Necessity and Freedom

or

Who finally governs this universe?

1. The Natural Law

Observing what is happening around us we concluded that for each phenomenon, for every event, there is a cause, a reason that gives rise to it.

Nothing happens in the world without a reason.

The way the result is related to the cause we called causality.

Determinism.

Whenever we studied a phenomenon, we discovered that a law led to its appearance.

We tried to describe this causality, using the only tool we have, the functioning of our brain.

We developed our own way of communicating, we constructed a language, Mathematics, which based on another invention of ours, Logic, helped us enormously to express our perception of causality in Nature.

We have continued this effort for centuries. We developed the natural sciences and their applications.

We are proud of our knowledge and our technological achievements with good reason.

We are aware that each law, as we express it, is just a reflection of the true law that rules in nature.

That is the Natural Law which operates independently from us and our observations,

and of course does not care at all about whether we describe it or how we describe it.

The Natural Law is the way the materials from which the Cosmos is constructed behave and interact with each other:

matter, energy, space, time, information, etc.
and it expresses the true nature of these components.

2. The ability to predict

Our way of describing the natural law, e.g. with an equation that we write on a piece of paper, reflects only roughly that which is prescribed by the Natural Law.

The accuracy of the description of what is actually happening is limited.

This approximate description though is extremely useful as it provides us with the ability to make a prediction.

It may be that the accuracy of our prediction is limited but nevertheless we can still achieve our purpose.

That is the way all applications are made:

We plan, say, the construction of an aircraft and we predict: This machine will be able to take off with a load of 60 tons and reach airspeed of 700 km/h.

After the construction, during the test flight, we note usually that we have erred only slightly. The machine carries 59.7 tons and it reaches 705 km/h.

Our ability to forecast varies from case to case.

We can predict the motion of a planet in the solar system with great accuracy; the movement of a leaf falling from a tree with less.

We know very well the reason why the accuracy of our prediction is limited.

It's due to the limitations of our knowledge.

The more we study the phenomena, the greater is the accuracy of our prognosis.

We correct our expression of the law, for example by introducing an additional factor into our equation, and we measure more accurately the initial conditions which sometimes affect the result considerably.

Sometimes we may need to change the whole formulation or even our perception of the phenomenon,

which does not mean that we should give special significance[1] to this event.

3. Absolute accuracy

Both Logic and Mathematics like any other product of the function of our brain are necessarily shaped by the way our brain works. They carry in them the characteristics of this function.

> We still know too little about causality in the function of our brain

but if we do not consider the possibility of external supernatural[2] influences

> we must accept that for this function the same physicochemical laws apply as for the rest of the Cosmos.

We are aware (?) that our capabilities are limited but we claim that the validity of our logic and the accuracy of our mathematics are absolute.

> One and one make exactly two not approximately two.

Herein lies no inconsistency.

Our brain may be finite and imperfect but this fact does not preclude the right to create, to imagine a system, Mathematics,

which by definition is perfect and has absolute accuracy in its results.

4. An interesting question

The fact that we can continually improve the accuracy of our predictions could lead us to the question:

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1 For some strange reason many people take delight when this happens. They remember it for years or centuries and refer to it again and again as if it reduces the value of Science.

2 These thoughts are expressed without assuming the existence of supernatural forces that intervene in the affairs of the Cosmos.

– *All right, we are ignorant and incapable. Therefore we cannot accurately describe the Natural Law and our predictions are inaccurate. How accurately, however, can the Natural Law determine what will happen?*

This question seems to be superfluous, because the answer is rather obvious:

The Natural Law must determine exactly what happens.

Didn't we agree that every event in the Cosmos takes place under its leadership?

We will not discuss other "external interventions".

It is not the responsibility of Physics to do this.

If the Natural Law determines only approximately what happens, if it does not govern one hundred per cent of the world, if it is, say, responsible only for 99% then who defines the remaining 1%?

Who is this "small shareholder" who has this tiny 1% of power over the World?

And one more thing:

If there existed this little non-deterministic percentage, not controlled by the Natural Law (what is inevitable we have already calculated to be 99%), would it always be constant or could it change from phenomenon to phenomenon? Could it perhaps become 10% or 50% or even more?

Then there must be phenomena where, no matter how clever we are at looking, we will never find their determinism.

Maybe we can find a part that is deterministic, but the rest is ***uncontrolled***!

It will remain forever mysterious and will appear at one time in one form and next time in another.

Not being subject to determinism it would not be obliged to appear always in the same form.

5. An important decision

Very nice physical considerations are these that we are making here, don't you think?

If we adopt a limited validity of the Natural Law we are on the way to abolishing Physics.

> Abandoning our belief in determinism we leave the floodgates open to every superstition, mysticism and other magic, from which we believed ourselves to be free for many centuries now.

Now we have to abolish every science, because all are based on the principle of the existence of determinism.

> And we have to reject our applications because they too are based on the natural sciences.

From now on, if we for example want to build an aircraft, instead of making calculations we will perform exorcisms.

Next we will hang an amulet around the neck of the pilot and finally we will give the order to take off by whispering some incantations.

> Here we must make a decision.
>
> There is no room for half-truths.
>
> Either the Natural Law rules the world or it does not.

The only correct answer is that the Natural Law defines completely what happens in the Cosmos.

It determines it with absolute precision.

Not with an accuracy of 99.999999 ... (several thousands of nines) but of 100%.

Full stop.

> The state, in which we will find the World at the next moment, is absolutely certain.

Nothing unexpected can happen, nothing not provided for by the Natural Law.

The state in the immediate future is exactly predetermined.

It is determined by the state of the present time and the Natural Law.

Due to incomplete knowledge we are, of course, not able to predict exactly what this state will be and although our ability to predict constantly improves, it may be that we never achieve an absolutely exact prognosis.

This however does not prevent the Natural Law from determining exactly what will happen.

6. A logical extrapolation

If it is so and we agree that the Natural Law defines the state of the world in the next moment with the infinite, the absolute accuracy of Mathematics, then

the state of the world at the present moment was absolutely determined by the situation of the previous moment and this from the previous one and so on.

This "and so on" however how far back does it go?

Well, as far as you fancy.

The unlimited precision of Mathematics allows us to extrapolate into time as far back as we like.

Why not until the beginning of time?

Maybe it's a bit difficult to talk about the absolute beginning of time in the universe since we do not know what was the situation before the Big Bang

which, as we believe, took place before about fifteen billion years and which is generally considered as the beginning of the evolution that led the world to its current state.

We could however assume that, for today's world which we study, the moment of the Big Bang is a characteristic time-milestone

where we have the right to place the relative beginning of time for the universe in which we live.

7. A strange conclusion

Thus, according to our assumption about the absolute accuracy in the power of Natural Law

anything happening any time anywhere in the world was exactly determined, it was preordained in every detail, since the moment of the Big Bang.

At that time absolutely everything was determined.

Everything that has happened so far and everything that will happen in the future in the universe.

Everything was determined with infinite accuracy at the moment of the Big Bang.

At that moment when the materials of the Cosmos didn't exist yet or had not separated from each other.

At that time when the Natural Law itself did not yet exist since it describes the properties of materials which were formed later.

At that moment the future of the Cosmos was definite in every detail.

What is happening now in some corner of the world was predetermined in every detail fifteen billion years ago.

It is the inevitable consequence of a long sequence of strictly defined steps which led from the Big Bang to each event.

To understand better perhaps the importance of such a conclusion let us consider as examples two phenomena which take place on planet Earth (a place insignificant in cosmic dimension, but so important for us).

1. The fall of a raindrop.

   What is the "story" of a water drop falling from a cloud to the ground.

   A purely natural event.

2. The work of a painter.

How an artist adds a red boat to the seascape he is painting.

An event associated with the phenomenon of life and the presence of man on earth.

8. A raindrop

At a precise moment, in a certain point of the globe a drop of water is descending from a cloud to the ground.

Its movement is controlled by the Natural Law.
It isn't free to do "whatever it wants".
It must do what is prescribed by the Natural Law.
With an accuracy of 100%, as we have agreed.

Its future is completely prescribed by the Natural Law.

And its past too.

What will happen in the next second is absolutely certain.

Likewise what happened up to now has always been precisely defined.

Let's make an effort to "imagine" the history of our drop.

The tiny droplets forming a cloud are already water in liquid state their very small size however allows them to float.

When some of them unite and their weight grows, the downward movement to the ground starts.

The whole drop shows a behaviour that we can understand fully. It moves in a way that we recognise and expect.

It is attracted by the earth; it meets the friction of the air.

It can change its course depending on the currents of the air it encounters.

Even with our imperfect instruments we could follow its movement and to some extent predict its further course.

Its story is a brief one.

Depending on the height of the cloud it may be a few minutes or more.

That which is worth further study
is the story of the water composing our drop.

9. The molecules

Our drop is composed of many molecules of water.

Approximately 10^{21}.

In 18 ml of water there are 6×10^{23} molecules.

A large drop (from a pipette) is about 0.05 ml in size.

The rain drops are usually smaller.

They did not all start their descent to earth simultaneously.

Some have been added on the way and others which were originally together left the road.

Water molecules are continuously added to the drop from the gaseous state of water vapour in the atmosphere while other molecules evaporate from the surface and pass from the liquid to the gas state.

The "fate" however of each of these molecules was, according to our strong deterministic agreement, absolutely predetermined.

As a molecule that was initially inside the drop came to the surface this didn't happen on its "own initiative".

Some other molecules pushed it during the incessant thermal motion, this total "pushing" that prevails in nature which is something we usually forget.

And when another molecule left the surface, this was because some of the interior molecules gave it such a strong "nudge" that provided the energy needed.

The same goes for condensation. Collisions of molecules in the gas state are those that led a molecule to pass into the liquid state.

The "crowd" of molecules in a gas may not be as large as in a liquid, but the crashes are again the norm.

A gas molecule under normal conditions "flies" at the speed of a very fast airplane, but it can't "enjoy" this speed.

It goes from crash to crash.

It suffers about 10 billion collisions per second.

The fate of the last seconds of the molecules of our drop is, except for gravity, determined by collisions.

Collisions with air molecules (which we call friction), collisions with water molecules which result in addition or removal of material.

What happened then before that?

Exactly the same.

Collisions brought a molecule of the ocean first to the surface and then to evaporation.

Collisions led it then, perhaps after months, to the atmosphere at that point where the drop was formed.

10. The atoms

So far we have regarded each water molecule as an autonomous entity which experiences its "adventures" undivided.

This may be true.

It may actually be that ever since the material of the earth was cooled off, a water molecule which is then formed is left intact after four and a half billion years and merely changed its place.

One time in the atmosphere, another time in a glacier, and another time in a cell in the body of a dinosaur.

But it may be that chemistry played a part to.

It may have been split for example during photosynthesis (which dissociates a large quantity of water each year) and later have been re-formed by combustion.

Not necessarily from the same atoms which were originally joined but from other hydrogen atoms each of which has its own "history" and an oxygen atom that perhaps never until now was in a water molecule.

The fact that chemistry is basically nothing but collisions between molecules is not something which we really need to analyse.

Since chemistry interferes it would be even more correct if we consider the atoms as the fundamental components of our droplet

**so that we can follow the story back
to the beginning, to the Big Bang.**

11. The atomic nuclei

Certainly for the atoms we should distinguish between nuclei and electrons.

These latter are so "unreliable" and so "unfaithful" that one cannot trust them. Today they belong to this nucleus and tomorrow to another. And the next day they get up and go and fly around freely.

It's better if we deal with the atomic nuclei.

The material from which the molecules of our drop are made spends only the last third of its life on Earth. Before that it was probably in a star.

The oxygen atom definitely doesn't belong to the prime material of the Cosmos. It was formed later by nuclear reactions (i.e. by nuclear collisions) in the interior of a star.

Well, it wasn't exactly an atom. It didn't have its electrons.

Inside a star there are such
temperatures that chaos reigns.

The nucleus of the oxygen atom however, ever since it was formed, has remained unchanged until now. Some electrons of lower energy levels, which remain with it for a long time, are picked up later.

In order for what we accepted about
absolute determinism to be valid,

each collision in this inferno of collisions inside the star should be absolutely predetermined to form the particular nucleus of the oxygen which, after the explosion of the star (it must be strictly determined in which direction each nucleus has to move), has to be found on Earth, in order to form the particular water molecule with the (strictly prescribed) protons and all the necessary (predetermined of course) electrons.

Let's see the whole
story in brief:

At the moment of the Big Bang it was strictly determined which specific protons would be formed which would result in this particular star where after the specified collisions with the absolutely predetermined other particles the oxygen nucleus would be formed, that

would arrive on Earth where after other predefined collisions would form one of the 10^{21} water molecules in our drop.

For the electrons, exactly the same reasoning apply,

with the difference that, because of their inherent "unreliability", we should admire even more the accuracy in pre-determining the outcome of every interaction.

12. The collisions

The history of the material of our drop is in reality nothing other than the story of a great many consecutive collisions.

If we would like to calculate roughly how many collisions there have been so far in the life of a particle since the beginning of the world, we could start from the fact that the collisions for a gas molecule at normal temperature and pressure are in the range of 10^{10} per second.

In the liquid state they are in the same order of magnitude.

There are many more inside a star. There are over 2×10^{17} collisions per second.

In the initial fireball of the Big Bang there must have been even more.

In interstellar space, where the particle was at some time, there are far fewer.

If we accept an average of 2×10^{15} we would not be far wrong.

With so many collisions per second, for the 5×10^{17} seconds of the history of the World we can say that

each particle must have suffered from the beginning of the world till today some 10^{33} collisions.

If every particle that makes up our drop has suffered so many collisions,

then how many collisions have determined the history of our drop?

It would be not easy, and it is not the purpose of these considerations, to find the true number of these collisions.

Only one thing is for sure.

It would not be sufficient to multiply[3] the number of particles in our drop with the number of collisions suffered by each particle.

That would just be the sum of the collisions suffered by all the particles in our drop.

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3 This means to calculate the product of $10^{21} \times 10^{33} \times 10$ (because each molecule consists of 18 original particles, which were initially separated and later united) which is already a huge number in the order of 10^{55}.

But this is only a very small part
of the number of collisions which
determined the fate of our drop.

In order for the result of a collision to be exactly determined the motion of each of the participating particles must be completely defined.

This movement however is affected by the last collision with another particle, which most likely is not in our drop, and whose movement is shaped through its previous collisions with others "foreign" particles and so on.

So the number of collisions that shaped
the history of our drop is very much higher.

If, as we accepted it, there exists a deterministic sequence from the beginning of the Cosmos to the moment when we consider the drop, the outcome of all these collisions must be exactly determined with absolute mathematical accuracy.

If only the smallest uncertainty existed about the outcome of the collisions

the result would be different.

It would not be deterministic!

Now that we have studied in greater detail such a simple phenomenon as the fall of a raindrop, the conclusion to which our decision to accept the absolute accuracy in the power of Natural Law led us, begins to seem unbelievable.

Were we perhaps a bit rushed to
reach this decision in chapter 5?

Maybe it would be advisable before we take such a serious decision about the determinism in Nature, to deal in more detail with the predictability of collision which is shown to be the major cause of the phenomena.

Before doing this, however,
let's take a look at the second example.

13. The little red boat

Our painter has almost finished his painting.

A beautiful sea shore flooded with the morning light. A fisherman is pulling in his nets.

The painter stands with the paintbrush in the hand and examines his work critically.

With his other hand he strokes his beard.

He takes two steps back.

He stands with narrowed eyes.

Suddenly his face brightens.

He steps forward, extends the brush to the palette, is again undecided for a moment and then begins to paint a little red boat barely visible in the background.

The phenomenon we are now witnessing is clearly more complex. It is not just the fact that now our system, i.e. painter - painting - easel - paint - etc. consists of more chemical elements and (due to higher mass than the drop) comprises more (approximately two million times) initial components of the Cosmos.

If this were only the case then we would only need to attach a few zeros to the number of the collisions and our admiration (about the possibility of all these collisions being predetermined fifteen billion years ago) would "merely" grow some millions times larger.

But things are much more complex.

Here we are faced with the incredibly complex phenomenon of life.

Our painter affects matter.
He intervenes in what happens
in the universe.

With his brush he places a few molecules of a distinct colour pigment on a certain point on the surface of the canvas.

This event, the fact that the material system "painter" affects the material system "paint - brush - picture" causing a new arrangement of molecules in space, should not impress us too much.

The interaction of the ground with the rain drop, when the drop finally hits the earth, also causes a rearrangement of the molecules in space.

14. Life

The problem is elsewhere.

There is a very important difference between the material system painter and the material system ground.

The painter put the paint on the spot he had decided on in accordance with his artistic senses and his opinion of how the boat should look.

This interaction is fundamentally different from the interaction soil - drop.

Anyone who looks at the picture later will recognize a small boat at this point.

The artist differs greatly from the ground.

He is an organized system, born from other organized systems, his parents. He has the ability of metabolism and growth and he is able to reproduce, causing the birth of new systems like himself.

The causal chain that connects the beginning of the universe to the application of the paint on the canvas includes the string of events, from the emergence and development of life on Earth.

If we would like to continue our calculations about the number of particle collisions, we should necessarily include the parents of the painter too. And his grandparents and great-grandparents and all previous ancestors all the way back to Australopithecus and even further back to the Ammonites and beyond them to the first unicellular organisms.

All these actions (interactions, collisions) that led to the creation and behaviour of all these ancestors were necessary steps in the deterministic sequence that led from the Big Bang to the painting of the boat.

If the father of the painter had not decided, at the last minute, to attend this party where he met his future wife, we would have neither the painter nor the boat.

And of course we should not forget the girlfriend of the mother of the painter who had organized that party, who wouldn't have come into

the world if her mother had not stopped to admire that hat in the window, where she was noticed by her future husband.

And we must certainly mention the essential role which was played in the whole story by the decision of the girl who made the hat, to leave the village when she was abandoned by her fiancé, and go to the city where, after many failed professional efforts, she learned later the art of hat making ... etc ... etc.

Now perhaps the complexity described in the case of the drop becomes clearer, when we said that the motion of each particle is not only defined just by the particles it has collided with, but by all the other particles each of them has collided with in the past ... and so forth.

It seems that these ideas have
got us into deep water.

15. Everything is interrelated

If we continue like this we will at the end implicate all people in our story, living and dead.

And why only humans and not all other
living systems, animals and plants?

Isn't there in the body of our painter matter incorporated from the bread he ate this morning, bread made from the seeds of wheat sprouted in the field where the raindrop of our previous example had fallen?

And why only the living systems?

In the water of his breakfast coffee weren't there some molecules from that drop? And the air he breathes, doesn't it contain a few oxygen atoms once connected to the water molecules of our drop?

And was not the morning light he saw when he visited the island last year, the reason which created his desire to paint this picture?

According to our decision on the absolute accuracy of the force of determinism, all this was absolutely predesigned at the moment of the Big Bang.

All this had to happen exactly so in order that we could reach this moment when the artist decided to paint our red boat.

Everything:
the hat, and the party, and the trip to the island.

And of course everything that has happened before and bears some relation to them.

The mining of the ore from which came the metal used for the construction of the ship which took him to the island.

The invention of the internal combustion engine which powered it.

The discovery and formulation of the principles of thermodynamics allowing the construction of the engine.

The works of Archimedes.

The thoughts of Pythagoras.

The discovery of fire ... and so forth.

> Everything was exactly predetermined at the moment of the Big Bang. That the Earth would be formed. That life would develop on it. That evolution, except for chicory, sea urchins and pelicans would produce humans as well.

That one of them would find a way to use fire.

> Not just anyone, someone quite specific.
>
> His name, the colour of his eyes, the scratch made on his left arm pulling the branch, everything was exactly predetermined.
>
> Just as the conditions at the time of the great invention.
>
> The gentle wind that was blowing, that revived the logs burnt by the lightning.
>
> The dry branch in the corner of the cave not soaked by the rain ... and so on.

That another one later would write a book[4] "***on the motive power of fire***".

That another would build a ship.

That our painter would travel with it to the particular island and would then be inspired to paint this picture. That in this picture all the molecules of the pigments would have exactly this specific place on the canvas. And finally that the painter would make the decision to paint a red boat with exactly this nuance of colour (not a little bit darker or

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4 Sadi Nicolas Léonard Carnot:

Réflexions sur la puissance motrice du feu et sur les machines propres à développer cette puissance,

Paris, 1824.

a little bit lighter) in this exact position (not just a little bit to the right or just a little bit to the left).

It seems that these ideas have got us into really deep water.

16. Free will

In our series of reflections we have reached the point of examining human mental activity.

Here we have a new element that deserves our special attention.

Not because it has some special significance for the World but because it is of great importance for us.

We know very little yet about the functioning of our brains.

We do not know what the mechanism of thought is, how an inspiration emerges, how we take a decision.

But since we are not examining the involvement of extra-natural forces, we must accept that in our brain cells some biological processes are taking place which ultimately can be reduced to simple physicochemical phenomena which have their origin on a molecular level.

Phenomena which obey the same laws as the rest of the Cosmos.

In the case of our painter we have a whole series of actions whose mechanism we know little about.

- He studies the picture critically.
- He brings his left hand to his beard.
- He takes two steps back.
- He tries to find out what is missing in the picture.
- He has the idea to paint another boat on the canvas.
- He is not sure what colour he should use.
- He decides on red.

We are not yet able to describe the mechanism of critical thinking, of doubt, of decision.

We cannot say in detail which cells in the brain of our painter, under which internal molecular processes and after which interactions between them, led to the decision to make the boat red.

Certainly this decision was not independent of elements affecting his brain:

- His experience from images of nature or of other painters.
- The colours already used in this picture and his sense of balance of colours in a painting.
- The light, the temperature and the relative humidity inside the studio.
- His mental state.
- The proper functioning of his liver at the time.

A complex series of deterministic sequences were influencing him.

A number of constraints which he probably didn't realize at the time he made his decision.

> But was the decision already anticipated a hundred per cent, just that our painter did not know it?
>
> Was the decision made by the Natural Law even at the time of the Big Bang?

If our assumption about the absolute accuracy in the determination of the Natural Law is true, then this is the case.

Only that the painter did not know it.

He believes that he freely decided that he should add a boat to the almost finished seascape, and justifiably spent some time trying to decide whether he should make the boat yellow or red.

He did not know that, just as for everything that happens in the universe, the decision about whether the boat would be yellow or red had been made long before.

It had been made in the moment of the Big Bang.

At that time the list of successive events (more precisely the long chain of collisions) was specified in every detail. Events which led to what he considers as a decision of his own free will about the colour of the boat.

Just as at the moment of the Big Bang it was determined that the person who is writing these lines would use the example of the painter to refer to free will.

The poor man!

He believed he had made a free choice, when he decided to use artistic creation as an example of free will.

It seems that these ideas have
got us into really very deep water.

17. A revision

This is what happens to someone who carelessly makes hurried and bombastic declarations of this type:

"Everything that takes place is determined
with absolute accuracy by the Natural Law".

We have been led to conclusions which are very difficult to accept.

This absolute predestination for everything that happens in the Cosmos starts to become really annoying.

Is it possible that the universe is predetermined in such a way?

The history of every atom and every molecule, the development and the evolution of life, the flight of every bee and the thought of every human being can all be absolutely predetermined?

You might say: why not.

There is absolutely no freedom.

Neither for atoms, nor for bees and nor for us.

This is so and we must accept it.

Whether we like it or not.

We accept other things too that we don’t like. As death for example.

We must accept that as well.

We delude ourselves by believing
that we are free

and live with the illusion that we can make decisions because we're stupid, short sighted and egocentric.

We do not yet know enough nor do we have the courage to draw the necessary logical conclusions from the little that we do know.

We do not like the idea of being not only totally insignificant in the Cosmos but also absolutely predetermined, and therefore we reject it.

But in reality this is exactly the case.

Whatever happens was fated, and whatever we do in the belief that we made a decision ourselves, we had to do it that way so that what was predetermined in fact happened.

In the first decade of the 21st century the controversy flared up again, and the "enemy camps" called their supporters "back to arms".

What had happened?

The neurophysiologists have found that before we can say we have made a decision, about 150 ms earlier, the electrical signal related to the action appears in the nerve cells.

Rather than sitting down and reflecting on their findings, that is to say asking themselves what mechanism connects the making of a decision with the perception that the decision has been made, they immediately drew the conclusion that we didn't make the decision ourselves.

"We don't do what we want
but we want what we do".

This provocative formulation stoked the fires of controversy again.

In the heat of the battle however they have forgotten to tell us:

If the decision is not made by us, by whom is it made?

Are there supernatural forces or is it the Natural Law?

If it is the Natural Law then the decision was taken at the moment of the Big Bang.

For this opinion of an absolute predestination of all events there are fairly widespread beliefs expressing exactly the same thing: The inevitability of fate.

"Το πεπρωμένον φυγείν αδύνατον".

Escaping destiny is impossible.

But of course not even the most faithful supporter of this view would come to the point of saying: I'm not getting up to get a drink because if it is my fate to die of thirst it is pointless to try to oppose destiny.

Nor would he say:
I perform no action anymore,

I think no thoughts,
I make no decisions.

18. Decision making

Throughout our lives we take decisions. We perform actions that require our deep faith that we are free to decide to do something.

And this faith is so deeply rooted that it cannot have been taught in school.

It is not an "invention" of
the ancient Greeks,

who let their Hercules
choose for himself[5] whether to follow
the path of virtue or of evil.

The belief that we can change the run of things by our action must be very old.

The team of our friend, who carried the lighted branch to the cave, must have had this belief, when they set out the previous day to hunt the mammoth.

A difficult and dangerous task requiring planning, effort and determination and presupposing the feeling of freedom of action.

We could probably already at this point accept that we must rethink our decision on the absolute accuracy in the effect of the Natural Law and deal with the consequences of such a change.

In Chapter 5 we were quick to accept something that have not been proven.

It was actually a kind of faith, a hypothesis that we made.

But now it turns out to be in stark contrast to what we can logically accept.

We have reached the point of not understanding the universe any more.

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5 In contrast to poor Adam who was forbidden to taste the fruits which would have given him the ability to distinguish between good and evil.

However, as someone might still insist on the absolute accuracy of the law, let's see what will convince us definitely

to make the difficult decision to doubt
the absolute accuracy of the Natural Law.

19. The "blur" and the "noise"

If there is any, even the smallest inaccuracy in the power of the Natural Law, any ambiguity in determining what it describes, if what it orders is not very clear, if the image that it gives of the world is a little bit "fuzzy", then this uncertainty, the "blur" of the photograph could be detected if we had a very high magnification.

If the picture was from the beginning,
by its nature, absolutely sharp,

if the boundary between black and white was certain with the absolute accuracy of mathematics, then the difference between black and white would remain absolutely clear no matter how much we increased the magnification.

If the picture was by its
nature a little bit "fuzzy",

then with low magnification, looking at it from afar, we would have the impression that it is quite clear, but if we increased the magnification, approaching with a more powerful microscope, we would notice the inherent ambiguity about the exact boundary between black and white.

There wouldn't be a mathematical line
separating the one colour from the other.

Both colours would diffuse into
each other in shades of grey.

We can make completely similar considerations using as an example electronic amplification instead of the magnification of an image.

Here also we could distinguish if there is any uncertainty in the power of the Natural Law.

With very strong amplification we would be able to identify if the boundary is clear between the existence of an diminishing signal and its absolute absence.

Well, what actually happens in reality?

In both cases the
boundaries are unclear.

In the microscopy the image becomes "fuzzy" and in the amplification the "electronic noise" appears which obscures the very weak signals in the end.

In both cases we know the source of this uncertainty.

It is thermal motion, something we usually forget although we know that it exists.

If we lower the temperature of our apparatus we get clearer pictures both under a microscope and in an amplifier.

Thermal motion is to blame for the luck of clarity.

This is a motion that is directly linked to the collisions which are the rule in the "life" of atoms and molecules and is the cause of most phenomena.

20. *Collision, mother of everything*[6]

All the considerations we have made up to now comprise as their base such simple collisions of particles, atoms or molecules.

If we used a great magnification or amplification we would find that our question whether the Natural Law strictly defines the fate of the universe is reduced to the simple question whether the output of an elementary collision can be predetermined with absolute accuracy.

That is all.

As simple as that.

What happens during the collision of two particles also happens in the whole Cosmos.

If the outcome of the elementary collision can be exactly predetermined then the whole universe was predetermined from the moment of the Big Bang.

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6 According to Heraclitus, "***War, father from everything***".

In the second half of the 19th century the kinetic theory of gases was developed which is today generally accepted because its results agree with our experimental observations.

On the basis of this theory are found the collisions of gas molecules (and also of liquids and solids ones) between each other and against the walls of the container they are in.

These considerations were based on the assumption that the molecules are something like little "hard balls" and that when they collide, they follow just the same laws of mechanics as the billiard balls when they hit each other or the sides of the table.

The question whether the trajectory of each particle after the collision could be strictly defined was not raised.

Anyway It was of no interest.

The theory describes correctly the behaviour of the gas.

The fate of each molecule was completely irrelevant.

Tacitly
(as such assumptions are usually made tacitly)
one could assume that there was no reason to put into question the absolute validity of the laws of mechanics.

21. The uncertainty

Before we try to answer the question whether the outcome of a collision can be absolutely predetermined, we should consider whether the state of each of the colliding particles before the impact can be exactly defined.

From the beginning of 20th century physics was in the midst of revolutionary developments which reordered our understanding of the Cosmos.

At first we found that light can be simultaneously wave and particle.

Then came the relativity theory and in the 20s we began to notice that there is an inherent inaccuracy regarding the location in space and the momentum of an electron.

It was the principle of uncertainty[7], or indeterminacy

which states that both the position and the motion of an electron are somewhat uncertain.

We had to develop new Mechanics, the Quantum Mechanics.

It was a real shock to our way of thinking.

A shock that we may not have completely surpassed yet.

What was happening here?

In reality nothing special.

It was what we mentioned about the blur in a photograph.

As long as we viewed the world from afar we believed the picture was quite clear.

As we increased the magnification and came close at the atomic level, it turned out that the image by its nature was somewhat "cloudy", somewhat blurred, somewhat uncertain.

For the difficulty we might still have in understanding the physical truth which this principle describes, three facts are to blame:

- the way in which it was initially formulated using the term "random",
- the fact that the calculations of Quantum Mechanics were based on probability and finally
- the thoughts used to make the principle easier to understand.

One of these said:

We will never be able to know exactly what are the momentum and the position of the electron be-

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7 Heisenbergsche Unschärferelation:

The product of the uncertainty about the momentum Δp times the uncertainty as to the position Δx is always greater than $\frac{h}{4\pi}$ where h is the Planck's constant.

$\Delta p \cdot \Delta x \geq \frac{h}{4\pi}$ or $\Delta p \cdot \Delta x \geq 0{,}5 \cdot 10^{-34}\,\mathrm{Js}$

cause, while trying to find it, we will interfere with the electron and therefore change its state.

***Consequently it is useless to ask about the state of the electron. We must accept it as random*.**

But is this really the problem? Whether we know it or not?

Does not this consideration re-introduce the age-old mistake of putting ourselves in the centre of the universe?

Shouldn't the electron be in a certain state no matter whether we are concerned about it or not? Is this not required by the principle of objectivity?

22. Randomness

In the present text so far, we have systematically avoided the use of terms such as "random", "luck", "fortune", "chance", "accident".

The reason is that we usually only express our ignorance when we use these words.

"When I was on my way home last night, by chance there was a lunar eclipse".

The eclipse would have happened anyway. Astronomers have known about it for a long time.

I just haven't heard about it.

Anyway, the shadow of the earth would have moved like this, whether there were people on the earth or not, either the knowledgeable astronomers or my ignorant self.

The trap of anthropocentrism lurks in every step of our thinking.

At the same time of course, we could use the term ***random*** (without quotes this time) for phenomena that occur without reason, whose appearance is not subject to the law of causality.

Such phenomena whose existence we denied with our decision in Chapter 5.

We could agree here whether we call these phenomena random (without quotes), or lawless because they obey no law, or free because they are not bound by obligation to causality.

Let us use the term *free* which refers to our freedom of thought.

Well, what is the kinetic state of the electron? Is it "random" (because we cannot know it) or is it free (because it is not subject to Natural Law)?

Neither the one nor the other.

Here something has happened that we meet for the first time and therefore our embarrassment is understandable.

We have found that the very nature of the electron contains a certain ambiguity about its kinetic state.

This means that the Natural Law itself (since it describes the nature, the deeper essence of the electron) is unclear!

It allows some freedom for the motion of the electron.

And this applies not only to the electrons.

The same thing applies even to heavier particles, to atoms and molecules.

It turned out that Quantum Mechanics applies to the entire Cosmos.

23. The wave nature of matter

However we arrive at the same results (equations, calculations) if we apply wave mechanics which instead of using the concept of "random", accepts that the electron has a wave nature.

Matter is, like light, simultaneously particle and wave.

Observing an object, say a glass, we get the firm impression that it has absolutely definite limits.

Somewhere the glass ends and the air begins.

If we go very close, using a high magnification, we expect maybe to find that the surface is not as smooth as it appears to us, that some irregularities are present, which previously were not detected.

In no case, however, would we expect that the boundary that separates the glass from the air to be unclear.

This, however, is our mistake.

That the boundary where a material body ends is perfectly sharp is something we have assumed but haven't proved.

Well, now it turns out that this assumption was wrong.

In reality the situation is different.

Electrons, atoms and molecules are not small, hard, shiny balls.

They are surrounded by a "wave cloud" which gives them exactly this lack of clarity certified by the principle of uncertainty.

The boundaries are unclear, their kinetic condition cannot be fully defined.

If it so, and (unfortunately or thank God?) it is so, and the basic building blocks of the Cosmos are by their nature "fuzzy", then it is clear that the result of each collision cannot be exactly predetermined.

This uncertainty lies at the basis of all phenomena associated with a collision, that is all phenomena of physics and all phenomena of chemistry,

and makes it impossible to draw a line, as we did it in Chapter 6, back from the current state of the Cosmos to its beginning.

With each collision the degree of uncertainty about the outcome increases because to the uncertainty of the first particle is added the uncertainty of those it collides with.

Collisions on the atomic and molecular level occur continuously.

The longer time passes, so many more collisions take place, and so much greater is the freedom of the system.

Is this perhaps the reason its entropy becomes greater?

Is entropy perhaps nothing more than the expression of uncertainty?

Is the Second Law of Thermodynamics perhaps not an axiom but the consequence of the uncertainty which is inherent in each collision of the molecules?

If the motion of gas molecules is completely determined, then does the second law still apply?

Shouldn't we be able to retrieve all the kinetic energy from a set of billiard balls colliding with each other?

24. The limit of influence

As an example of the (unknown to us) strict determinism that governs the phenomena and connects an impressive result with a distant invisible cause, the hypothesis is often used that a butterfly can beat its wings in Beijing and as a result of this a typhoon devastates the Caribbean.

The idea behind this example is that the effect of the beating of a butterfly's wings weakens as we move away (in space and in time) from the source but it never reaches level zero.

It only reaches level zero in an infinite distance and at infinite time.

That is in fact never.

So, if there exists somewhere a very sensitive equilibrium, like those which shape the weather, this tiny distant effect could be the reason to tip the balance in favour of creating a hurricane.

This example is not correct.

Certainly every phenomenon has its impact on the world.

But if the cause is weak and the path connecting it to the supposed result long, which means a very large number of collisions intervene between the cause and the effect, then the causal relation is lost.

It disappears under the uncertainty that is added by each collision.

Now that we know that the uncertainty exists we can understand that it is not necessary for the effect of the wings of the butterfly to reach level zero.

It is sufficient if, weakening continuously, it passes below the limit of uncertainty.

Then the specific direction of the action in space cannot be recognized, so that it cannot any longer serve as a "signal".

The action will be lost forever in the "swamp of noise" of the uncertainty of the thermal motion.

This line which we drew, from the current state of the world back to its beginning (which led us to such strange conclusions that we began to doubt the absolute power of the Natural Law) is not possible.

The current state of the world was not completely specified at its beginning as we supposed in Chapter 6.

It was specified only in general terms.

The Natural Law granted freedom to the basic particles to follow different paths.

Nothing is absolutely predetermined.

If the Cosmos were to be shaped from the beginning again, we probably wouldn't have this actual planet, nor the specific rain drop falling at this precise moment to this certain place on the earth, nor our painter with his particular inspiration.

25. The return of the "small shareholder"

There is no need to revise the decision of Chapter 5. No need to assume the existence of phenomena that are not causal.

We didn't make a mistake when we accepted that Natural Law has absolute validity.

Absolute validity, yes that is what it has.

Absolute accuracy in the determination of the result, no it hasn't.

The Natural Law itself contains this inaccuracy, allowing for the freedom in the universe, without which we wouldn't be able to understand it.

The Natural Law holds 100% "power" over the World.

However it doesn't determine what will happen with the same percentage of accuracy.

The "small shareholder", whom we mentioned in Chapter 4, and who allows that what will happen to be not strictly determined, he does really exist.

But he is no other than the Natural Law itself.

The state of the cosmos at the next moment is prescribed only by the Natural Law.

Nothing is going to happen that was not foreseen by the Natural Law.

Whether we can foresee it that is another story.

Besides we are so stupid that we do not can see beyond our nose.

Here we are in danger of extinction not only for ourselves, but for the whole planet because of our greed, and we do nothing to prevent the obvious disaster heading towards us with steadily increasing speed.

There is no part of nature that is not controlled by the Law

But the Law is somewhat flexible; it allows a small ***percentage of freedom***. What will happen is not completely predetermined by the Law. It is determined with great accuracy but not with an accuracy of 100%.

In the details it is only approximately predetermined. It can develop either this way or that way. It can freely follow either direction.

For this decision, whether the phenomenon will develop in the one or in the other direction, no reason is required.

Both directions are "legitimate and equal in the eyes of the Law".

26. The percentage of freedom

It would be very interesting if we knew this percentage of freedom.

If we knew it we would be able to calculate how far the accuracy of the Natural Law reaches, and until what point we can hope to improve our prediction.

This percentage of freedom however is not always the same; it varies from phenomenon to phenomenon.

If we have a phenomenon where small interferences of freedom weaken, then the degree of freedom that we can expect to find, will be small.

As an example we could consider the motion of a large mass in a high vacuum where we have no friction, that is to say collisions, to allow more freedom.

In the movement of a planet around the Sun, the collision with a particle moving uncontrolled in space will not have a big impact.

There we can count on high accuracy for our prognosis.

If we have a phenomenon of very high amplification, where the effect of some free motion at the atomic level increases excessively, then the degree of freedom will be much larger.

For example in an electric discharge in the form of lightning, where the initial motion of a single ion induces a whole "electric cataract", or in a chemical explosion, in which an initial free radical leads to the conversion of a mass many times greater,

we should not expect repeatable behaviour nor should we hope for the possibility to make an accurate prognosis.

27. Freedom of thought

And what about the decision of our painter what the colour of the boat should be?

Here the degree of freedom is very big.

We are dealing with a phenomenon of very large amplification.

The origin and the evolution of life is a phenomenon where the freedom hidden in any collision grows to gigantic proportions, thanks to the storage and the very large multiplication enabled[8] by the DNA.

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8 A very nice description of this process is given in the book by

Jacques Monod: *Le hasard et la nécessité*,
Paris, 1970.

Free changes pass "crystallized" as mutations in the genetic code and then they are multiplied as many times as the DNA divides in the body itself and its descendants.

That is several orders of magnitude.

We have a second level of amplification in the development of the system "painter" itself.

An amount of matter which is many powers of ten greater was "built", organized, on the instructions of a single original DNA molecule.

A free decision on the level of a cell, for example if the egg should be fertilized by this or that spermatozoon, decided the future of the painter.

A third level of amplification we have, finally, in the central nervous system of our painter.

We do not yet know how it works, but it is very likely, that when we find out, we will discover mechanisms with a great degree of amplification.

We already know that for the transfer of a message from one nerve cell to another only a few molecules of a neurotransmitter are needed to spill out into the synapse[9], the narrow space between the neurons.

In the case of the nervous system of an insect it has been shown that it is sufficient for just one molecule of the appropriate pheromone to reach his antenna in order to put the entire insect into "alarm mode".

The mass ratio of molecule to insect

is similar to that between man and the whole Earth.

This great amplification may be the explanation why what we call inspiration suddenly appears.

Free molecular actions amplified constantly reach the critical part of the brain where they are filtered and while most of them, without realizing it, are rejected, some are selected and can be used as a ***working hypothesis*** to solve a problem.

This process of critical control might be more or less strictly pronounced from person to person.

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9 We have some 10^{14} or 10^{15} synapses connecting our 10^{12} or 10^{13} nerve cells to each other.

We could assume that for artists for example, this control is more flexible.

In sleep, where the control of the critical section is less strict, the free impulses find the opportunity to project themselves as a dream.

This state of reduced control can be induced as well by chemical agents (e.g. alcohol).

Then thoughts and behaviour appear, with a higher degree of spontaneity and "freedom".

This process of rational filtering must be an important part of the whole function of our brain.

It could not be otherwise.

Could you imagine what chaos would prevail if our 10^{12} neurons would begin to send their signals uncontrolled, right and left in the brain?

However it wouldn't be correct to pursue our thoughts further along these lines, making hypotheses, since we don't yet have reliable scientific knowledge available in this area.

By the way we don't need it, because we have already arrived at our destination.

We have reached our goal.

28. Conclusion

Our basic question
has been answered.

- In nature, along with the strict determinism, there exists freedom too, provided by the very nature of the material bodies.
- The uncertainty located at the atomic level due to the wave nature of matter, passes through the collisions which cannot be strictly defined, in the form of freedom to all phenomena.
- In the world the Natural Law rules without limitation.

  Its validity is undeniable but it is just a bit flexible.

  It determines with finite precision what will happen.
- In our desire to predict the future there are two obstacles.

- The first one, the more immediate, is the result of our ignorance.

  This is constantly being pushed further back because of the steady increase of our knowledge.

- The second, the more remote, lies in the nature of the Cosmos.

  It has nothing to do with our shortcomings.

  It stands motionless there for ever and is the absolute limit to our knowledge.

- The Natural Law offers freedom as a basic component of the Cosmos on an equal standing with the necessity of obedience.

- Freedom is not a fantasy and not a delusion.

  It is a part of the world.

- Life itself is a product of this freedom.

- In cases of great amplification, for example in the phenomenon of life or in the function of the central nervous system, freedom appears so powerfully that it becomes evident.

- One species can evolve; one person can make decisions which (on a large or small scale) can influence the course of the Cosmos.

  The Natural Law itself guarantees this.

- That a species or an individual always makes good use of freedom (i.e. in the sense of preserving and developing life on Earth) this is not guaranteed by anyone.

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P. Bekiaroglou