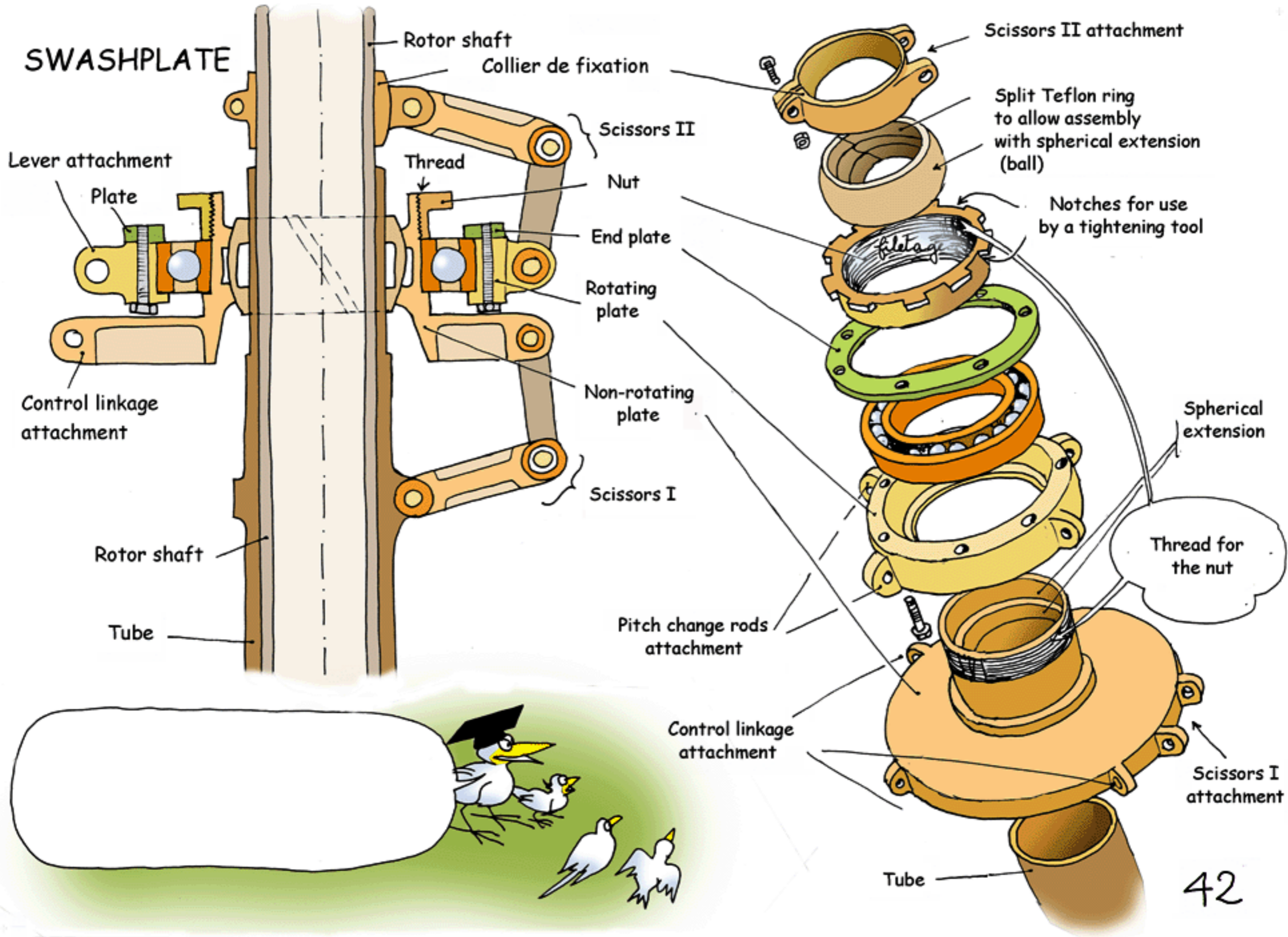
The bearing is a split Teflon ring, its interior is cylindrical and the exterior extension spherical.

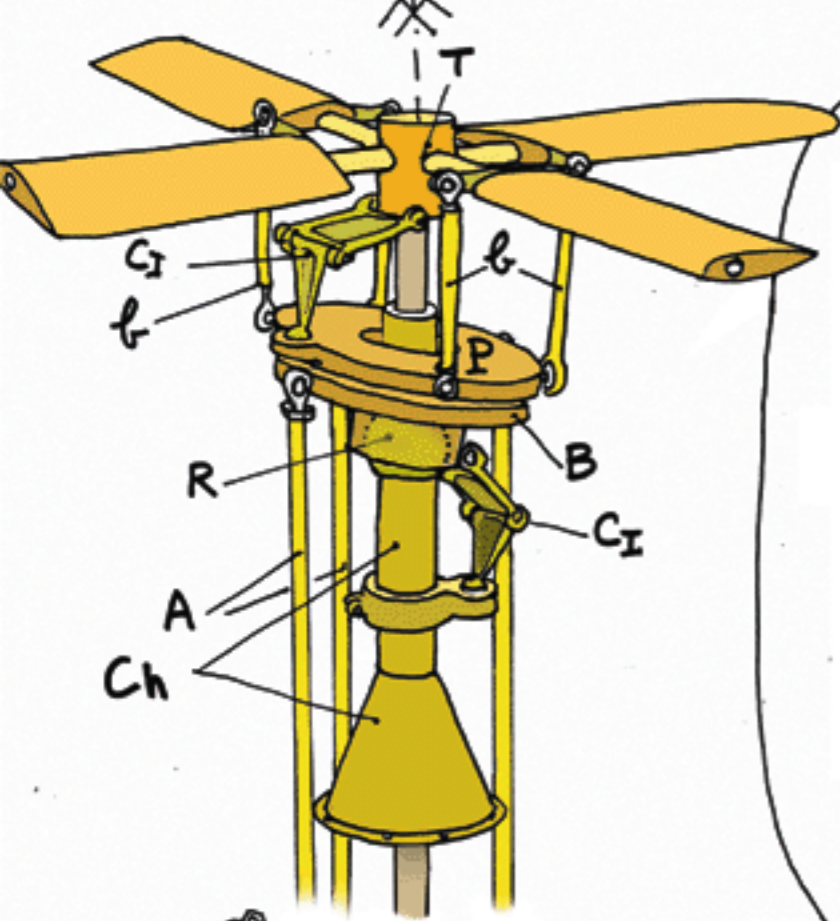
By deforming it as shown, it can be slid into the tube in which the rotor shaft turns.



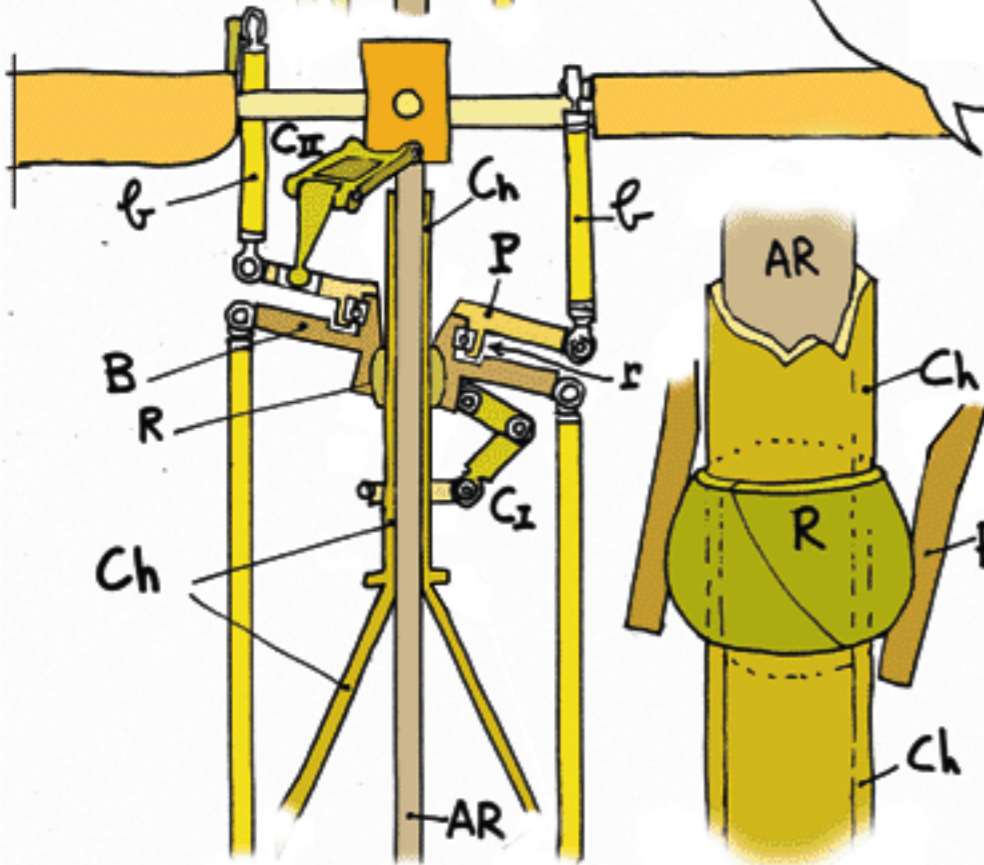
Synthesis on the following page →

SWASHPLATE





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 **CI**, 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 **CII**, 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.

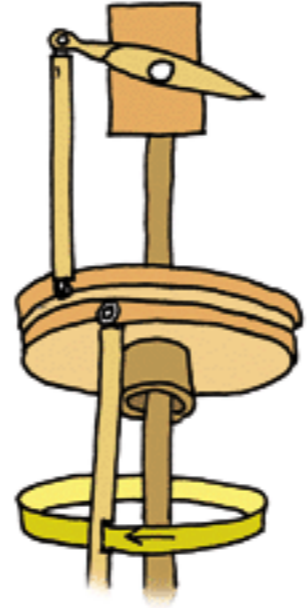
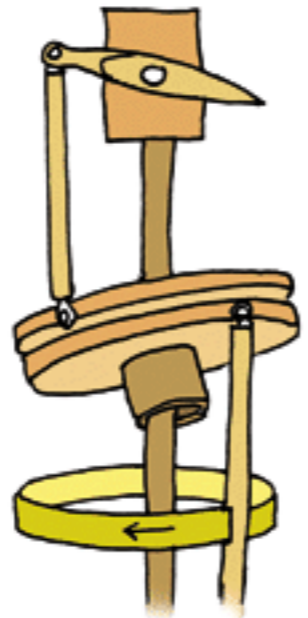
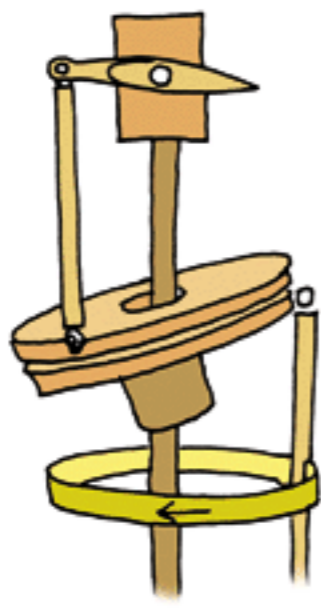
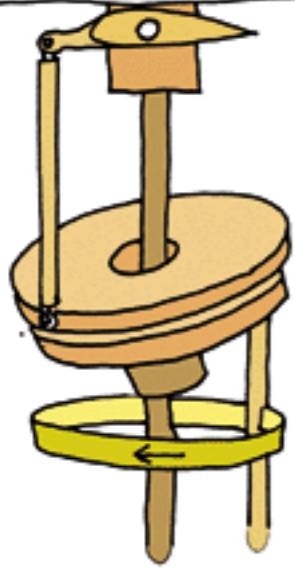


Now we have to imagine the flight control mechanism that will allow me to move the three vertical bars

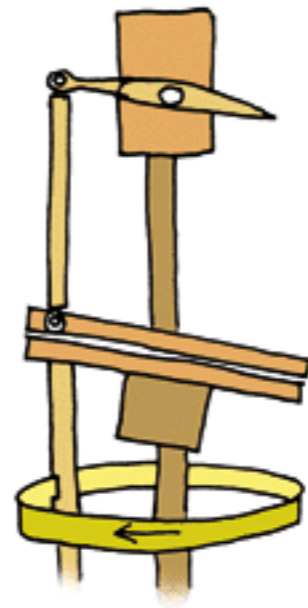
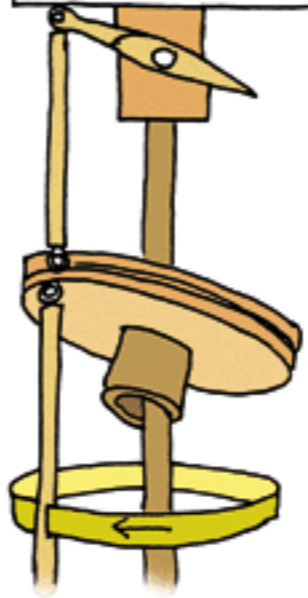


And the job will be done

Minimum incidence

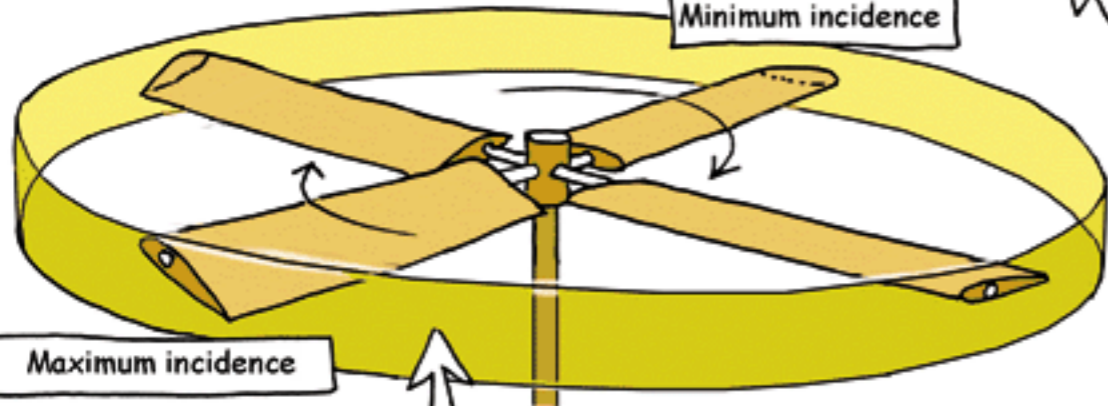


Maximum incidence



Etc...
Below, the
apparent movement
of one of the control
linkages

Minimum incidence



Maximum incidence

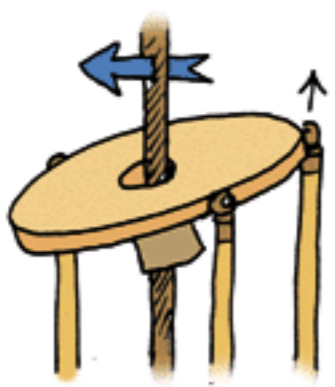
Above we follow one blade's movement. Its incidence varies periodically between a minimum and a maximum value

Here the blades occupy four different positions in the plane of rotation

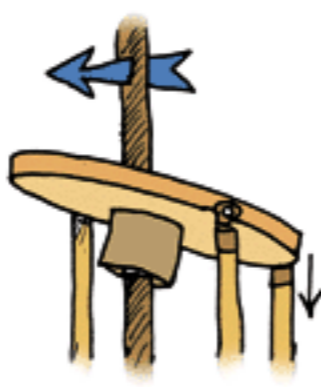
The arrow points towards the front of the aircraft.

Three rods are enough to control the non-rotating plate's attitude.

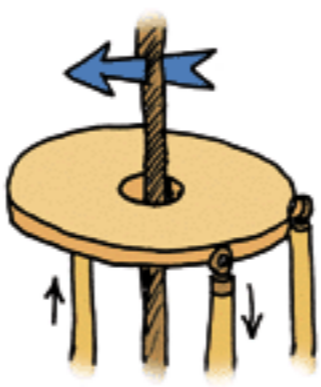
Fly the helicopter by increasing the blade incidence



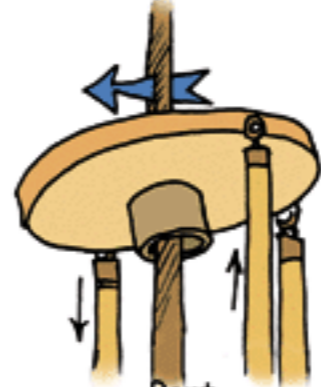
Back



Front

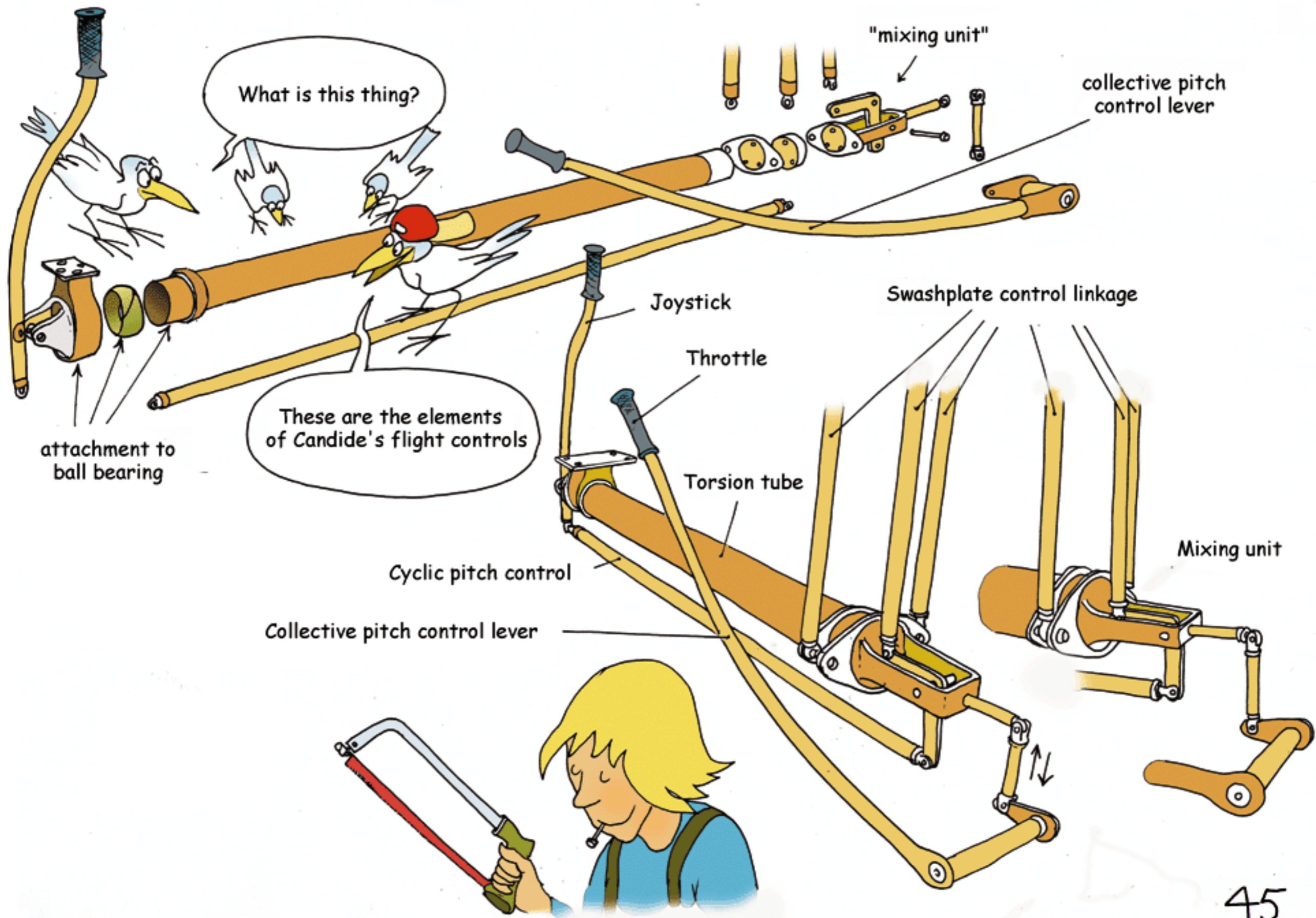


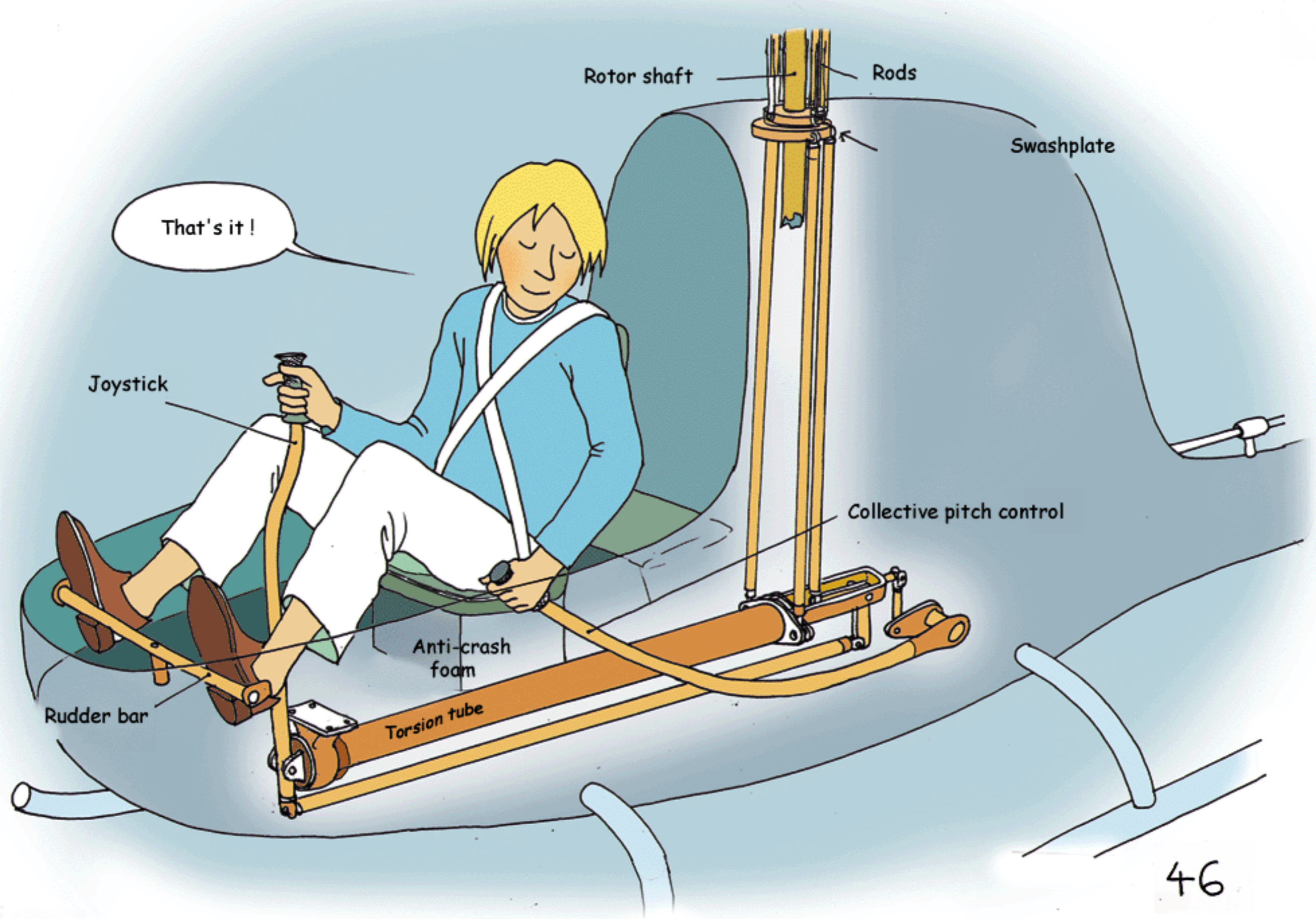
Starboard



Port







Everything is ready this time Pangloss.
I am just about to free Miss Cunegonde



Let's go!



**PATAKLONK
PATAKLONK
PATAKLONK**



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...



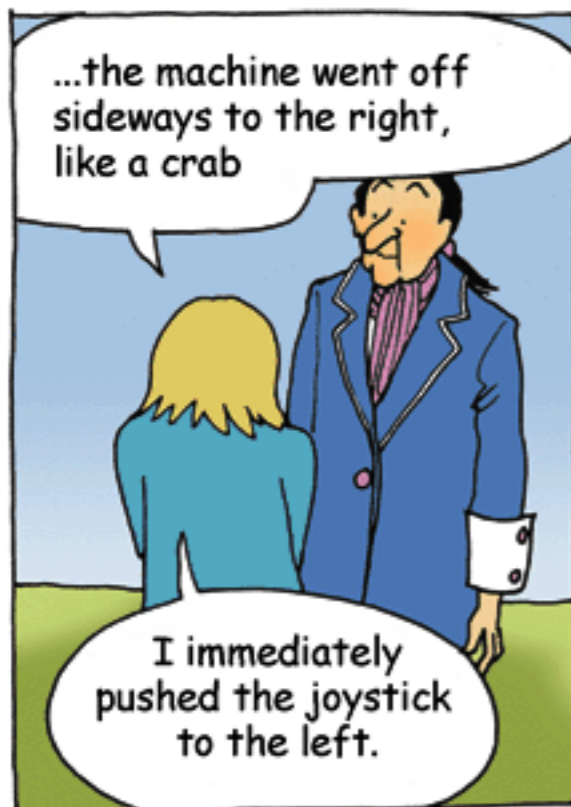
What then, my dear Candide?

I thought I had put into practice the best of all possible fluid mechanics



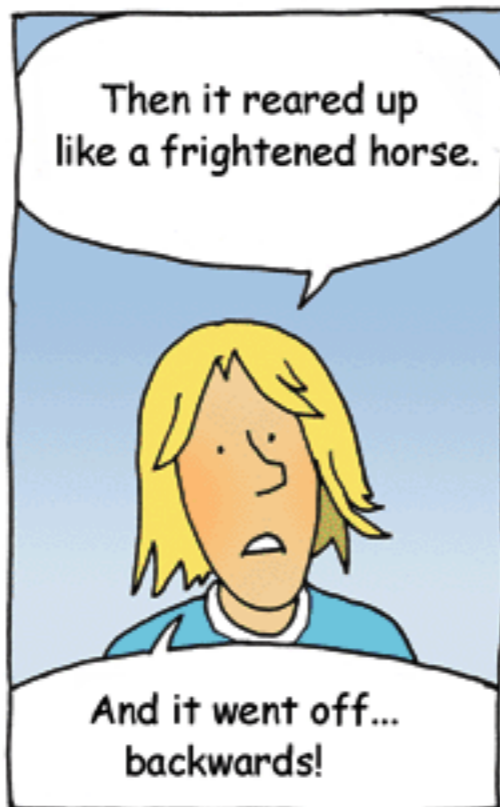
And do you know what good master? When I pushed the joystick forward...





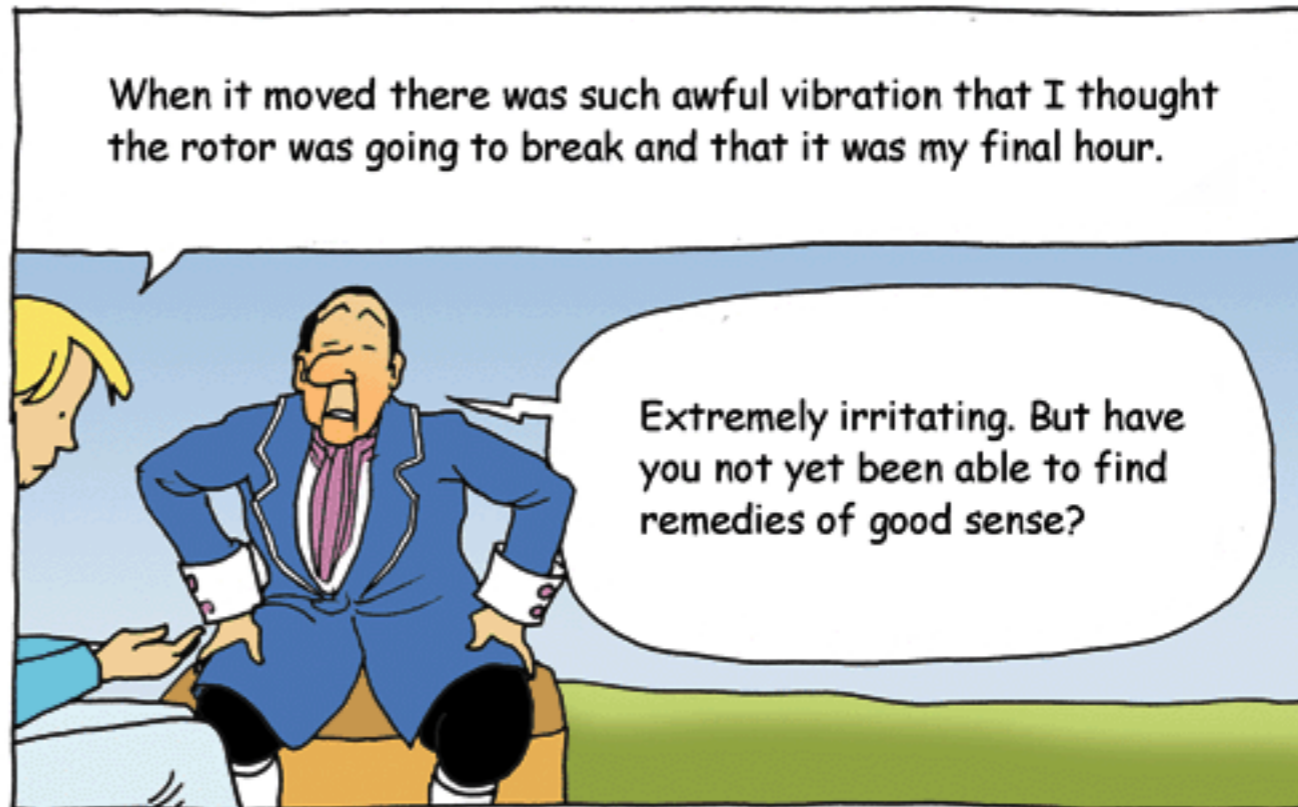
...the machine went off sideways to the right, like a crab

I immediately pushed the joystick to the left.



Then it reared up like a frightened horse.

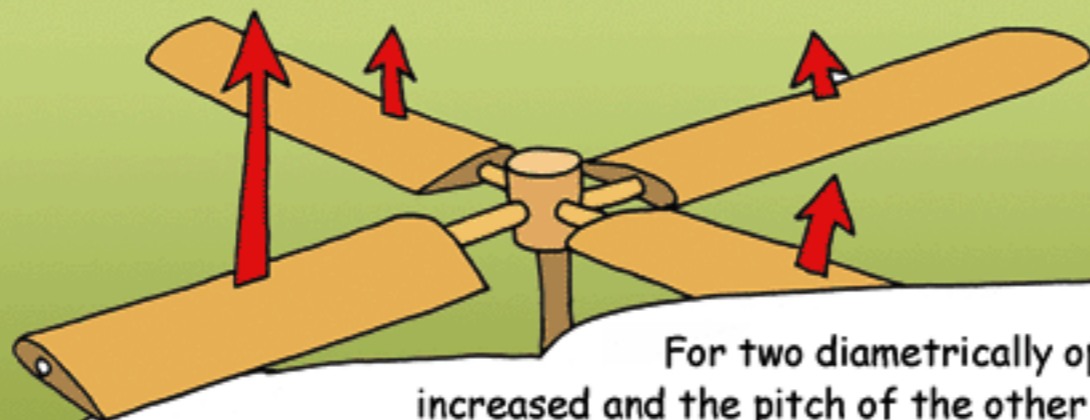
And it went off... backwards!




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?

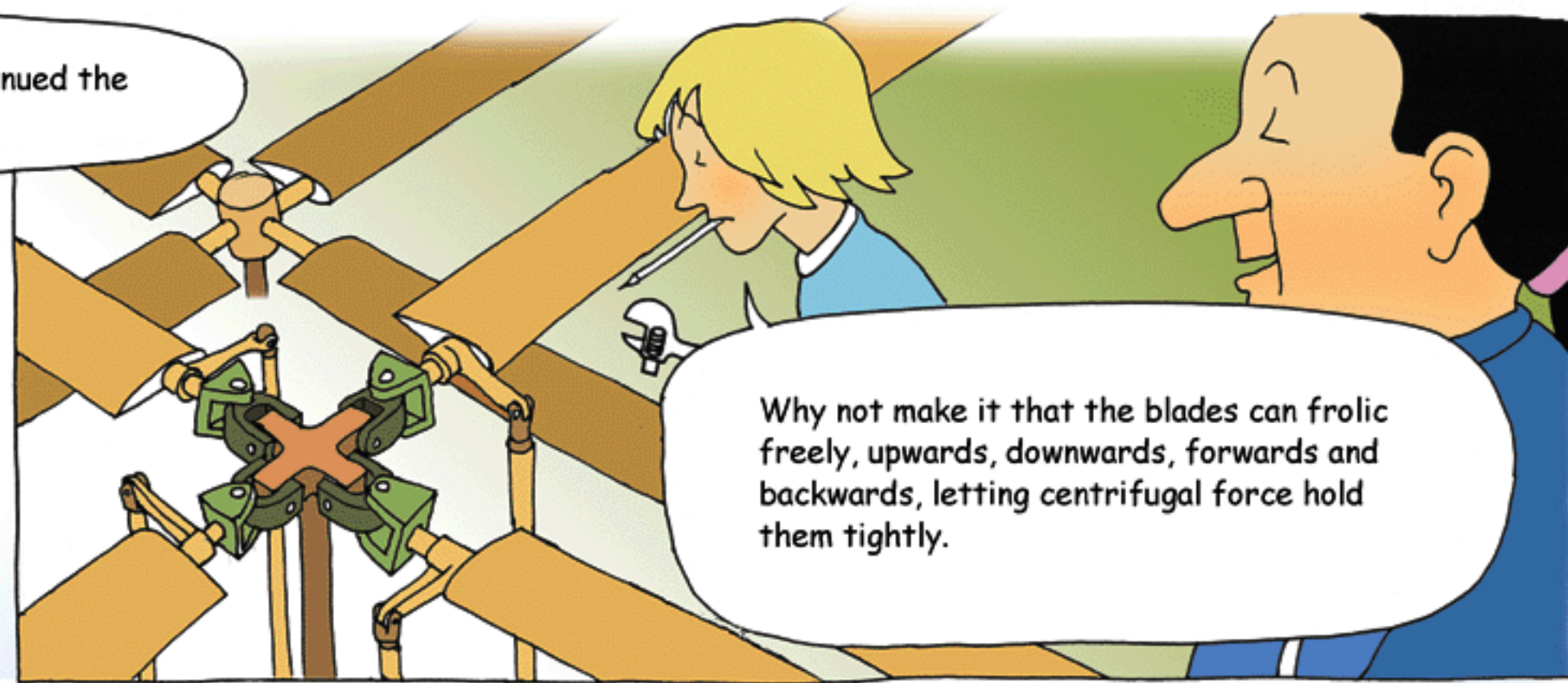
I felt that the machine began shaking when I used the pitch cycle variation. It was as if an invisible hand had seized the boss of the rotor



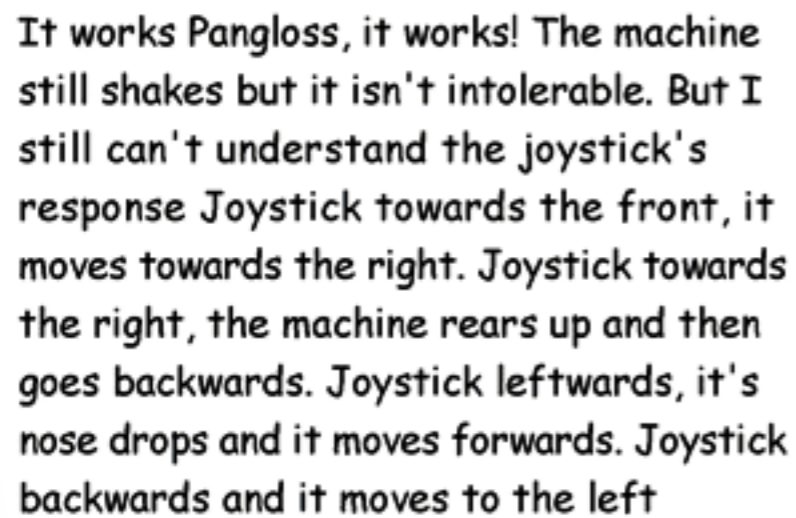
For two diametrically opposed blades, if the pitch of one is increased and the pitch of the other decreased, the aerodynamic forces are different in intensity and in direction, which explains the bone-shaking vibrations.



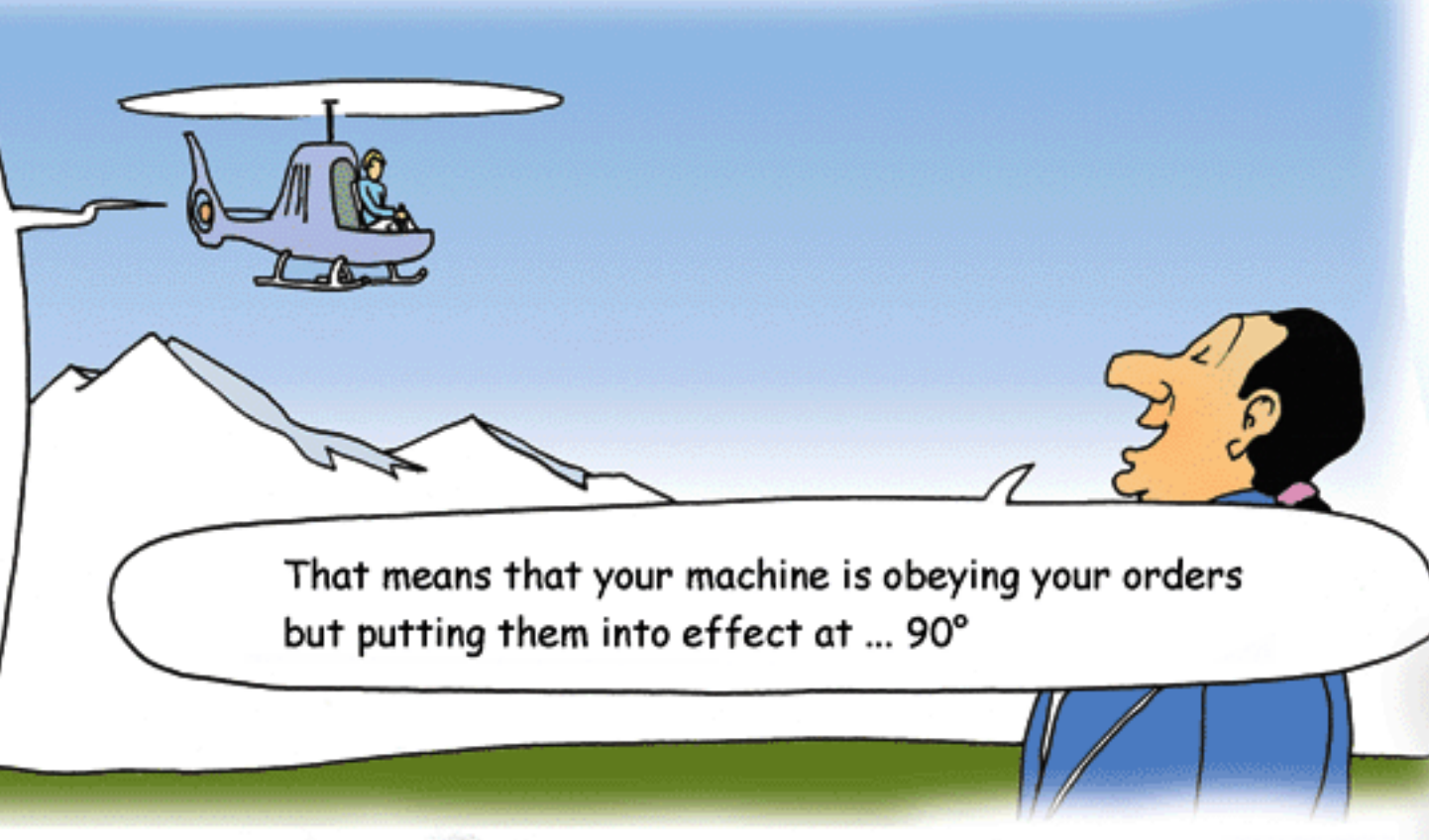
I felt that if I continued the rotor could break.



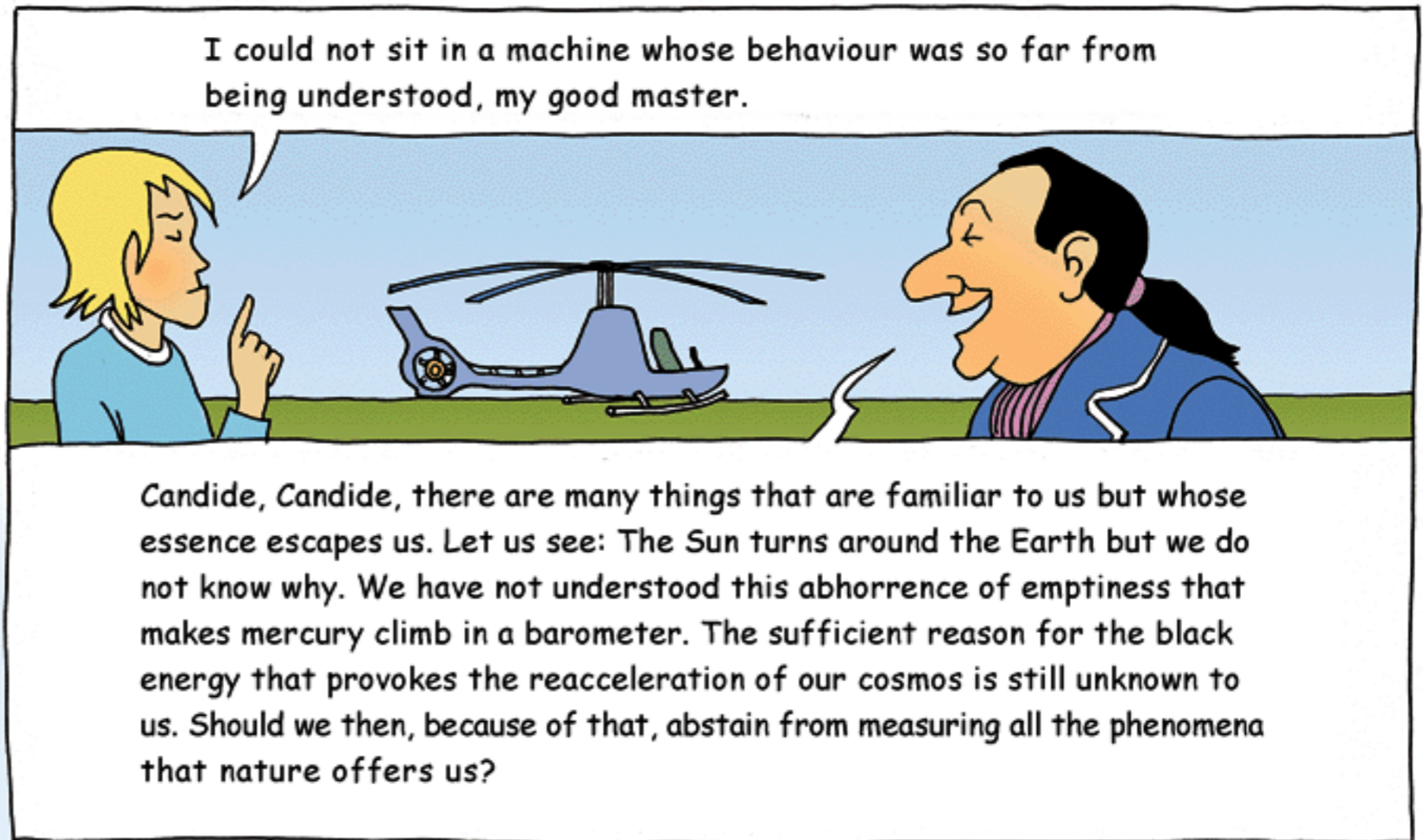
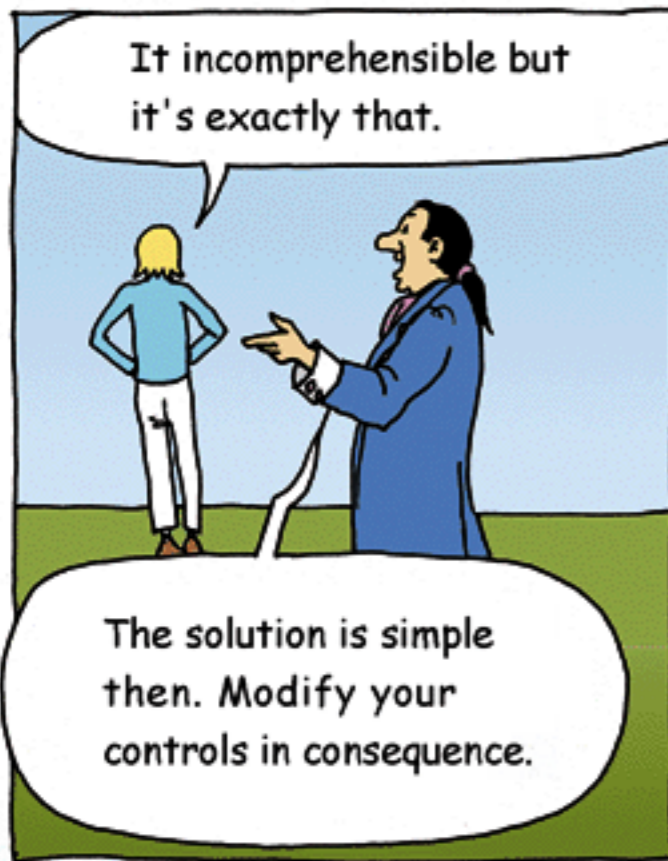
Why not make it that the blades can frolic freely, upwards, downwards, forwards and backwards, letting centrifugal force hold them tightly.



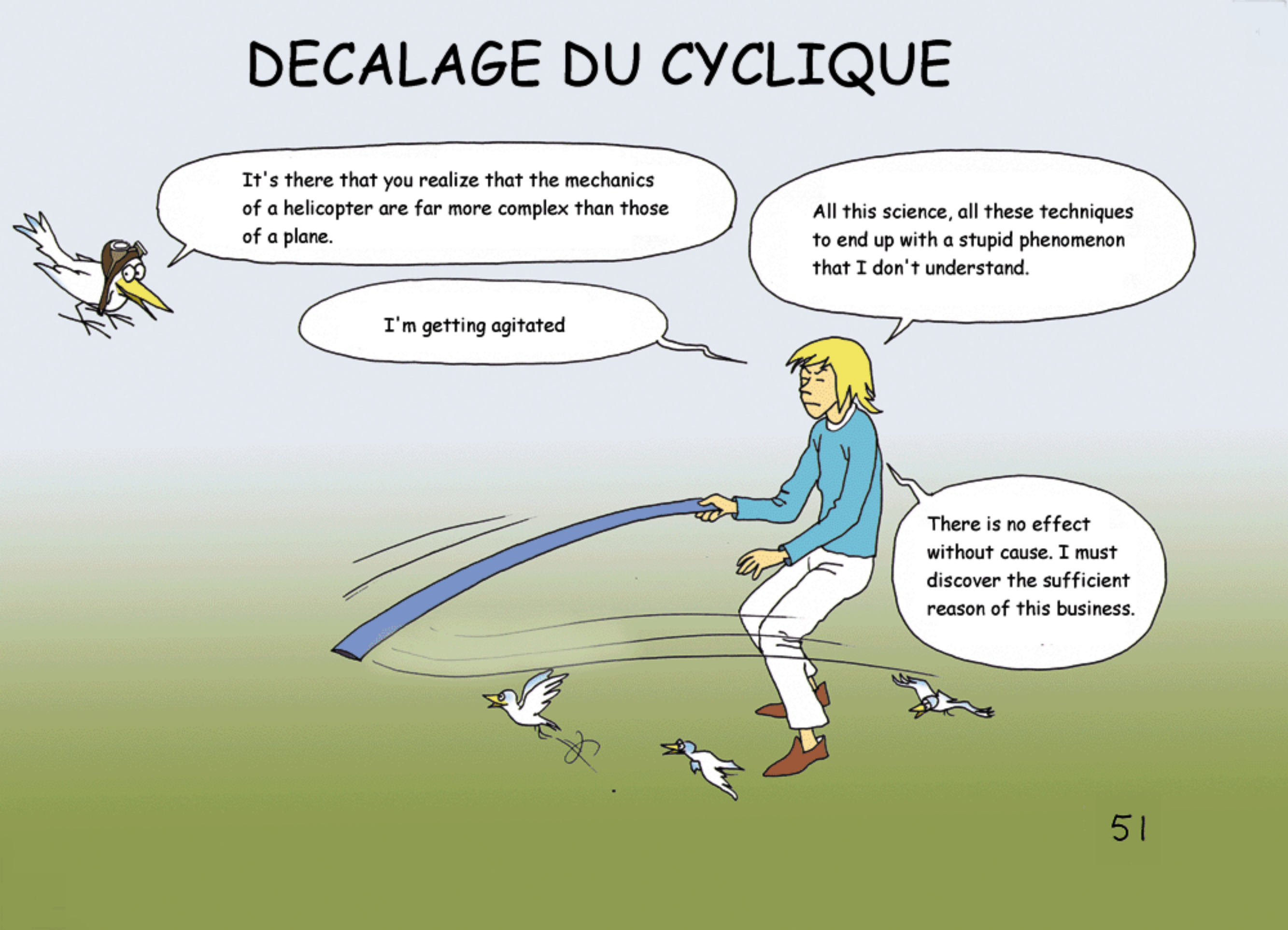
It works Pangloss, it works! The machine still shakes but it isn't intolerable. But I still can't understand the joystick's response Joystick towards the front, it moves towards the right. Joystick towards the right, the machine rears up and then goes backwards. Joystick leftwards, it's nose drops and 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°



DECALAGE DU CYCLIQUE



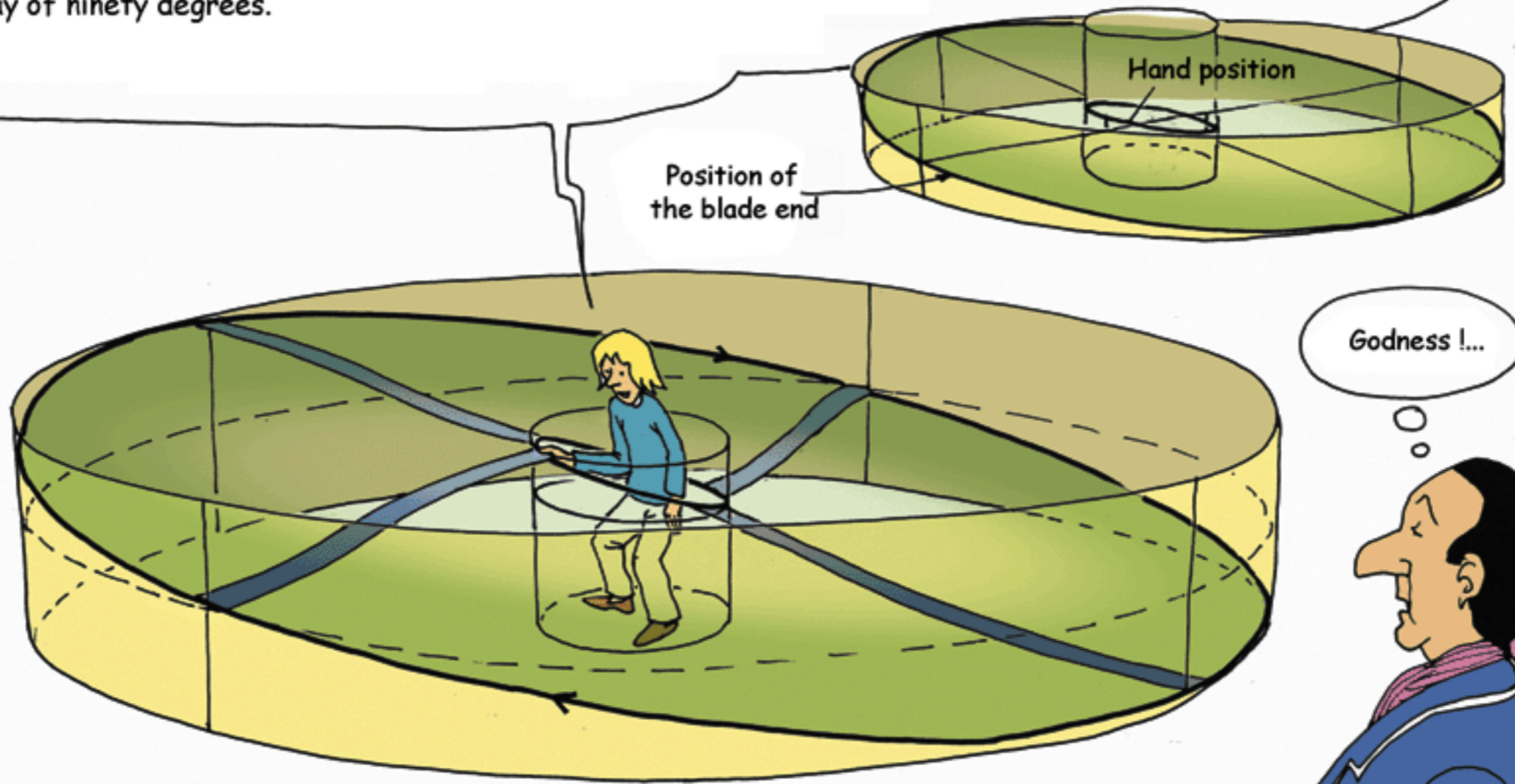
It's there that you realize that the mechanics of a helicopter are far more complex than those of a plane.

All this science, all these techniques to end up with a stupid phenomenon that I don't understand.

I'm getting agitated

There is no effect without cause. I must discover the sufficient reason of this business.

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.



Godness !...

In scientific terms it translates the behaviour 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.

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**.

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"

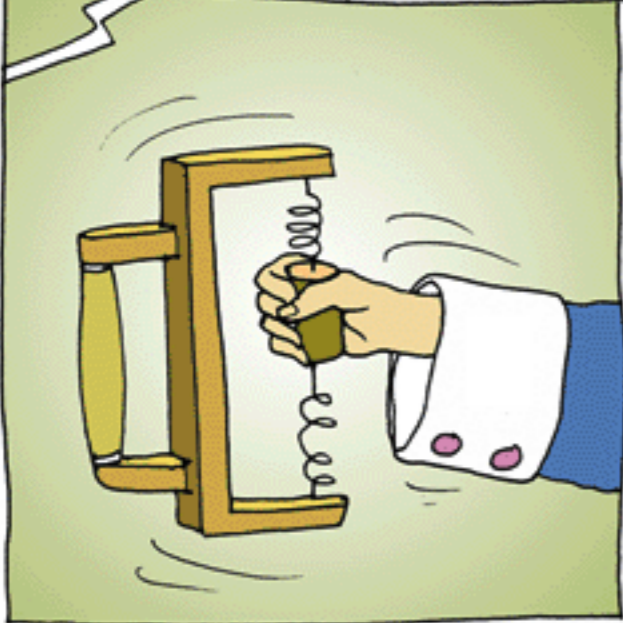
So how does fluid mechanics matter here?

I'm sure you're a terrible swimmer

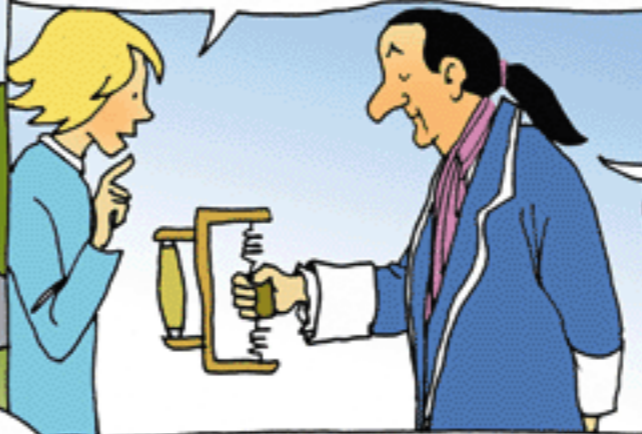


Let it drop, dear. We don't want to start an argument with this penguin. The book is complicated enough already.

The structure responds also ... in opposite synch

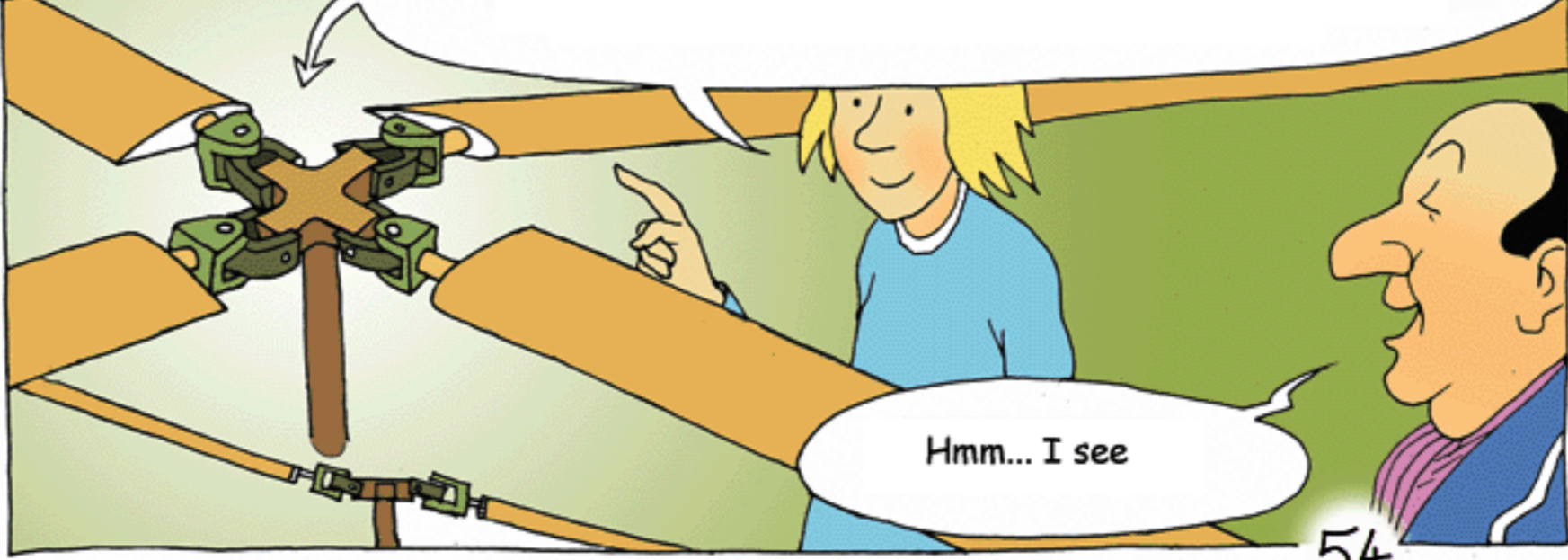


Take the elastrotron, not it's bob weight and shake it according to its system eigen mode T

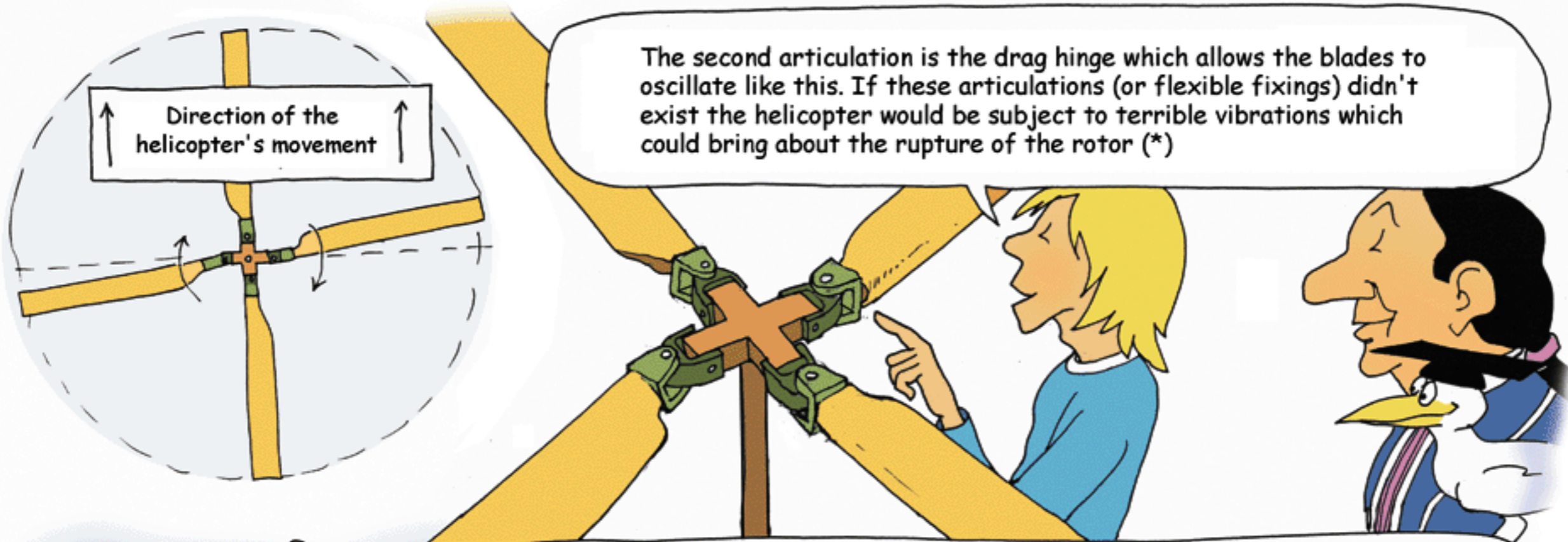


OK. I grab it like this and I shake it according to its ... eigen mode

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.

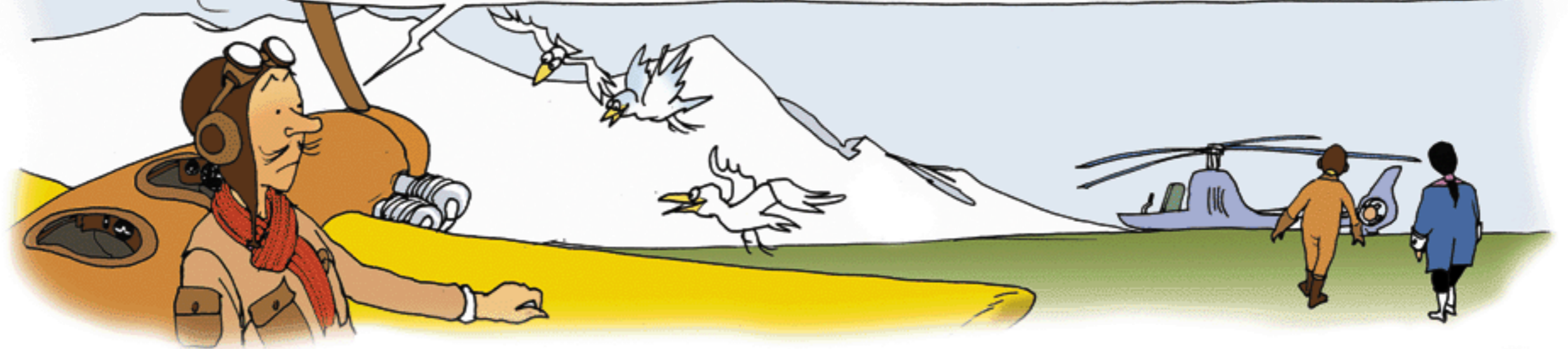


Hmm... I see



The second articulation is the drag hinge which allows the blades to oscillate like this. If these articulations (or flexible fixings) didn't exist the helicopter would be subject to terrible vibrations which could bring about the rupture of the rotor (*)

Do I have response problems with second order systems?

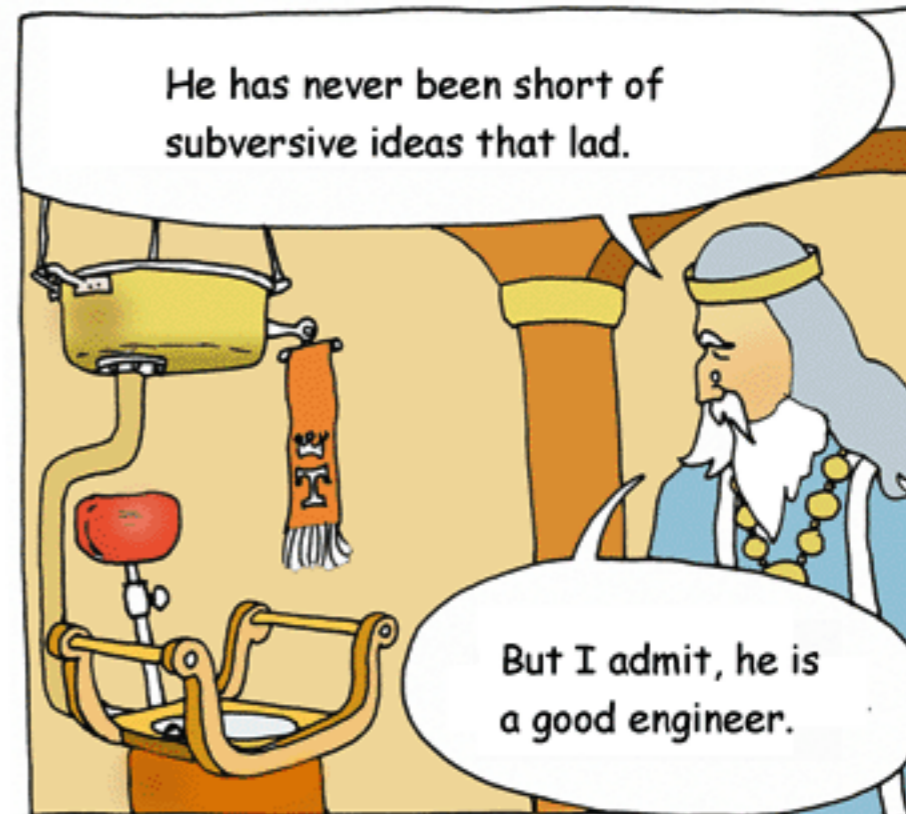


(*) Because of the problems he encountered during his experiments with his autogiro, the Spaniard de la Cierva had to hurriedly introduce a system of "articulated blades plus shock absorbers" or else his rotor would have broken.



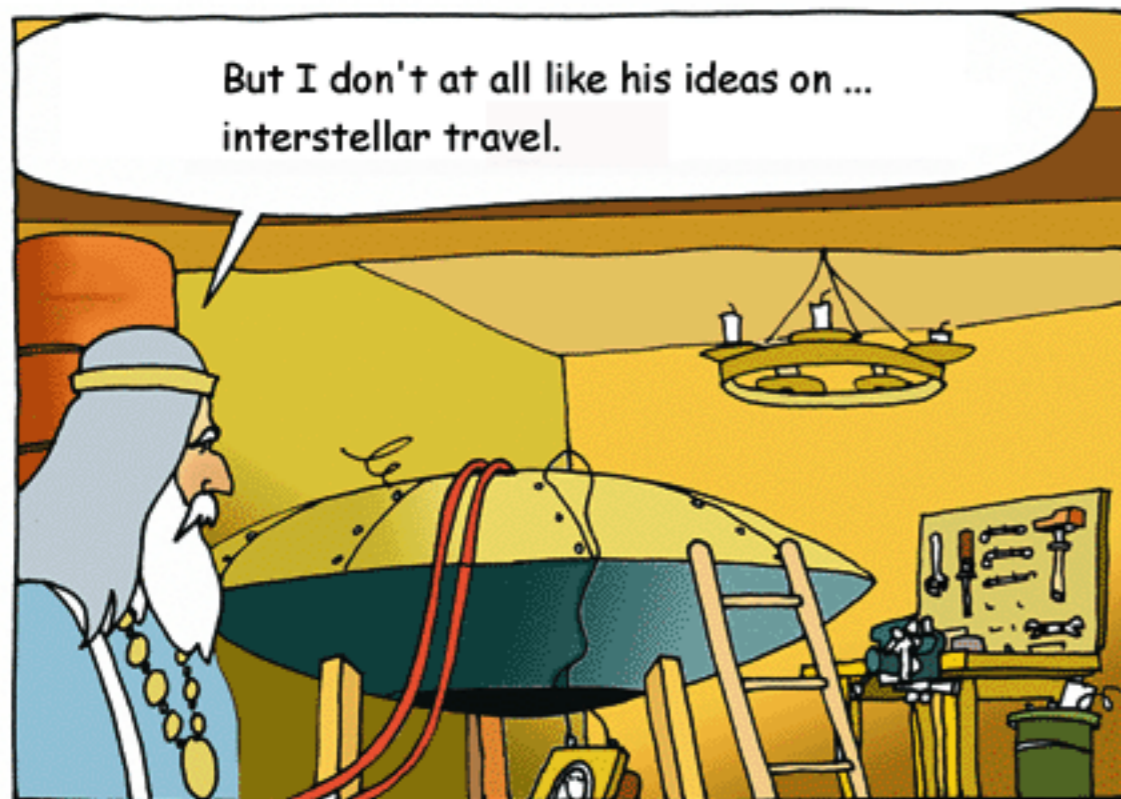
I wonder what Candide is doing. It's been a while since we had any news of him. It worries me.

It makes you wonder what else he could invent.

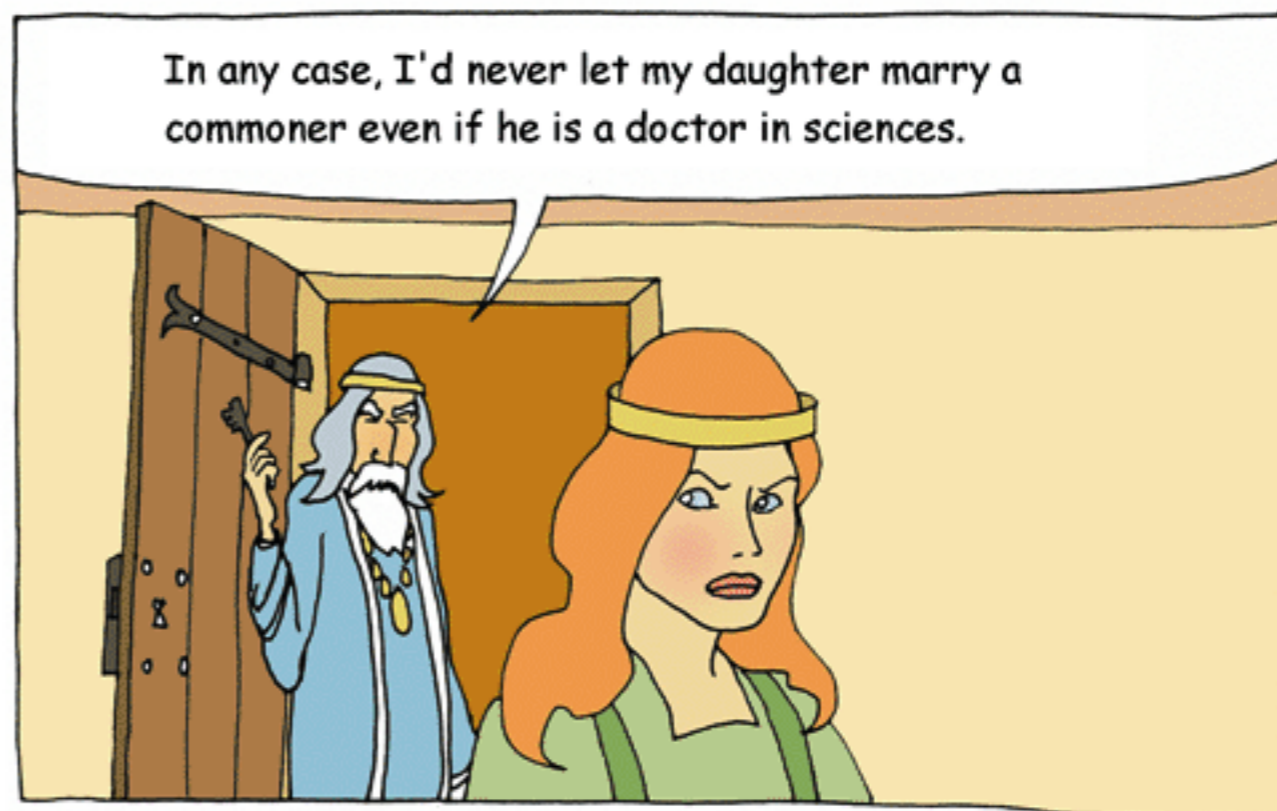


He has never been short of subversive ideas that lad.

But I admit, he is a good engineer.

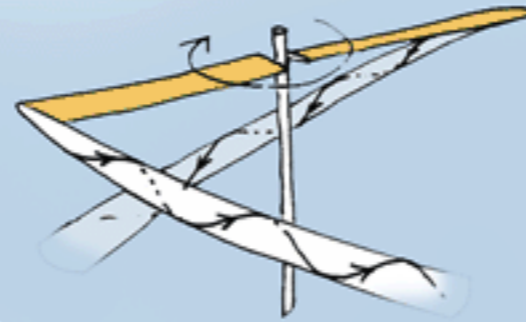
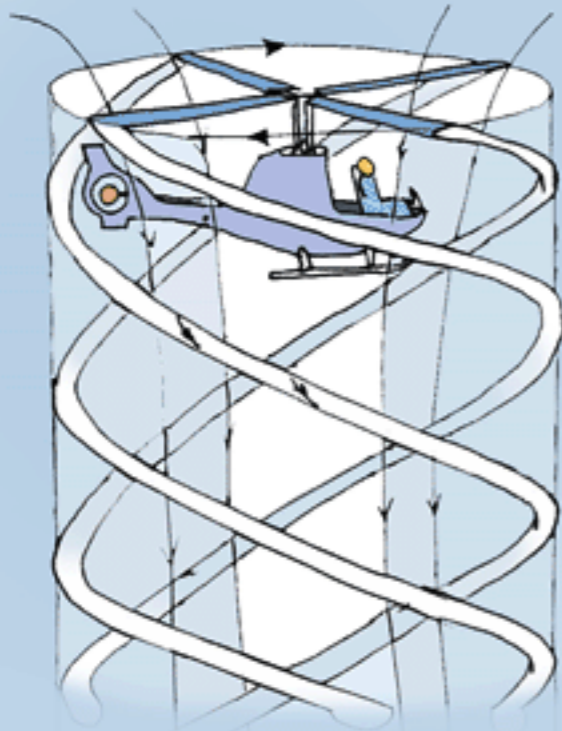


But I don't at all like his ideas on ... interstellar travel.



In any case, I'd never let my daughter marry a commoner even if he is a doctor in sciences.

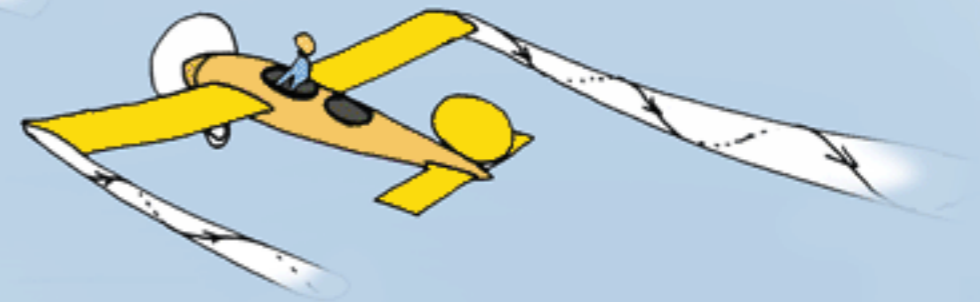
TRANSITION



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



This useless turbulence represents a portion of energy



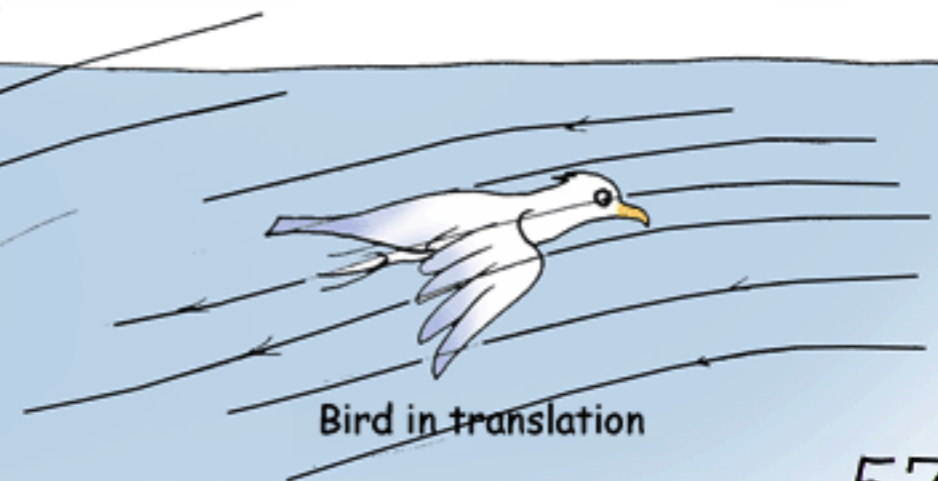
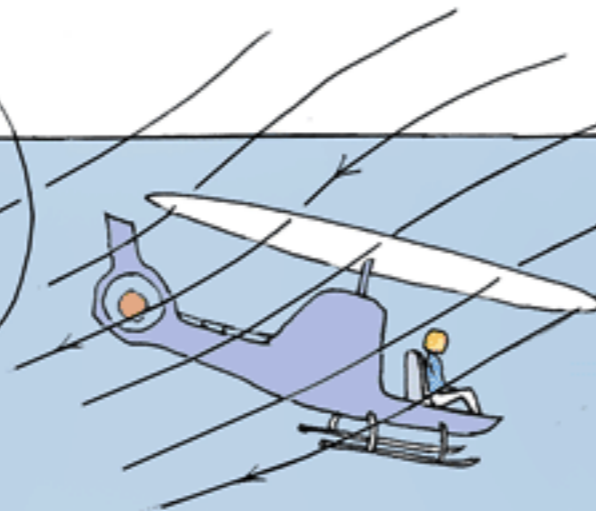
These vortices are created at the blade's extremity which causes water vapour condensation (condensation drag) at high altitude.

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?



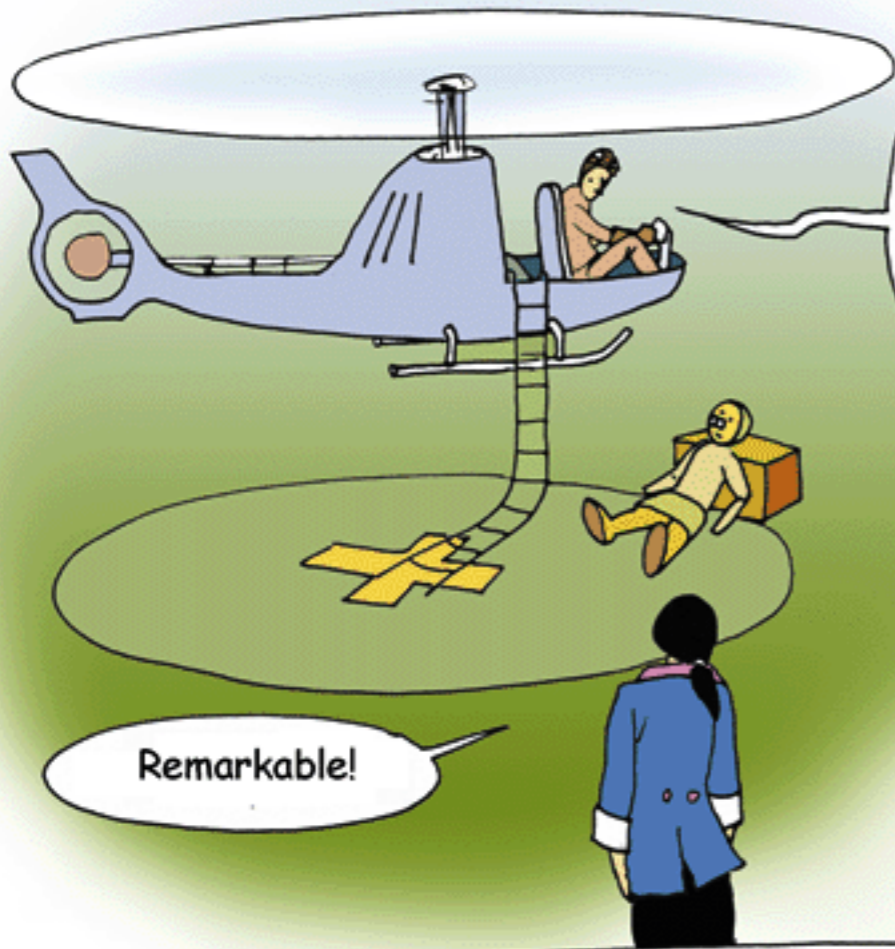
It isn't hard. Look down there,
there's something interesting, a fish.



You rear up to slow your speed
and immobilize yourself in the air.



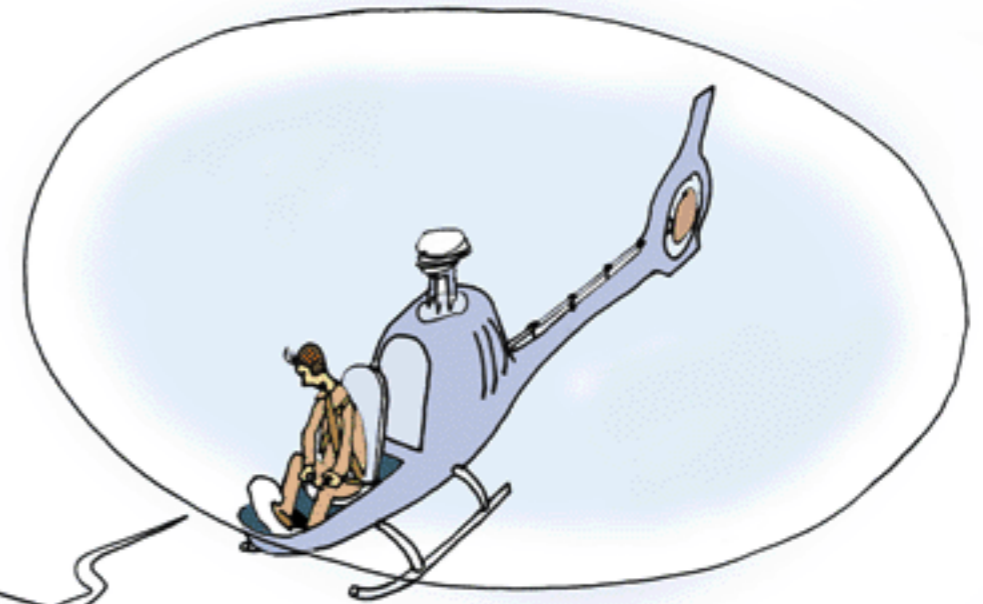
And there you get back to a stationary flight regime by creating
strong turbulence, therefore using more energy.




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.



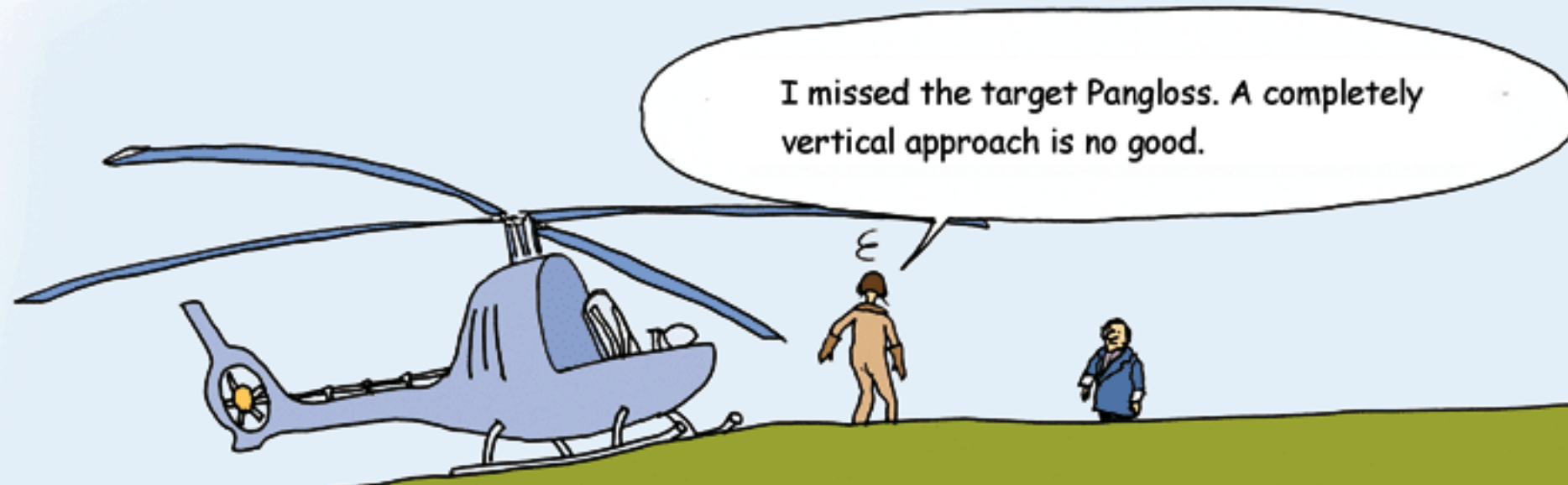


Oh dear, it's completely unstable.

And it vibrates as well



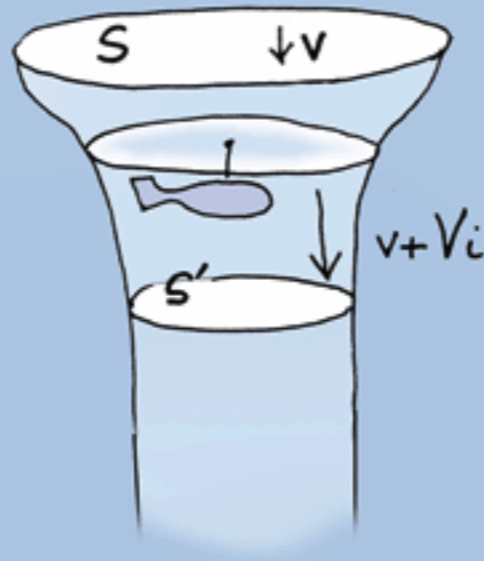
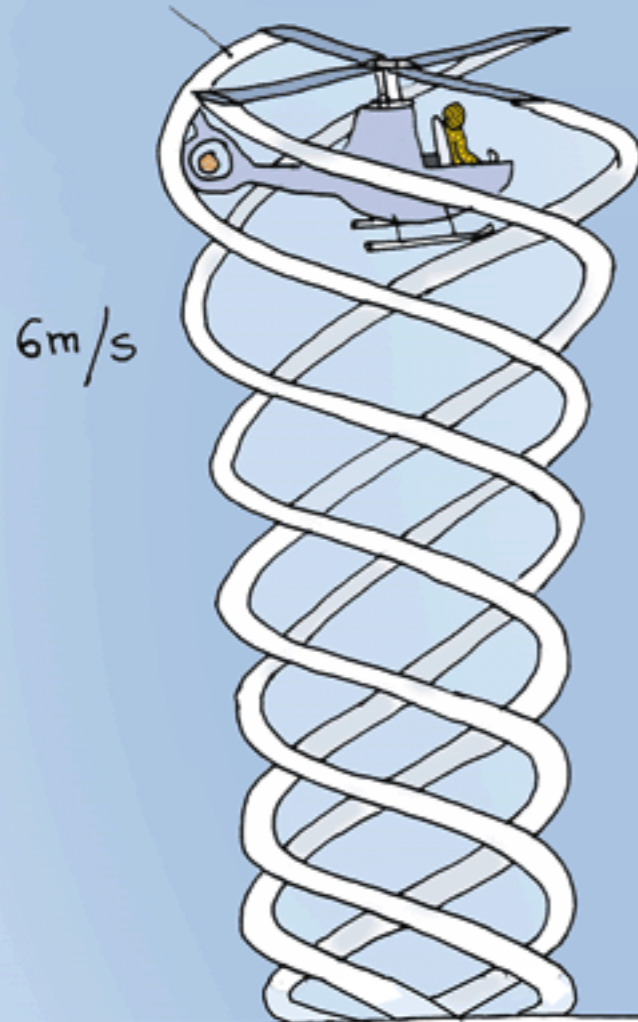
I have the impression that my helicopter is resting on a sort of formless mass, completely unstable. I've got to get out of here quickly. Well the rapid vertical descent is definitely no good at all.



I missed the target Pangloss. A completely vertical approach is no good.

INDUCED SPEED

Blade tip vortices



$$\rho v S = \rho (v + V_i) S' \quad (*)$$

The fact that the helicopter maintains lift by "pushing air downwards" implies communicating an induced speed V_i which is of the order of 6m/s



Tip vortex

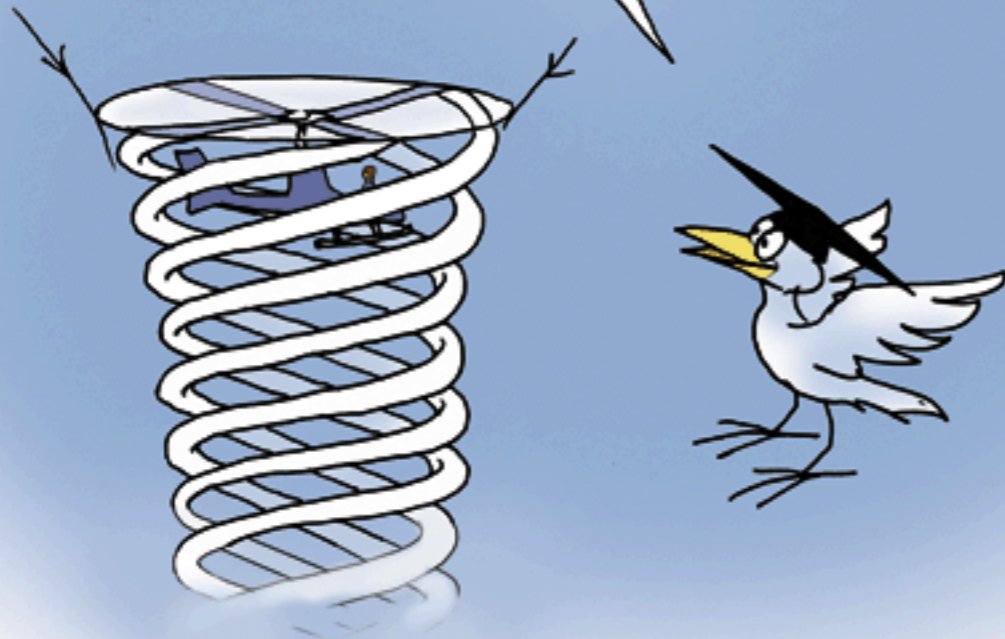
A plane also flies by "chasing air downwards" though the induced speed effect is less apparent.

(*) 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

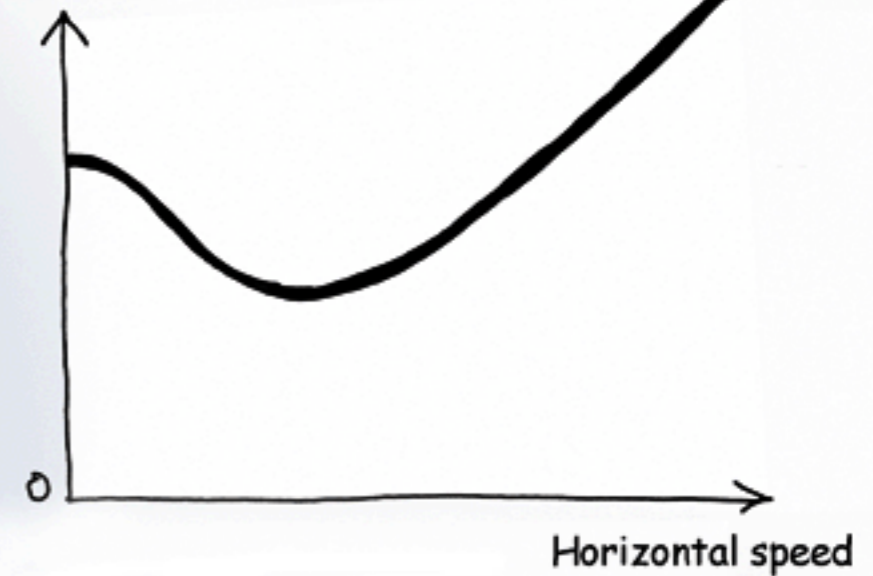
Everything that is turbulent represents a loss of energy. Flight in translation avoids establishing a turbulent regime. So this way of maintaining constant altitude gives a lower energy consumption therefore.



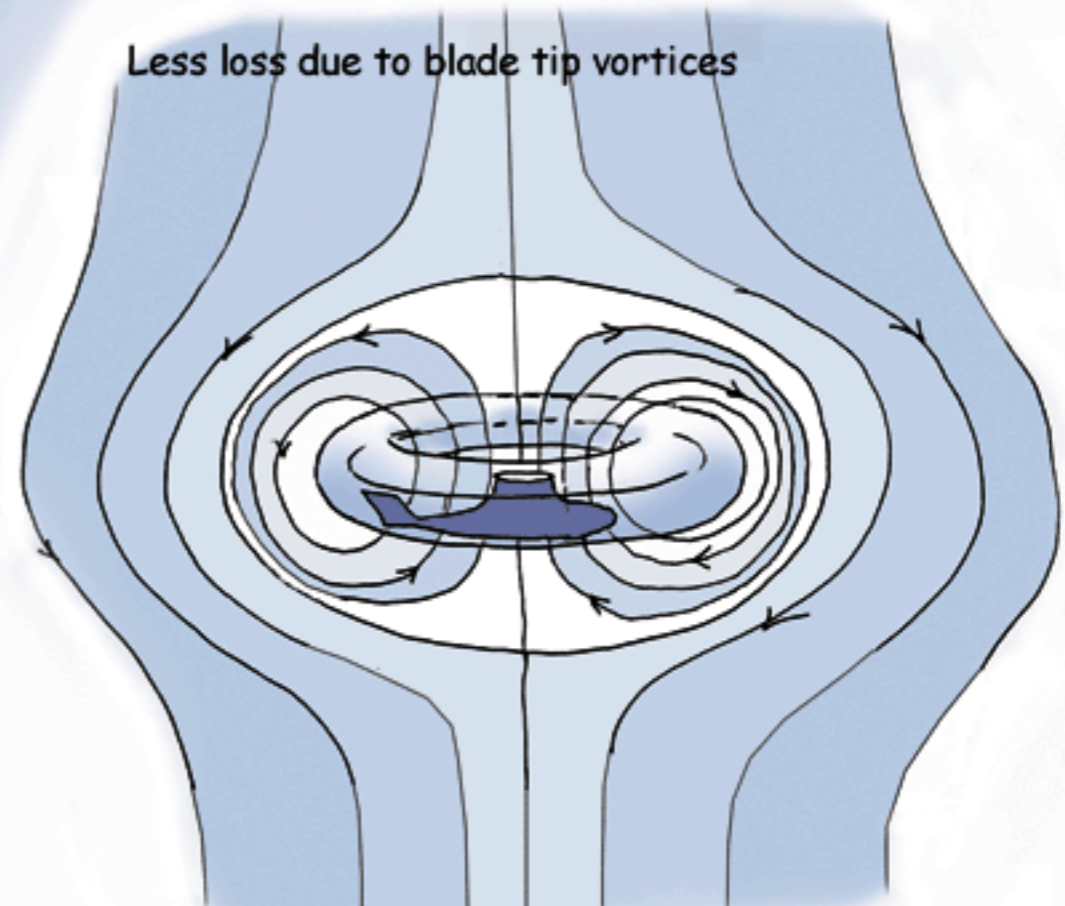
When the helicopter begins a vertical descent, the tip vortices interact when the vertical speed reaches $\frac{1}{4} V_i$



Power necessary for flight

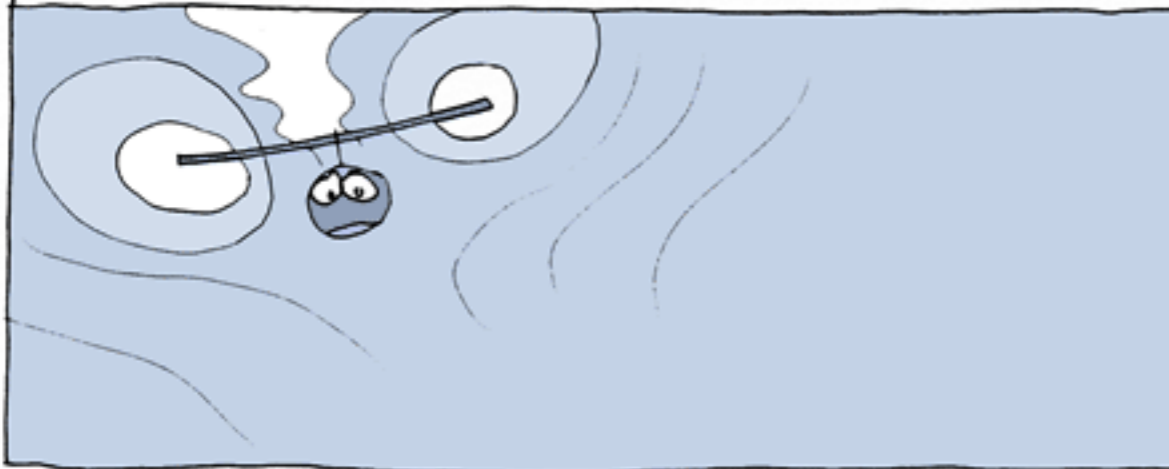


Less loss due to blade tip vortices

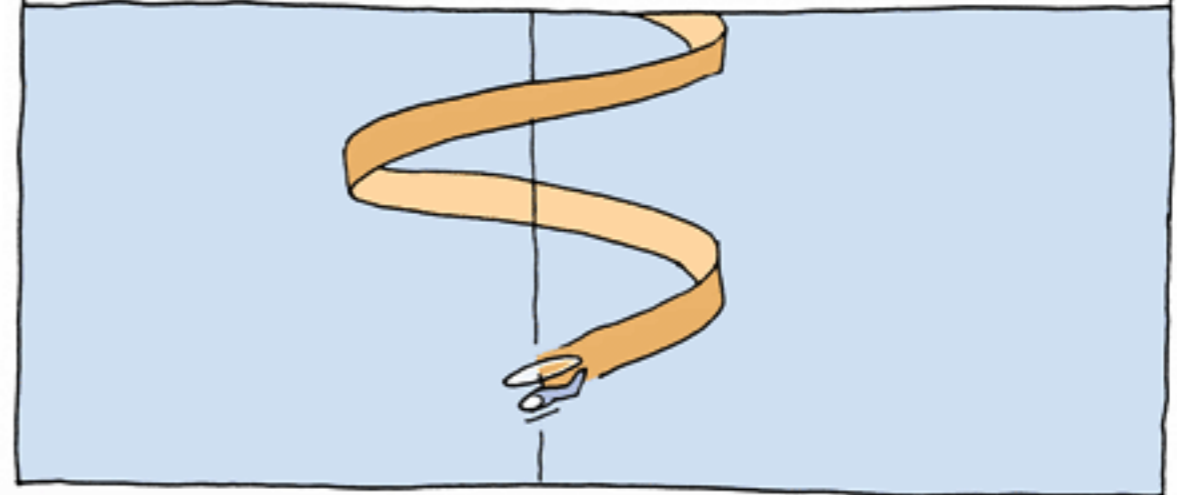


When the speed of descent reaches three quarters that of the induced speed, the vortices come together and form a large toric **vortex**.

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.



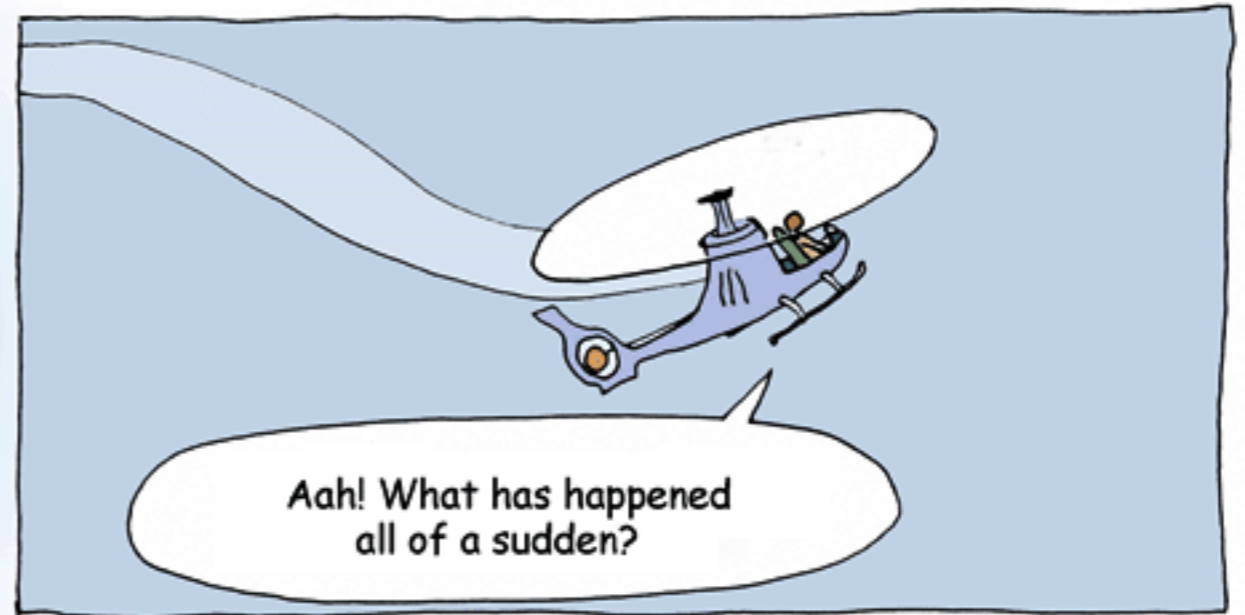
Morals: I'll approach the top of the tower horizontally. I'll sharply reduce my speed at the last moment going into stationary flight then making a final descent at a moderate vertical speed, let's say one meter per second.



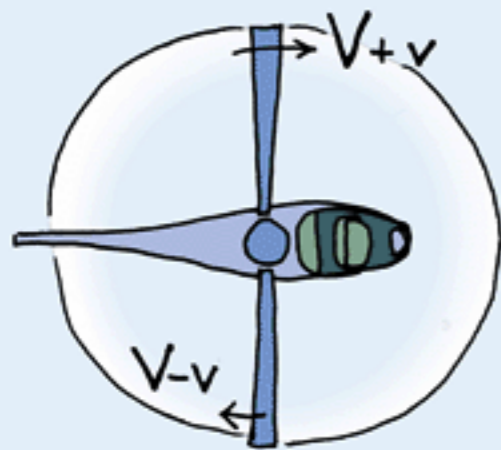
So as to avoid the dangerous passage into a vortice regime

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

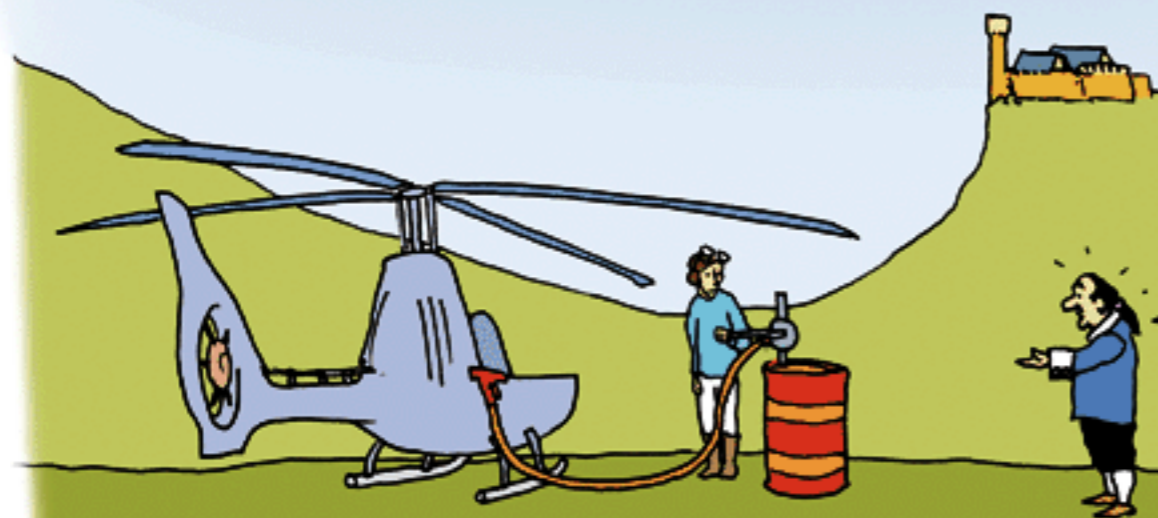
Advancing blade

We would be 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.



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.

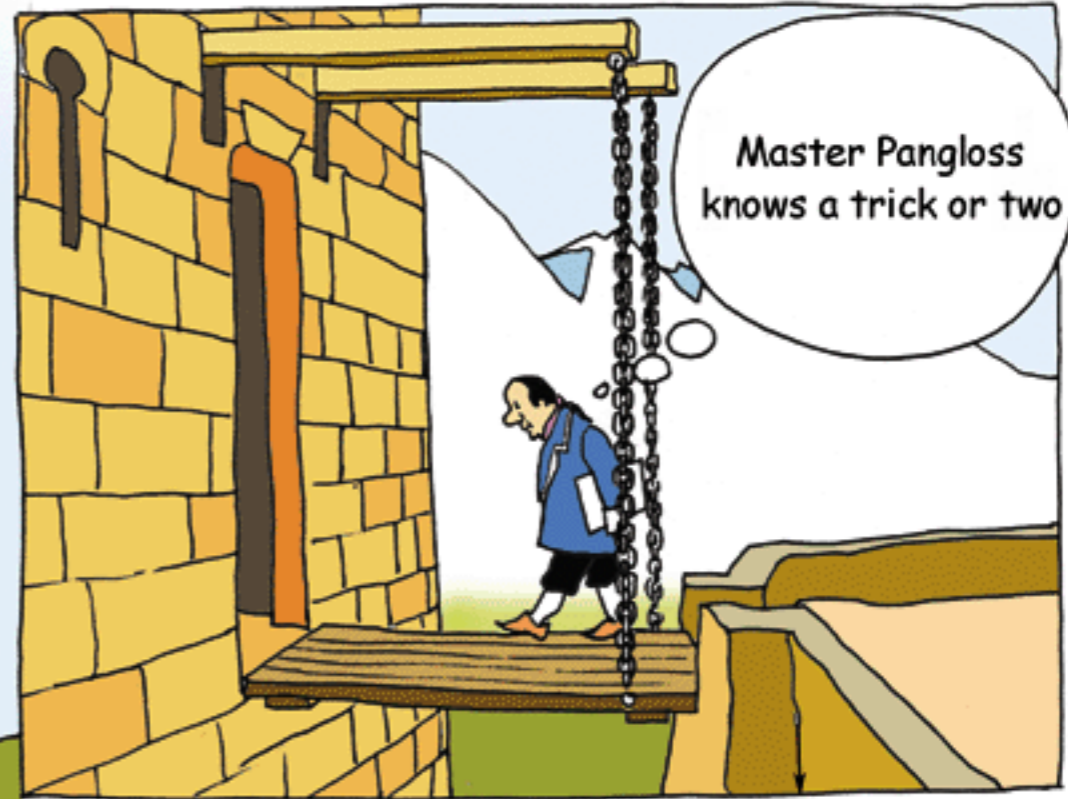
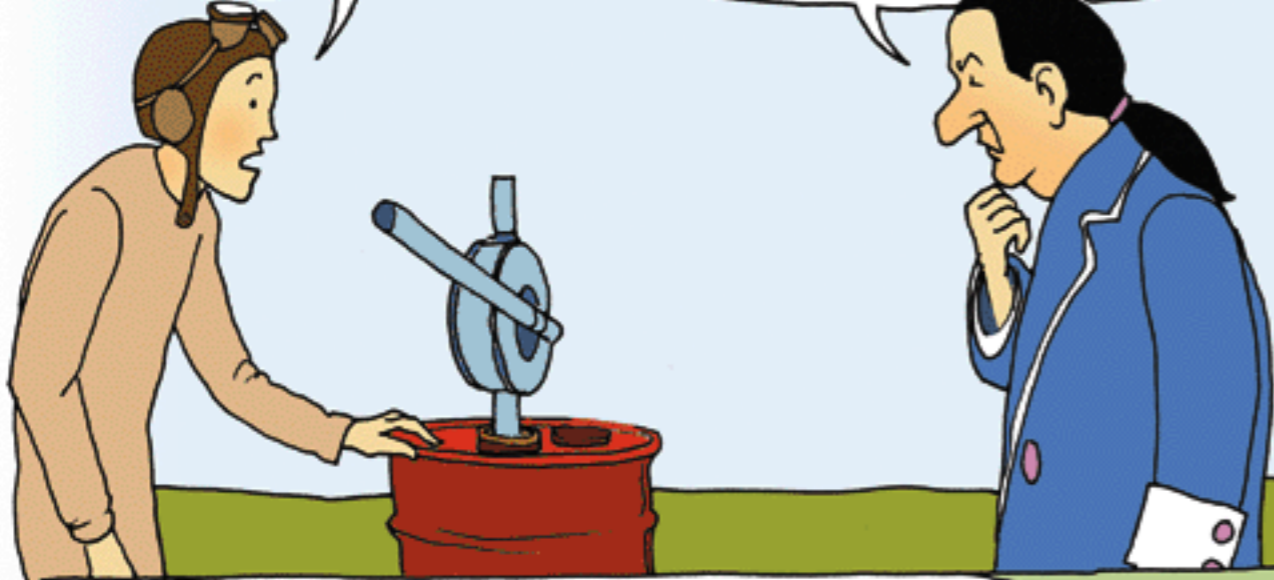
The Management



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

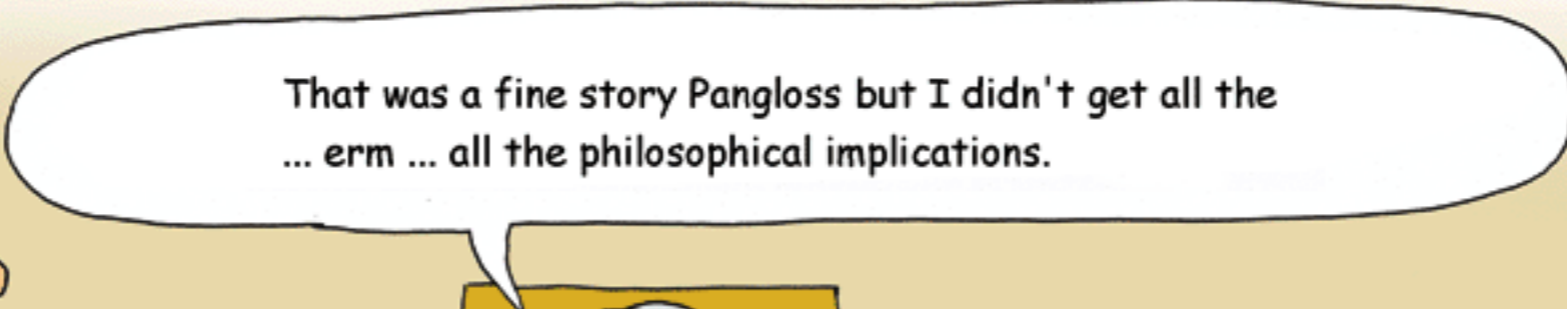


Once upon a time....

...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.

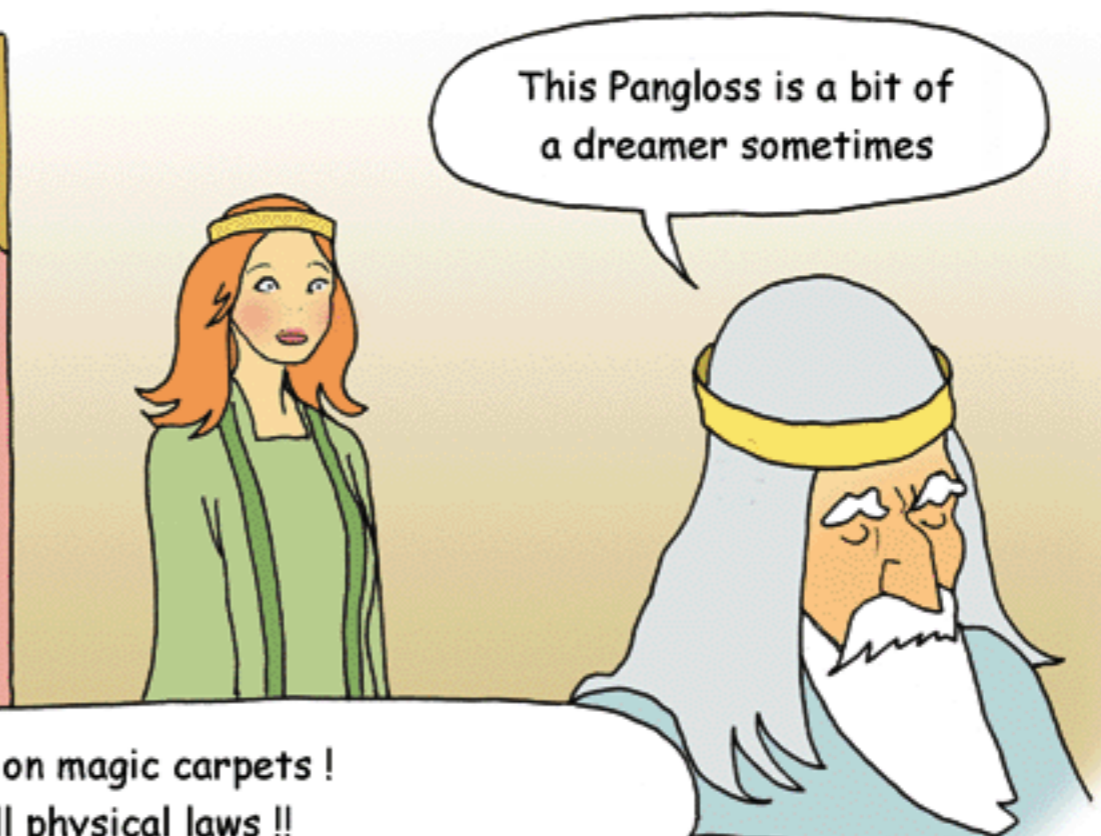


That was a fine story Pangloss but I didn't get all the ... erm ... all the philosophical implications.



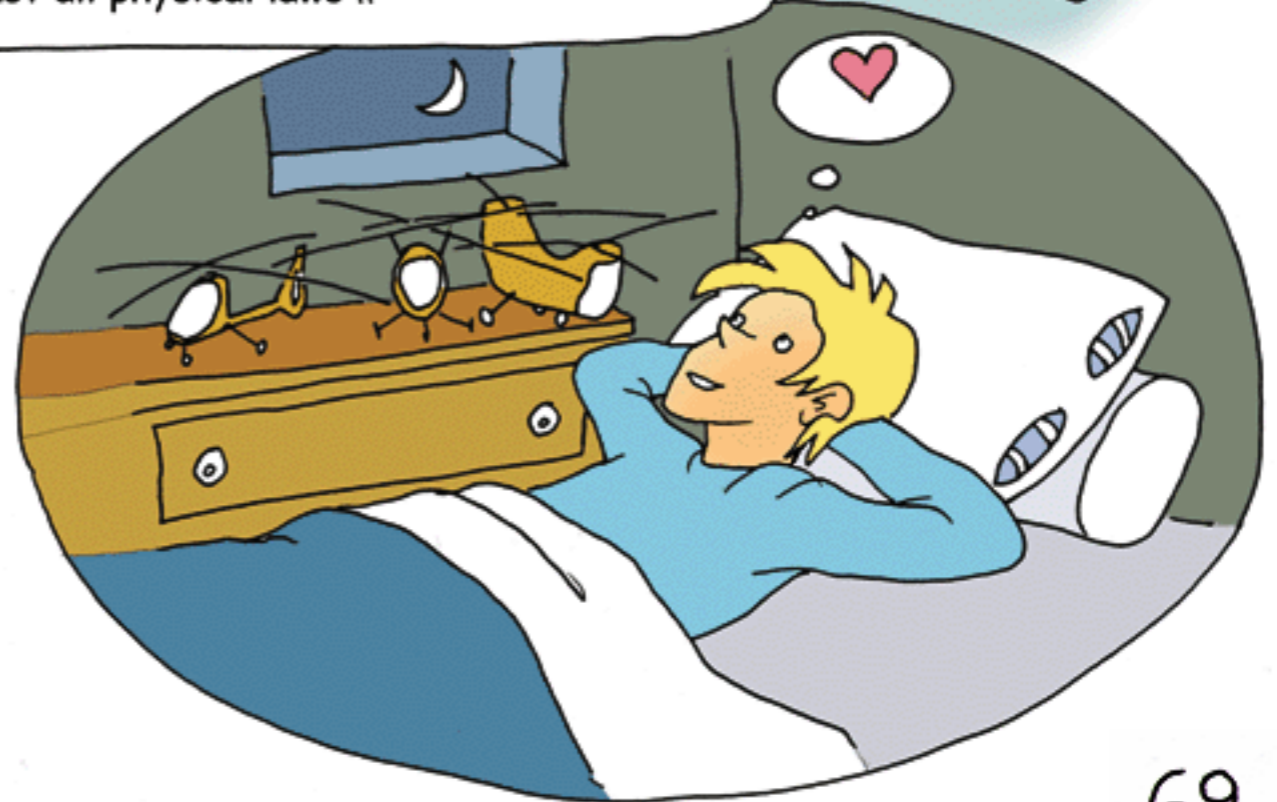


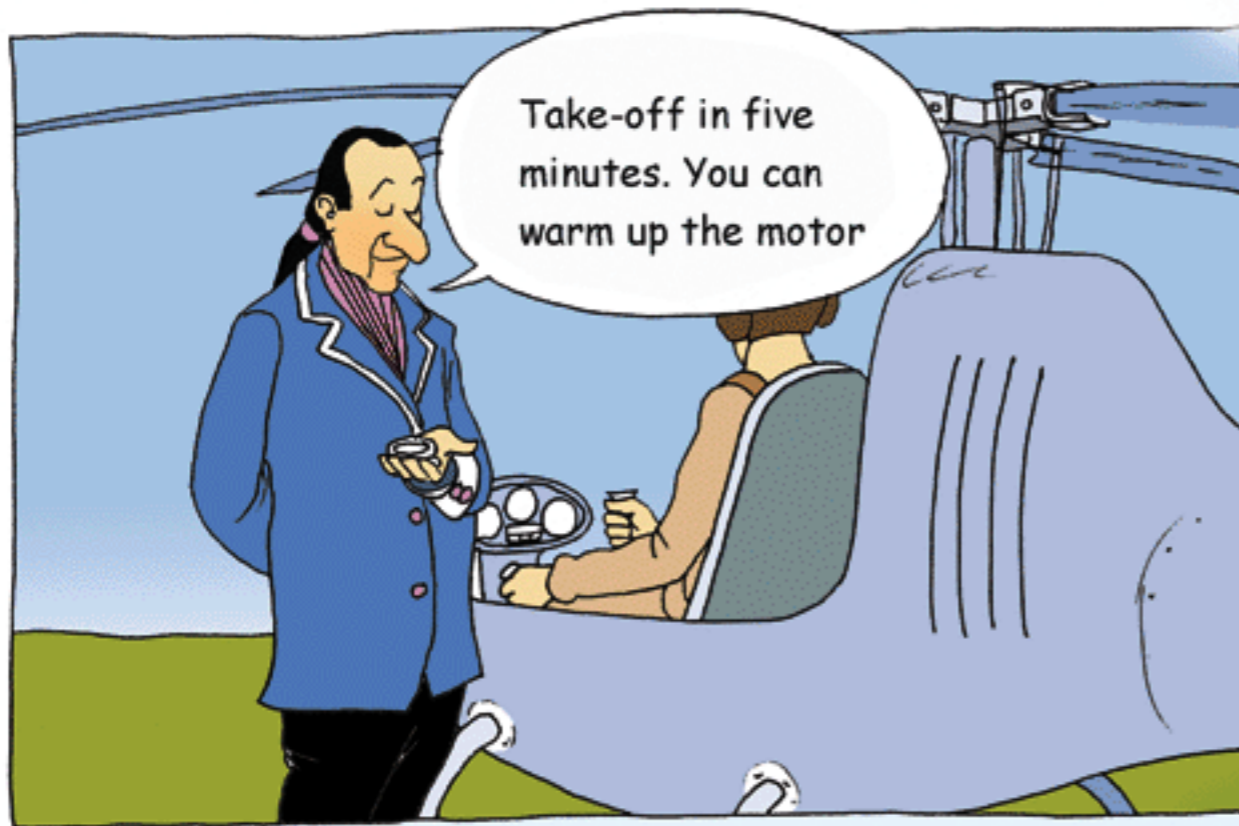
Stories like that only exist in fairy tales, or you have to believe in Father Christmas



This Pangloss is a bit of a dreamer sometimes

Princes arriving on magic carpets!
It's against all physical laws!!





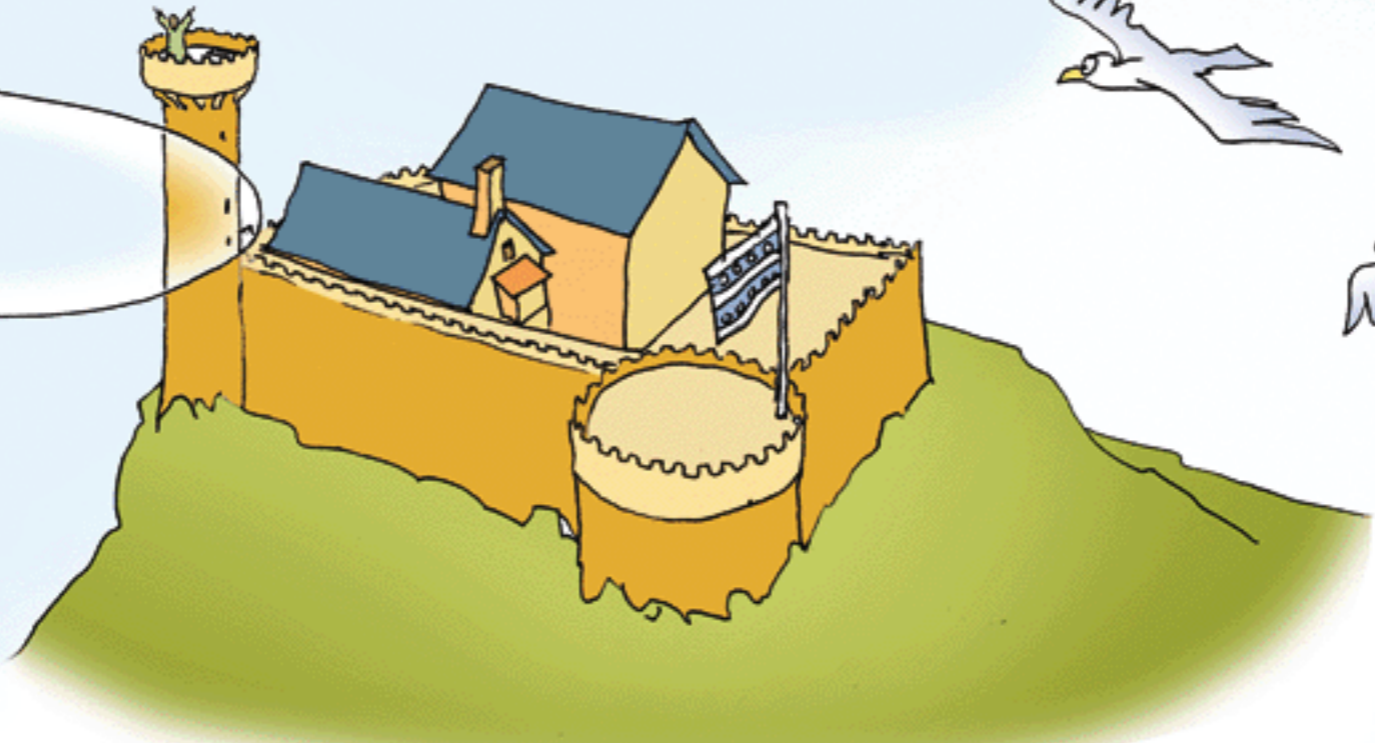
Take-off in five minutes. You can warm up the motor

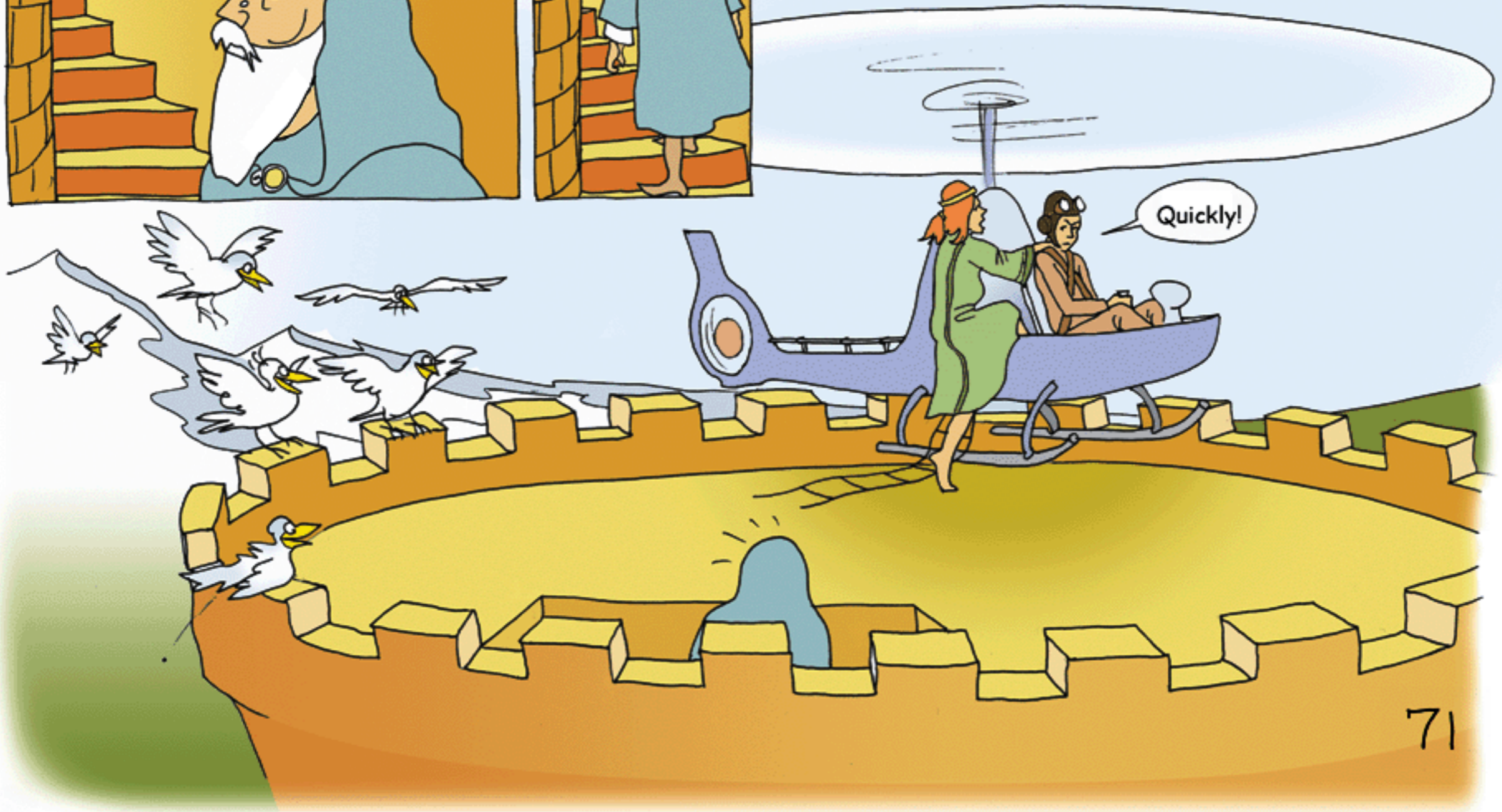
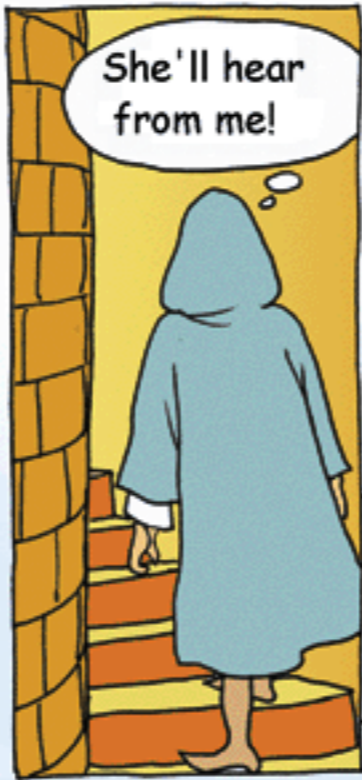


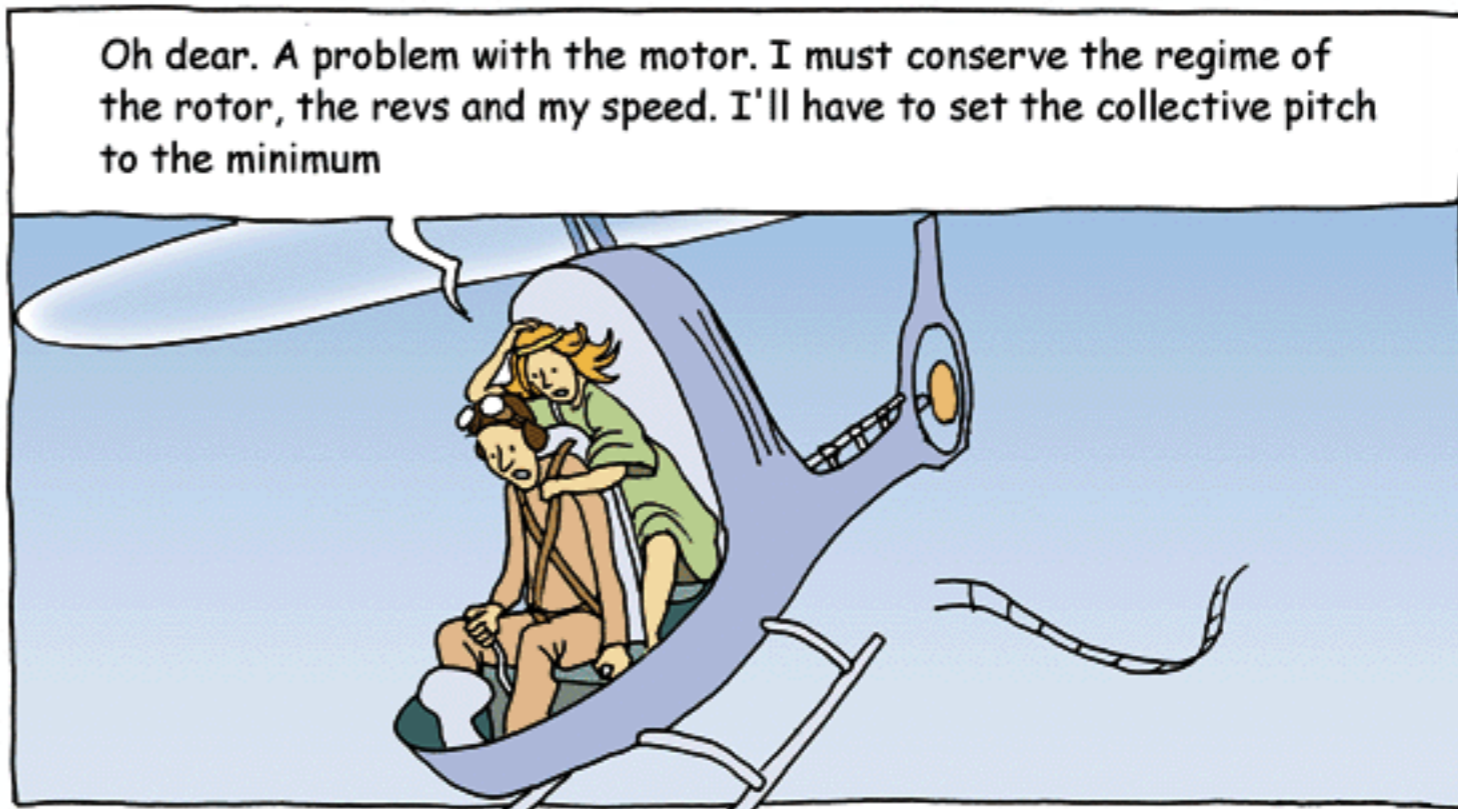
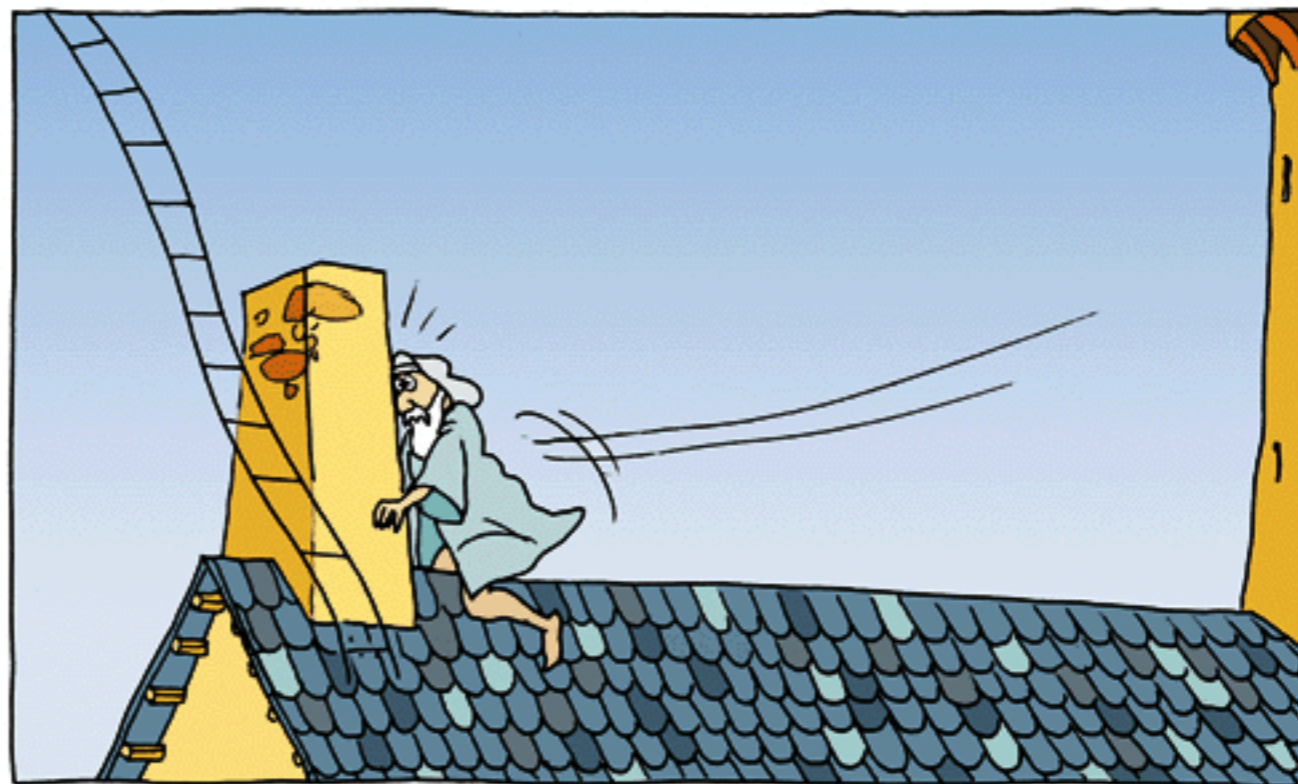
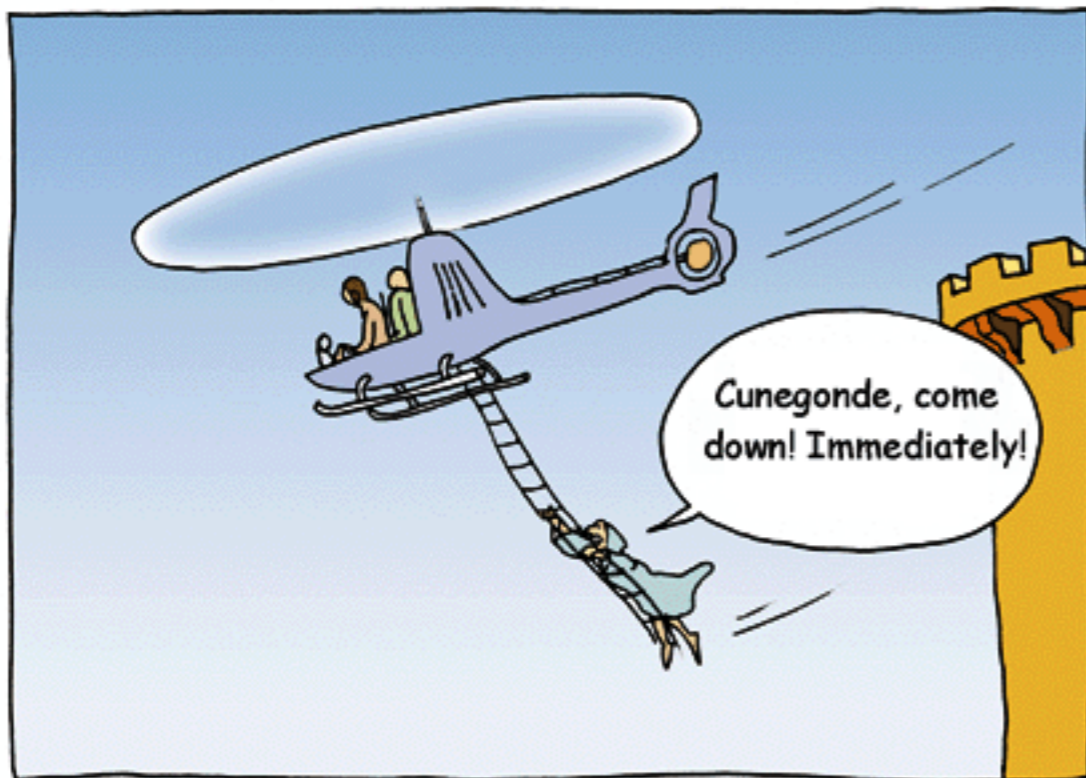
Pangloss said midday. The clock is beginning to strike. I must get up to the terrace



Here we are!!









OK, now the air flow is inverted. It's going from the top to the bottom. My helicopter has been turned into an autogyro. The motor part, the rotor's autorotation, pulls the rest.

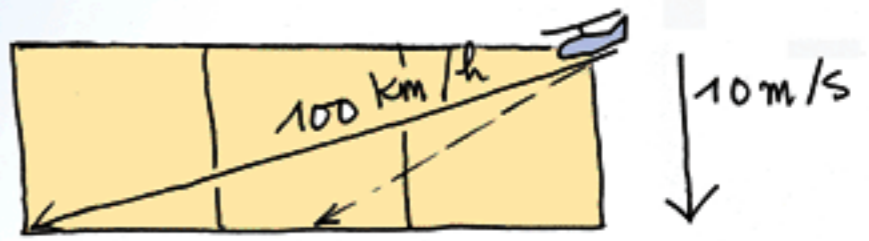
So a helicopter can ... glide?

Have to believe it.

We're descending very fast though: 10 m/s
Not like a stone, but not far off.

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



Impact at 5 m/s



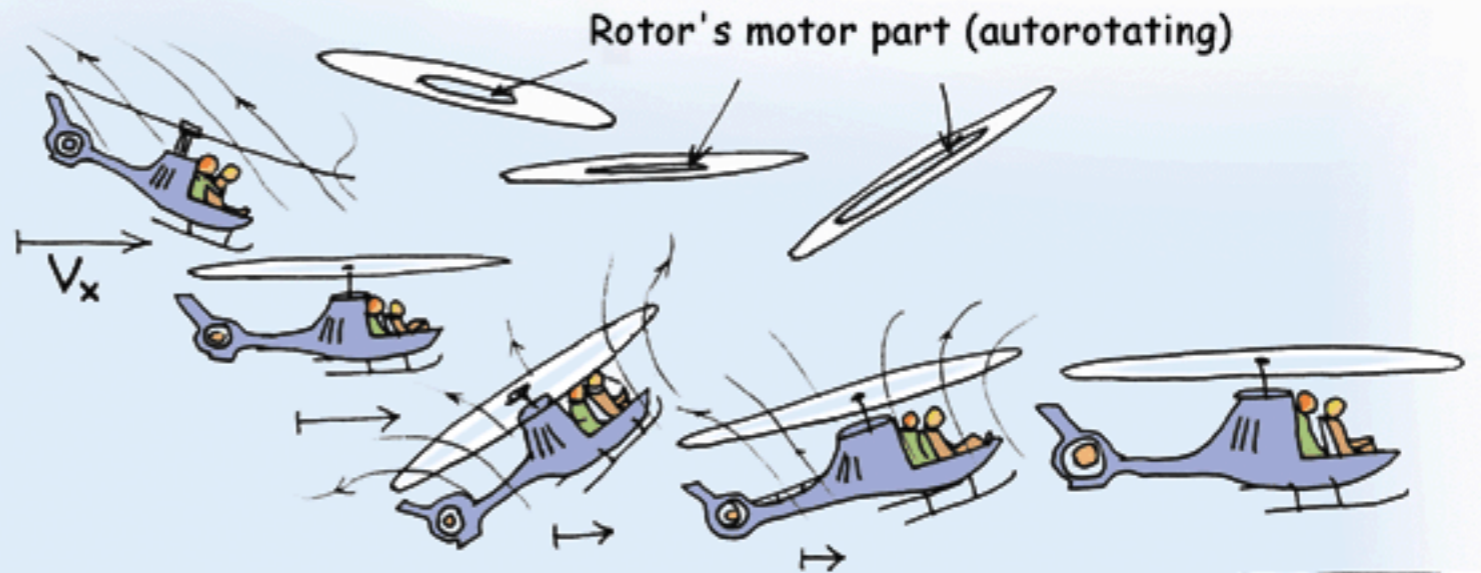
$$(*) V_{(m/s)} = \sqrt{2gz} = \sqrt{20z} \text{ (meters)}$$

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

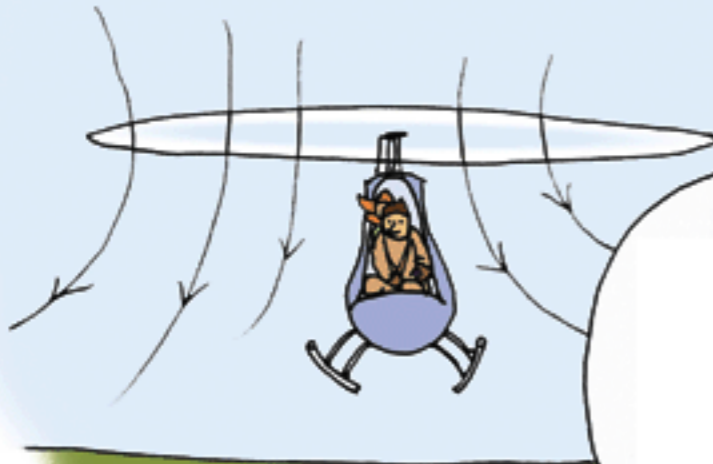


FLARE

I'll have to improvise ...



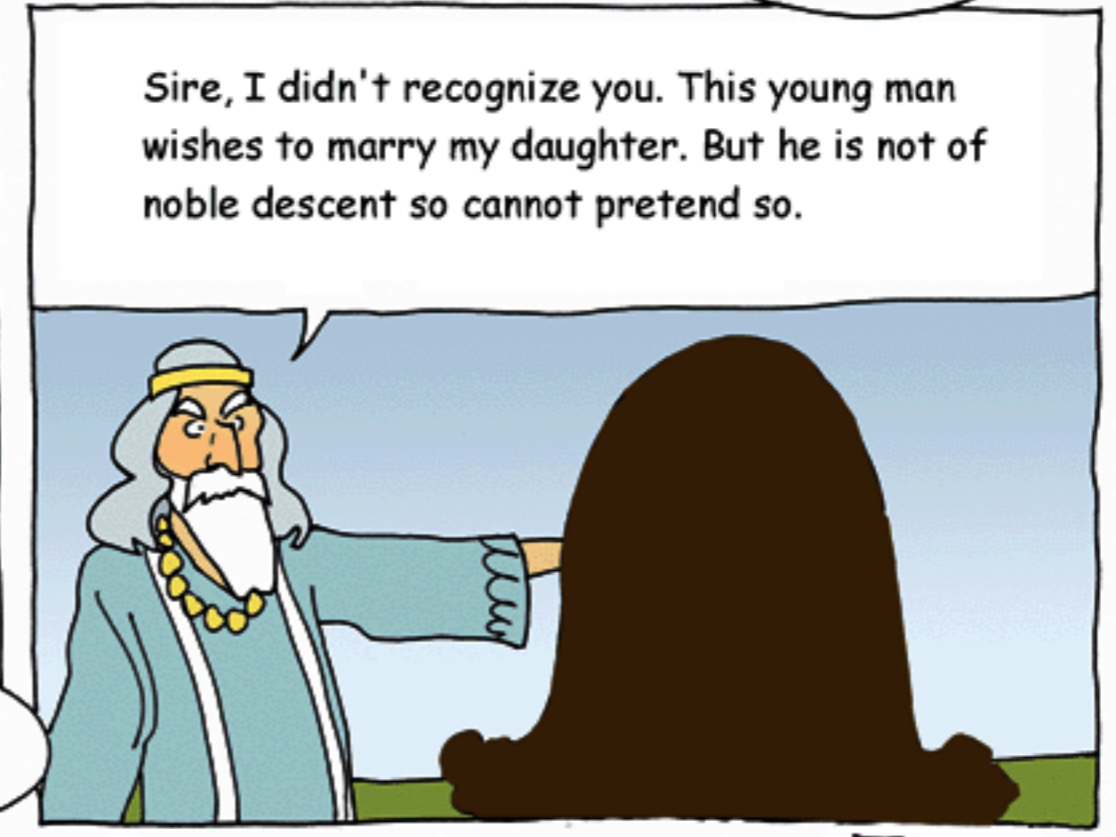
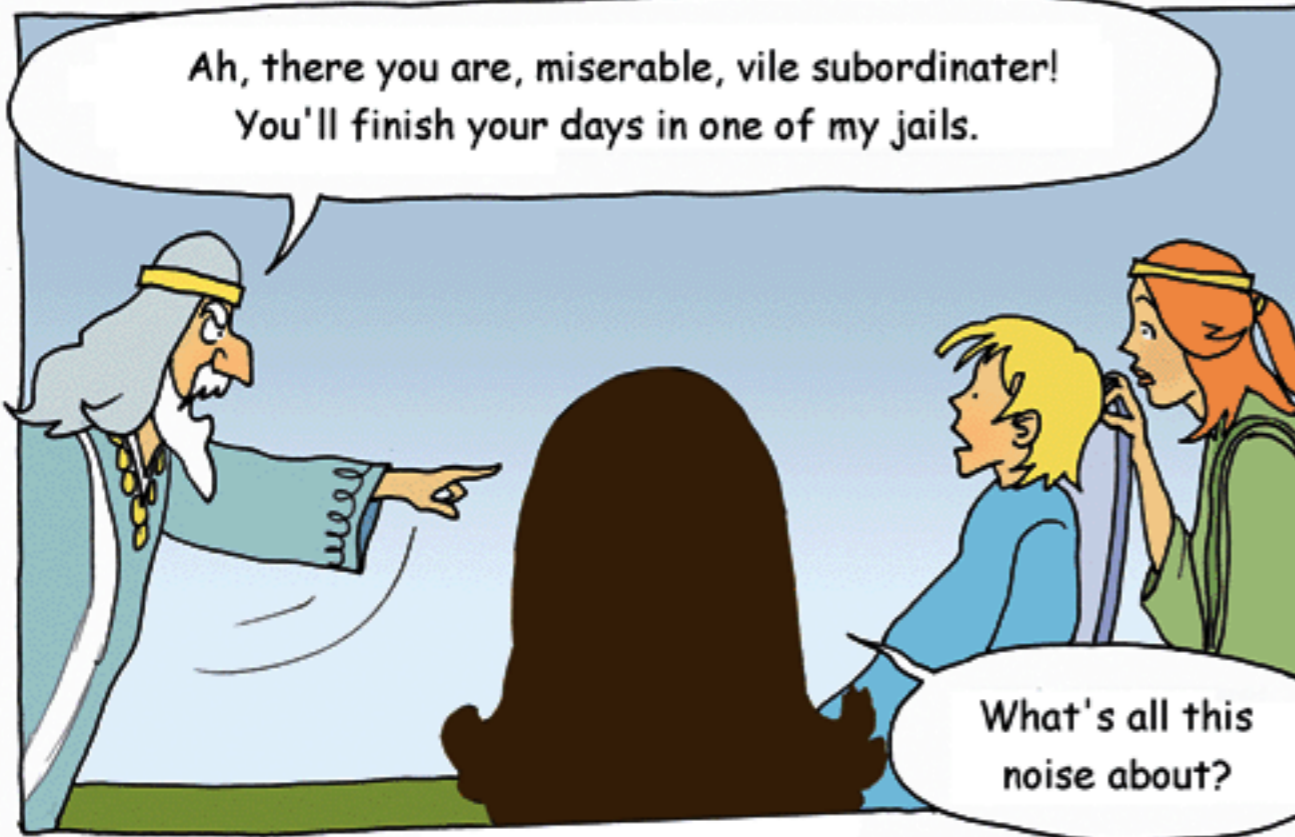
At ten meters up Candide pulls the joystick hard and maintains the collective pitch at minimum. The machine lifts up its nose and the blades are attacked with a stronger relative wind incidence, which increases the motor part of the autorotating rotor. It then converts the translation's kinetic energy 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 (*)



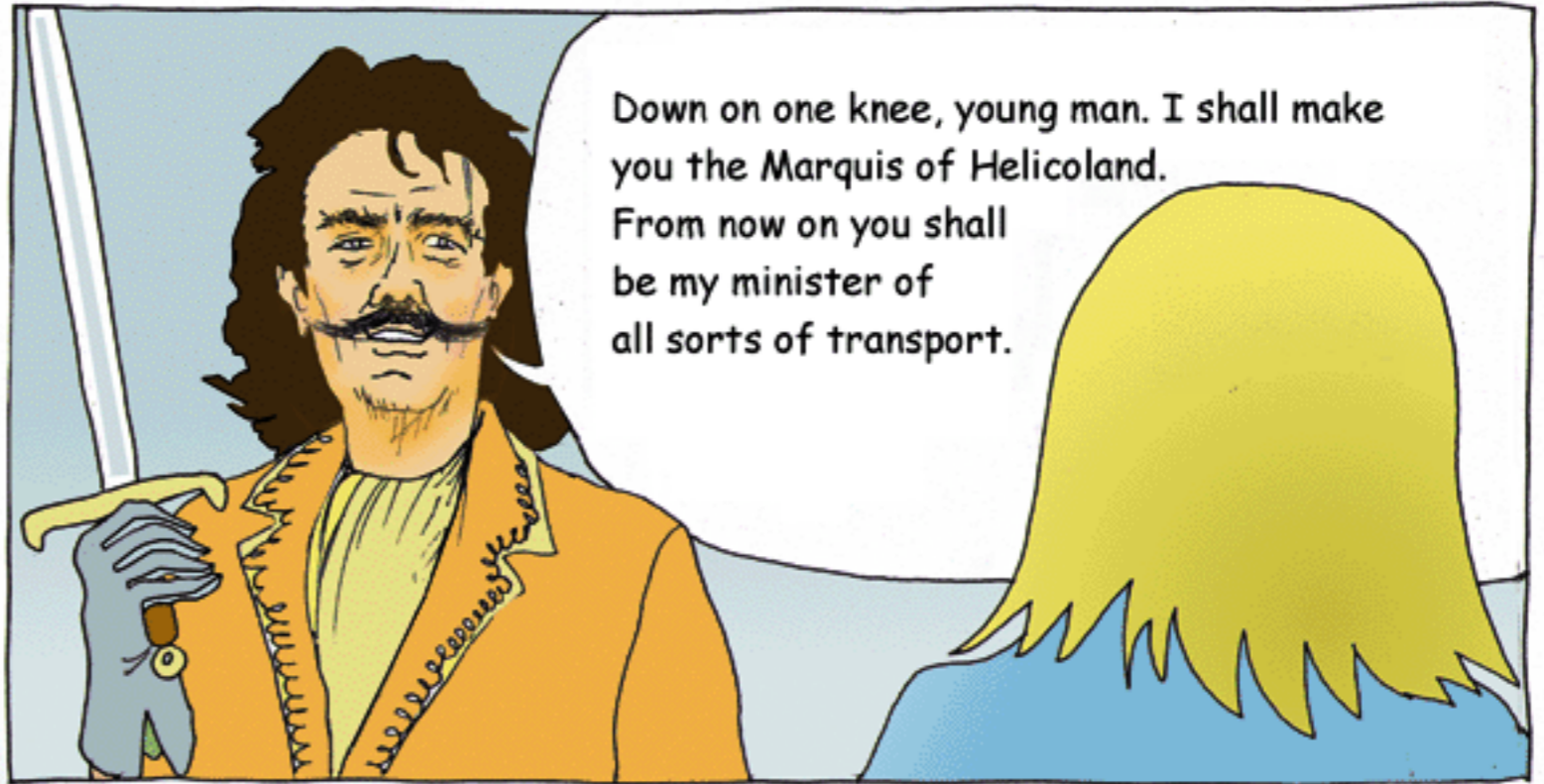
(*) This manoeuvre consumes a lot of adrenaline



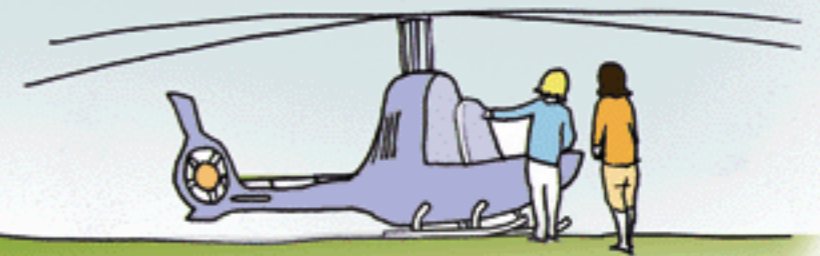
How boring this baron is. For once something amusing appears and he wants to lock up the inventor. We shall sort this out. Plissonneau, pass me your sword if you please.



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.



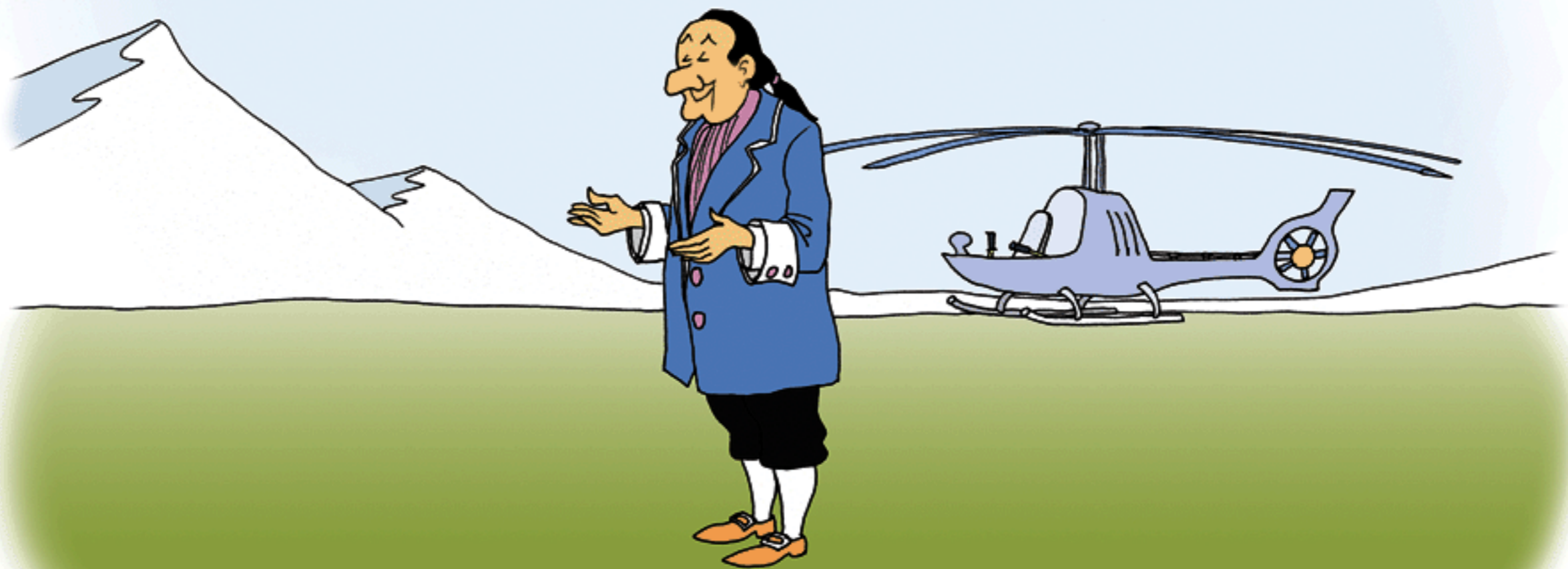
And Marquis is much better than Baron. So now will you go easier daddy?



End

76

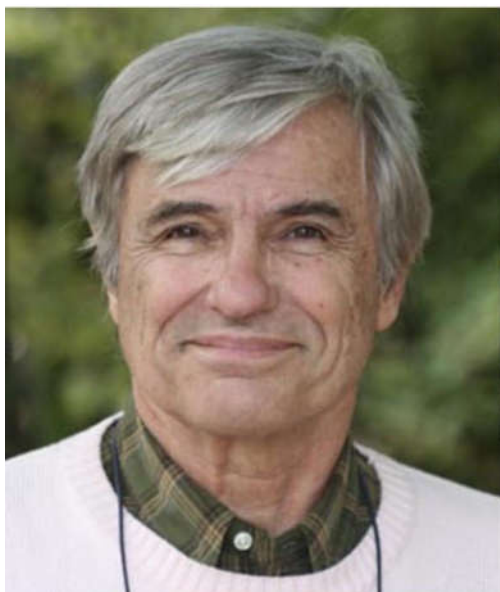
You see, my dear Candide, that everything is for the best in all possible worlds. For if you had not been thrown out of the baron's castle, with many kicks in your nether regions, you wouldn't have invented the helicopter



Many thanks to Pascal Chrétien for his precious technical advice

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