The CLOCK and The ARROW

A BRIEF THEORY of TIME

Claes Johnson

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Prolog

> The ordinary man (or woman) thinks he knows what time is but cannot say. The learned man, physicist or philosopher, is not sure he knows but is ready to write volumes on the subject of his speculation and ignorance. (David Landes in *Revolution in Time* 1983)

> The sight of day and night, and the months and the revolutions of the years, have created number and have given us conception of time, and the power of inquiring about the nature of the Universe. (Plato in *Timaeus*)

> ... in a purely mechanical world, the tree could become a shoot and a seed again, the butterfly turn back into a caterpillar, and the old man into a child. No explanation is given by the mechanistic doctrine for the fact that it does not happen. (Ostwald)

> ... a complete explanation of the arrow requires explaining why the universe started out as it did. It is a problem in cosmology. (Hawking)

The concepts of *space* and *time* are basic to human existence and culture but remain mysterious even after millennia of investigations by the most able thinkers. To come up with new aspects on the concept of time would seem almost impossible. But new possibilities are emerging as we are now entering into the *information age*. Life and society is getting increasingly dependent on *information processes* governed by *digital computers* executing the instructions of *computer programs*. *Google* offers a wealth of information by searching lists of *digital data* using supercomputers programmed according to a clever *mathematical search algorithm*. Digital computation has *finite precision* because computer *microprocessors* have finite *clock rate* and can only execute a finite number of *instructions* per time unit.

In this new world it is natural to view also physical, biological and psychological processes as (some form of) *computation of finite precision* following (some form of) a computer program written by (some form of) a *Creator*. The genetic code can be seen as a set of instructions written in the language of a DNA and RNA and the ribosoms as processors building proteins by executing the instructions. The precision of this computation is finite, and error correction is an important part of the ribosom computation. The idea of viewing thought processes as forms of computation was proposed already by Thomas Hobbes (1588-1679), and today has a new actuality. We know that also thought processes have finite precision.

The basic idea of this book is to study the concept of time viewing the World as the result of some form of *computation of finite precision*. This is a modification the classical mechanistic idea of *the World as a clock of infinite precision* into:

- *the World as a clock of finite precision.*

The approach is multi-disciplinary combining aspects of mathematics, science, literature and arts into a synthesis of science and fiction, or *science-fiction*, hopefully readable for a wider audience.

The most mysterious aspect of time is the *direction of time* or the *Arrow of time*: Why is time moving forward and not backward? Why is it impossible to reverse time, like pressing a rewind button on a video player? The basic laws of physics are time reversible, and the mystery is from where irreversibility comes, if not from physics? This book gives an answer based of finite precision computation, which is different from the standard answer based on statistical mechanics.

Coordinated Universal Time (UTC) is the high precision atomic time standard of the *Global Positioning System (GPS)*. One may argue that many of the classical questions concerning physical time and time-flow can be answered by UTC: Physical time and time-flow is simply what is measured by UTC. But the enigma of the Arrow remains, since an atomic clock has no Arrow, and subjective perception of time is much richer than UTC.

Two main aspects of time are *change* and *no-change*, which meet in *repetition*: Each day changes into a new day in linear time, but it is also very much the same as last day in circular time. Both linear and circular time have an Arrow: the new day is not yesterday and Spring always comes before Summer. But a clock does not have a direction, it only ticks, so the Arrow of time must come from something else than a clock, and then from what?

This book is part of the educational BodyandSoul project [3, 15], and in particular relates to the books *Computational Turbulent Incompressible*

Flow [12] and *Computational Thermodynamics* [13], which in mathematical detail show that the phenomenon of *turbulence* harbors the Arrow. This book presents this message without mathematical technicalities.

The reader can more material related to this book on my home page, including articles on Google Knol collected into *My Book of Knols* and posts on my blog *Claes Johnson on Mathematics and Science*.

The book is written as a dialog between *Philippe*, retired journalist and amateur philosopher, and *Mathew*, retired owner of a hardware store and amateur mathematician, meeting at *Atomic Clock Cafe* at *Times Square* in their old home town.

> It is a hopeless enterprise to search for the nature of time without studying physics. If there is a solution to the philosophical problem of time, it is written down in the equations of mathematical physics. (Reichenbach [24])

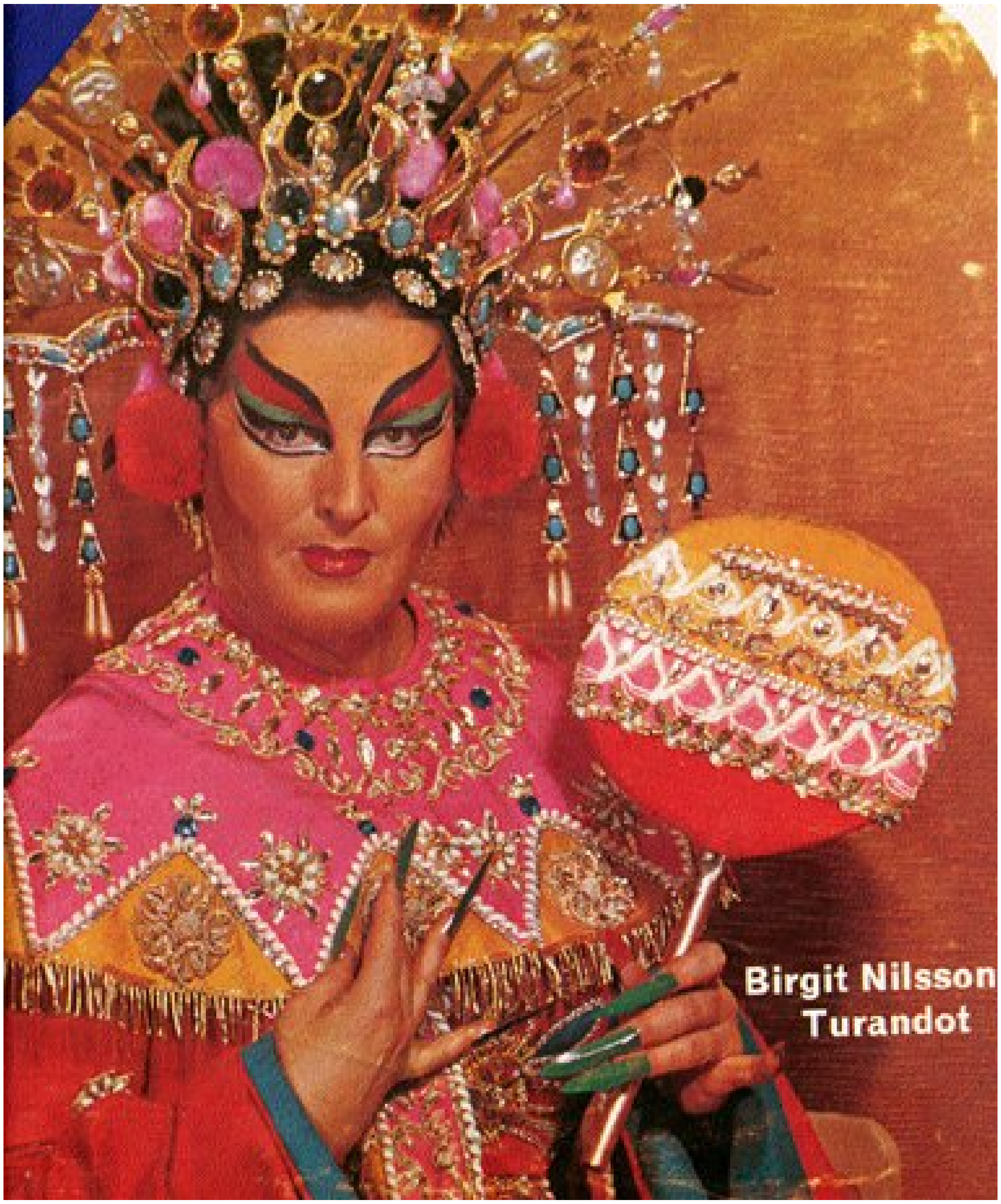


Figure 1: Princess Turandot's three riddles: *What can only move forward? What do you have but cannot touch? What do you get every day, but can never keep?*

Part I

Inventio

Chapter 1

Atomic Clock Cafe

> Time is the substance of which I am made. Time is a river which sweeps me along, but I am the river; it is a tiger that mangles me, but I am the tiger; it is a fire that consumes me, but I am the fire. The world,unfortunately, is real; I, unfortunately, am Borges. (Jorge Luis Borges in *A New Refutation of Time*).

> It doubtless seems highly paradoxical to assert that Time is unreal, and that all statements which involve its reality are erroneous. Such an assertion involves a far greater departure from the natural position of mankind than is involved in the assertion of the unreality of Space or of the unreality of Matter. So decisive a breach with that natural position is not to be lightly accepted. And yet in all ages the belief in the unreality of time has proved singularly attractive. (John Ellis McTaggart, The Unreality of Time, Quarterly Review of Psychology and Philosophy 17 (1908), 456-473.)

Mat: Hello Phil! How are you? We haven't seen each other for a very long time.

Phil: Hello Mat. Yes, it is ages since we met. Well, I have recently retired from my job as a reporter on a little daily journal up North, mainly writing obituaries. Or rather I was laid off because there is no more any special talent needed for writing nekrologs. Nowadays people can write their own. So now I am back to our home town again. The circle closes. And how are you?

Mat: Well, I have just closed the hardware store I have been running the last 30 years down South, and now I am also back to where it all started. Remember when we as young boys were exploring the World and the mysteries of engines, girls and Big Bang!

Figure 1.1: Atomic Clock Cafe.

Phil: Yeah, those were happy days! But now the prospects don't look too good. I got divorced, my economy is in ruins and my heart has lost its usual steady beat.

Mat: Sorry to hear. I also got divorced, the hardware store wasn't worth much and my memory is not what it used to be.

Phil: It seems that things only go one way, from bad to worse. It does not look too good. Sometimes I am dreaming that I could rewind my life back to the beginning and restart and then this time act a little wiser. Why isn't there a rewind button in our lives? Or is there?

Mat: Don't think so, but why does life only go one way, from birth to death, one day after the other, inevitably?

Phil: Well, lets see. This is an Internet Cafe so let me Google on *"philosophy of time"* and see what we get. I have always kept an interest in philosophical matters. The first hit is a certain *McTaggart*, who evidently claims that *time does not exist*! It is *unreal*! Pure fiction!

Mat: Sounds really surprising to me. But if time does not exist, then maybe we are not aging and there is some hope after all. What is the argument for this strange conclusion? And who is McTaggart?

Phil: John McTaggart Ellis McTaggart (1866-1925) was a lecturer at Trinity College, Cambridge, and a leading British idealist philosopher in a long tradition going back to the school of Parmenides in ancient Greece and including giants such as Spinoza, Kant, Hegel and Schopenhauer. In his *The Unreality of Time* from 1908 he showed that if you attempt to define time as an order into *past*, *present* and *future*, which is referred to as the *A-theory*, then you run into a *vicious circle*. McTaggart was a man of contradictions; radical in his youth, increasingly conservative, influential in the expulsion of Bertrand Russell from Trinity for pacifism during World War I, an advocate of women's suffrage, atheist from his youth, firm believer in human immortality and a defender of the Church of England. An interesting character with taste for contradiction. He not only formulated contradictions, he was one himself!

Mat: Contradictions? A-theory? Is there also a *B-theory*? And what is a vicious circle?

Phil: Yes, there is also a B-theory of *earlier-later*. You get into a vicious circle is when you get back to where you started, without any progress. McTaggart explains this disappointing experience as: *Our ground for rejecting time, it may be said, is that time cannot be explained without assuming time.*

Mat: That sounds really hopeless. But why do you have to assume that time exists to speak about past, present and future?

Phil: This is because the concept of time is intimately connected to the concept of *change*; if nothing changes there is no time. Now to speak about change it seems at least, you have to speak about before and after change, or about past and future with present in between. Thus it seems that you

Figure 1.2: Times Square with the Clock and the Arrow and the One Way Direction without permission to stand still in the Now.

have to know what time is to speak about change. Thus you cannot define time in terms of change, since change requires time to be defined.

Mat: OK, so McTaggart claims that time does not exist. Disappointing, but intriguing! But how can we talk about something which does not exist?

Phil: No problem. You talk or write about many things which do not exist. Fiction is only imagination, not reality, you know. Some believe that fiction is more real than non-fiction or documentary, or at least more interesting. If you would only talk about things which do really exist, then discussions quickly would become pretty boring. This is like only discussing the various parts of your motor-bike. Or only watching documentary soup operas. So we can go on talking about time as long as we get pleasure out of it following the device of Bertrand Russell that *the time you enjoy wasting is not wasted time*.

Mat: Does McTaggart say anything about the the *direction of time* or the *Arrow of time*? Why time is moving forward and not backward? Why there is no rewind button in our lives? Scientists must have an answer to such a basic question, unless tax money is wasted? From my experience in the hardware store I have some insight into science, mechanics and physics of nuts and bolts you know, and I have also kept an interest in mathematics. In school I did pretty well, if I remember correctly.

Phil: No, McTaggart doesn't say much about any Arrow. Maybe it is rather a problem in physics and mathematics than a problem in philosophy?

Mat: But I recall that the basic laws of physics, Newton's laws in classical mechanics and Schrödinger's equation in quantum mechanics, allow time to be reversed. By reversing all velocities at the final time of a system evolving forward in time, the system will return to its state at the initial time. Each process in forward time has a twin process in backward time. To your life process from birth to death, there is a twin backward life process from death to birth.

Phil: No, the backward process is not possible. Life only goes one way! And so does time!

Mat: From where does *irrevesibility* come then, if not from physics?

Phil: Let's find out! The web is at our disposal.

Chapter 2

Shortcut Through Time

> It is generally believed that there is color, something which is sweet and something bitter; in fact there are only atoms and emptiness. (Democrite (460-370 BC)

> It is also clear that if there were no such thing as time, there would be no such thing as the now, and that if there was no such thing as the now, there would be no such thing as time. (Aristotle, *Physics*, Book IV)

> Life presents itself to us as evolution in time and complexity in space. Regarded in time, it is the continuous evolution of a being ever growing older; it never goes backwards and never repeats anything. Considered in space, it exhibits certain coexisting elements so closely interdependent, so exclusively made for one another, that not one of them could, at the same time, belong to two different organisms: each living being is a closed system of phenomena, incapable of interfering with other systems. A continual change of aspect, the irreversibility of the order of phenomena, the perfect individuality of a perfectly self-contained series: such, then, are the outward characteristics–whether real or apparent is of little moment–which distinguish the living from the merely mechanical. (Henri Bergson in *Laughter: An Essay on the Meaning of Comic*, 1901)

Phil: Let's see if we can identify some common ground for a discussion. Can it be some form of *rational materialistic mechanistic* world view, which can be traced back two millenia to the school of the *atomists* in ancient Greece formed by *Democrite* around 400 BC and widely spread by *Epikuros* during the later half of the 3rd century BC? According to the atomists, *matter* is formed by (very small) indivisible *atoms* (from Greek *atomos* meaning uncuttable) and all physical phenomena ultimately result from interactions of atoms in an empty *space* over *time*. The atomists were remarkably visionary, but since the atomistic nature of matter was experimentally detected first in the beginning of the 20th century, they lost the initiative to the idealistic philosophy of *Socrate*, *Plato* and *Aristotle*, geometry of *Euclide* and religious scholastics, together dominating science until the the scientific and industrial revolution got initiated by *Leibniz* and *Newton*, who developed the mathematical basis of science in the form of (differential and integral) *Calculus*. But why did it take more than two millenia from the atoms of Democrite to the atom bomb and nano-technology of our society?

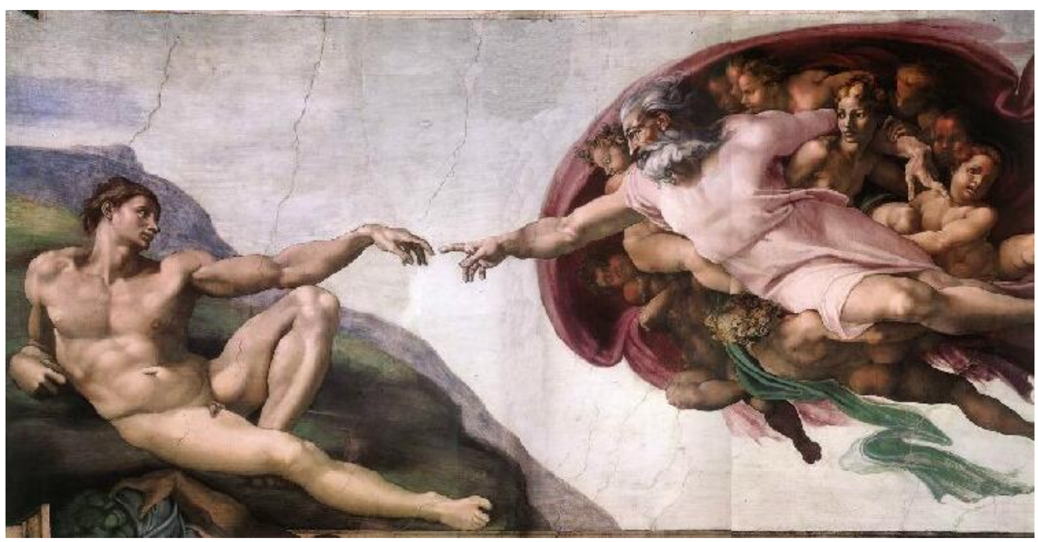


Figure 2.1: Local interaction.

Mat: Good question. Note that there was one important novelty in *Newton's theory of gravitation*: The atomists viewed the World basically as a large collection of atoms subject to *local interaction* by collisions, while Newton introduced the new idea of *instantaneous action at distance*. *Newton's law of gravitation* states that the Sun attracts the Earth with a force inversely proportional to the square of the distance between the Sun and the Earth in the direction of the *instantaneous position* of the Sun. Local interaction is like spreading a message mouth-to-mouth, while action at distance corresponds to transmitting it (almost instantaneously) electronically by electromagnetic waves.

Phil: Do you suggest that the atomists were too simplistic allowing only local interaction?

Mat: It may seem so since modern *quantum mechanics* of the atomic world also builds on action at distance, but the difficulty is to explain how action at distance can be established. Physicists are today searching for a hypothetical particle, named *graviton*, transmitting gravitational forces, but have not found anything like that, yet. So action at distance is still a mystery, and so is modern physics.

Phil: Is modern physics a mystery?

Mat: Surprisingly, our enlightened time is not as enlightened as you may think. Modern physics, the basis of science, is filled with mysteries: *black holes*, *dark matter*, *dark energy*, *string theory*, *wave-particle duality*, *curved space-time*... An eldorado for all writers of popular science. For the moment let us just note that both the atomists and Newton needed the concept of *absolute space* (like a big empty container), where atoms or celestial objects could move around. Instantaneous action at distance also required *absolute time* flowing at the same rate everywhere (like water flowing out of an standardized faucet), so that a notion of *simultaneity* could be established. Newton viewed time as part of the fundamental structure of the universe, a dimension in which events occur in sequence, and time itself is something that can be measured. However there is no Arrow in a Newtonian world, since all collisions and motions can as well be *reversed in time*. Or so it seems at least...

Phil: But isn't Newton's gravitational theory today replaced by *Einstein's theory of relativity*?

Mat: Yes, so we are told, and the upshot was an apparent difficulty with the concept of simultaneity identified by the mathematician Poincaré and then utilized by Einstein in his crusade against Newtonian mechanics and absolute space and time. Einstein's new mantra was: *there is no such thing as simultaneity*, which opened the way for the *theory of relativity* and its *curved space-time*. Physicists of today tell us that our intuitive conceptions of time and space are wrong, that we should not distinguish time from space

Figure 2.2: Instantaneous action at distance.

and instead mix time with space into a common curved space-time. However, in Einstein's curved space-time there is no Arrow of time, and thus if we are searching for the Arrow, we have to look elsewhere.

Phil: OK, so we can identify a line Democrite-Newton-Einstein from ancient Greece into our time, however without any Arrow. The measurement of time has developed from the Sun dials of early civilizations over the mechanical clocks of the industrial society to the atomic clocks of our present information society. The accuracy has improved from hours over minutes to nano-seconds of today.

Mat: Recall that Leibniz defines *space* as the *order of coexistence*, and *time* as the *order of succession*, thus avoiding the concepts of absolute space and time. Leibniz emphasizes that space and time are different: time is sequential while space is not. But there is no Arrow in Leibniz order of succession, since the succession seems to be reversible.

Phil: Of course, our direct experience tells us that for sure there is an Arrow pointing forward in time, inevitably making us a bit older every second that passes, and that our life time is limited. We also know very well that time can be reversed in a movie by playing it backwards pushing the *rewind* button, but this is not possible in reality. But why? Why is there no rewind button in reality? Or is there?

Mat: This question was understood already by *St Augustine* in the 4th century, but surprisingly has remained without a convincing answer into our time. Not even *Richard Feynman*, Nobel Prize in Physics 1965, seems to have any answer: *Where does irreversibility (the Arrow) come from? It does not come from Newton's laws.*

Phil: No answer? My tax money! But haven't we forgotten, apparently then like Feynman, that the *2nd Law of Thermodynamics* presented in any book on *statistical mechanics*, defines forward time by increasing *entropy* or *disorder*?

Mat: Yes, you are right: The standard answer is statistical mechanics but the trouble is that this is so damned difficult to understand, that even the minds of people like Feynman and Einstein boggles. But there might be a better answer, an alternative to statistical mechanics as an explanation of *why* there is an Arrow of time. Let me google a bit and I will be back with some info,

Figure 2.3: St Augustine (354-430) in Confessions: *What then is time? If no one asks me, I know what it is. If I wish to explain it to him who asks, I do not not know.*

Figure 2.4: Richard Feynman (1918-1988): *Where does irreversibility come from? It does not come form Newton's laws. Obviously there must be some law, some obscure but fundamental equation. perhaps in electricity, maybe in neutrino physics, in which it* does *matter which way time goes.* (The Feynman Lectures on Physics 1963).

Chapter 3

Ghosts of Science and Religion

> Hominids turned to the sacred realm because they evolved to relate in deeply emotional ways with their social partners....and because the human brain evolved to allow an extension of this belongingness beyond the here and now. (Barbara J. King in *Evolving God*)

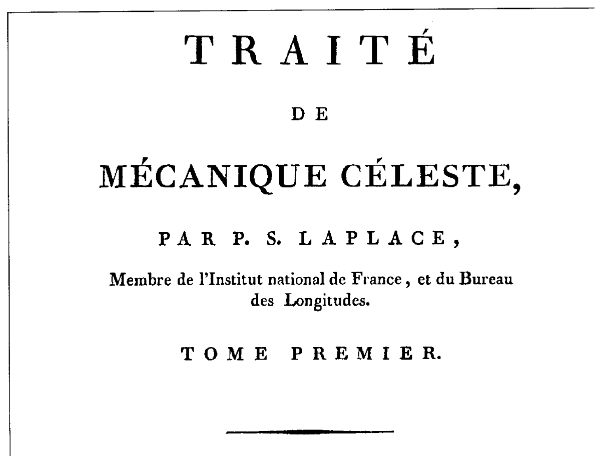
> Then I went back into the house. It is midnight. The rain is beating on the window. It was not midnight. It was not raining. (Beckett in *Molloy*)

Phil: Some experts of human genetics claim that homo sapiens probably has a "religious gene" giving us a particular capability of "believing in ghosts", which has turned out to give an advantage in Darwin's struggle for existence. The "ghost" may have religious, political or scientific character or a combination thereof, and different "ghosts" have dominated during different periods of the evolution of human society.

Mat: Today, the "ghost of science" has taken the initiative from religion and politics: The general belief seems to be that the threat of *global warming* can only be met by clever scientists in cooperation with educated responsible citizens and politicians, and not by prayers, healing or simply relying on "fate".

Phil: You are right: The scientific and technological revolution initiated in the 17th century which has caused the warming, will now have to be carried further to avoid a catastrophe. This is maybe the toughest challenge facing humanity ever. A challenge indeed to all rational scientists and engineers.

Mat: It all started with the *Calculus* of Leibniz and Newton in the 17th century laying the theoretical foundation of the mechanistic world view. The mathematician Laplace (1749-1827) perfected Newton's mechanics in his monumental Mécanique Céleste in five volumes appearing during 1798-1825, describing the Universe as a clock following immutable laws of mechanics. A beautiful reversible Universe which could as well go backwards in time, without an Arrow.


TRAITÉ

DE

MÉCANIQUE CÉLESTE,

PAR P. S. LAPLACE,

Membre de l'Institut national de France, et du Bureau des Longitudes.

TOME PREMIER.

Figure 3.1: Laplace mathematical analysis of the Universe as a clock.

Phil: Our ancestors were sitting in the caves or roaming the savannas for hundred thousand years, before somebody got the bright idea to go forward and *change something*, to define an Arrow. Their idea of time probably was circular in an endless repetition of birth followed by death or creation followed by destruction. Most of the cells of a human body get replaced over a month, and the members of a society get born, live their lives and die away, while the society continues to exist. Eternal love with changing subjects.

Mat: Yes, that is the idea of the *sustainable society*, an eternal society that will never die. The idea is that if we recycle enough, then human civilization can nicely continue for ever: It will be sustainable. All politicians speak about *sustainability*, and they have to do that to remain credible. But is it credible? Can a sustainable society be realized, or is it just a dream? Is there an Arrow necessarily leading to destruction, of a cell, a human being, a society and a civilization?

Chapter 4

Change and Time

> Change is the law of life. And those who look only to the past or present are certain to miss the future. (John F. Kennedy)
>
> There is something essential about the now, but whatever it is, it lays outside the realm of science. (Einstein)
>
> Events in the past and future have to be every bit as real as events in the present. (Paul Davies)
>
> Times are a'changing. (Bob Dylan)

Phil: Aristotle states in Book IV of his *Physics* lecture notes on *What Time Is*:

- *What is worth considering is the prevalent idea that time is variation and change.*
- *For without change (or any notable change) in our minds, time does not seem to pass, as in the story about those who sleep in the sanctuary of the heroes in Sardinia, who wake up and do not think that time has passed. Clearly time does not exist without change.*
- *Time is thus change, or rather an aspect of change.*
- *Time is that feature of change that makes number applicable to it.*

- *In a sense, the now is something single and identical, but in a sense it is not. In so far as it is to be found at successively different points, its is different–this is what it is to be "now"–but the actual thing that is now is the same.*

- *By the same token, a moving object, by which we know change, and what is before and after in change, follows a point. The actual thing, that is the moving object is the same, but in definition it is different, just as the sophists take Coriscus in the Lyceum to be something different from Coriscus in the city square. A moving object, then, is different by being successively in different locations, and now follows a moving object just as time follows change, for it is the moving object that enables us to know before and after in change, but the now exists in so far the before and after are numerable.*

- *So in a sense the now is always the same, and in a sense it is not, because the same goes for a moving object.*

Evidently, Aristotle states that time is a feature of change which can be measured by a pointer moving along a line of numbers, such as an analog clock with moving arms, or the (apparent) motion of the Sun in the sky. He also, admirably so, explains the both changing and unchanging aspects of the "now". Time and change thus are intimately related.

Mat: I agree, Aristotle understood something essential about the nature of time.

Phil: But concerning the Arrow, Aristotle hesitates and gets into lengthy discussions about concepts like "first change" and cause-effect, without clear conclusions.

Mat: Yes, connecting the Arrow to cause-effect with the cause preceding the effect, is of course natural. But the question is what makes the cause the cause and not the effect in reverse order?

Phil: Yes, that is the enigma of the Arrow. Is there no light in the tunnel?

Figure 4.1: Instrument for measuring change, of what?

Chapter 5

Prof. Dr. Zeitmund Leibschnitzel

> It is now or never. (Prof. Dr. Leibschnitzel)
>
> I listen with attention to the judgment of all men, but so far I can remember, I have followed none but my own. (Michel de Montaigne (1533-1592)
>
> Time and space are modes in which we think and not conditions in which we live. (Einstein)

Mat: When I search on "direction of time" on Google, I get 3 billion hits, and the top one is a certain *Prof. Dr. Zeitmund Leibschnitzel.* Are you familiar with this name?

Phil: No, who is that? Never really heard of him.

Mat: Evidently, he has formulated a new principle, referred to as *Principe Perfeito*, supposedly explaining the Arrow of time, that is why time is moving forward and not backward, in the *non-perfect World of finite precision* he claims that we are living in.

Phil: Principe Perfeito? A perfect principle governing a non-perfect World, which explains the Arrow? Too true to be good? Is this a more precise version of the classical mechanistic idea of the *World as a clock* into: the *World as a clock of finite precision*?

Mat: Exactly! Evidently, Prof. Dr Leibschnitzel spent all his life in the little town of Zeitbaden in his study, working incessantly on all sorts of topics, only occasionally getting a few hours of sleep in his chair at his desk, without following any clock, suffering as he was of *tickopanic*, fear of clocks. Some view him as the last universal genius, the pinnacle of German idealism/realism. He also developed a theory of time, more precisely about the different months, which he referred to as *Monatologie*, the *theory of months*. Difficult to read, but supposedly very deep, taking Kant one step deeper and higher. Prof. Dr. Leibschnitzel says that the question of the Arrow has

Figure 5.1: Prof. Dr. Zeitmund Leibschnitzel with some of his finite precision models of the World.

many facettes and connects to the following questions:

- How can there be *irreversibility* in a *formally reversible system*?
- How can there be *imperfection* in a *formally perfect world*?
- Why do not all people follow all laws?
- Why do you have to pay a fine for breaking the law?

- How can there be *friction* in a system *formally without friction*?
- Why is a *perpetuum mobile* impossible?
- How can there be a *free will* in a *formally deterministic world*?
- Why do we have to pay interest on a loan?
- Why did the Soviet Union collapse in 1989?
- Why did the New York stock market collapse in 1929?
- Why does it take so long time to grow up?
- Why does writing take much longer time than reading?
- What makes a funny story funny?
- Is it necessary to forget to remember?
- What makes the cause the cause and not the effect?

Phil: So many questions! All connecting to the Arrow? And to the idea of the World as a clock of finite precision?

Mat: That's right. Let's uncover the secret!

This thing all things devore;
Birds,beasts, trees, flowers;
Gnaws iron, bites steel;
Grinds hard stones to meal;
Slays kings, ruins town,
And beats high mountain down.
(Gollum's fifth riddle)

Figure 5.2: Principe Perfeito ready to go.

Chapter 6

Principe Perfeito

> Quid est ergo tempus? Si nemo ex me quaerat, scio; si quaerenti explicare velim, nescio. (St. Augustine)
>
> Love is yesterday, it will be born today, and it was tomorrow. (Jan Skácel)

Phil: Can you explain Principe Perfeito?

Mat: Yes, take at look at this figure:

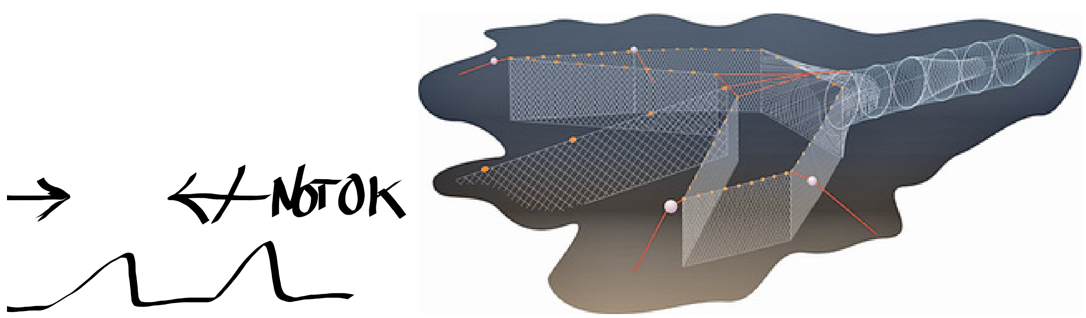


Figure 6.1: Motion to the right is easy, but motion to the left is difficult.

Phil: What do we see? A fish trap?

Mat: Yes, we see two devices where motion to the right is "easy", while motion to the left is "difficult". The device on the left mounted on an assembly line in a factory, will allow objects to slide from left to right, but will block motion from right to left. The device on the right is a fish trap based on the principle that it is easy for a fish to get into the trap, but difficult to get out. We could say that it is a matter of *precision*. To get in does not require much of precision, because the fish is guided into the net. But to get out requires a very high precision, and fish aren't smart enough to sneak out by pure intelligence and cannot find the way by trial and error before they die. So the trap works.

Phil: Aha, so both devices are *directed* and Principe Perfeito says that time is similarly directed for a similar reason: It is "easy" for time to move forward, but "difficult" to move backwards, because the requirements on precision are vastly different.

Mat: Yes, that is a correct interpretation. Another formulation of Principe Perfeito is expressed in the seemingly innocent statements:

- *mixing is easy (fast) and can be done with low precision,*
- *unmixing is difficult (slow) and requires high precision.*

To mix milk into your coffee is easy, to un-mix is virtually impossible. Simple as it seems, this idea contains a deep truth. Yet another formulation is:

- *imprecise separation may be easy and fast*,
- *precise separation may be difficult and slow.*

To rip a piece of paper apart is easy and goes quick, to separate a tumor from healthy tissue may require extreme precision and may take long time.

Phil: I understand what you say, and evidently there is here no talk of statistics, only finite precision.

Mat: Yes, that is the beauty. The essence of Principe Perfeito can also be expressed as:

- *a mechanical clock shows time but has no direction*,
- *life is a clock with direction.*

Phil: You mean that there is connection between *biological processes* and the Arrow?

Mat: Yes, I do. A *life process* from birth to death, of an amoeba for example, clearly has an Arrow, and conversely: Life processes define a direction of time. We can here use the term life process in a very general sense, and include e.g the life of a star from its birth through gravitational mass concentration followed by ignition into nuclear fusion to its death as a white dwarf or black hole. Or the birth and growth of a cyclone sucking energy from the hot waters of the Mexican Gulf and dissipating it over the coast and main land.

Phil: What is then a life process?

Mat: The life of a living cell can be described as an interplay of the two processes of

- *creation of difference* or *anabolism*,
- *destruction of difference* or *catabolism*,

where anabolism represents growth and division of cells and catabolism represents production of energy and building material for the anabolism. Anabolism is slow/precise, while catabolism is fast/imprecise and this makes life processes irreversible. Life could in principle have been reversible using the same precision in both anabolism and catabolism, but such forms of life would not be competitive in the battle of survival of the fittest.

Phil: Is there a coupling to *complexity*? That life processes are irreversible, because they are complex? A mechanical clock can be reversed because it is so simple, while a life clock cannot because it is complex?

Mat: I guess you said something essential there: Limitation to finite precision makes complex processes irreversible.

Phil: Maybe life is a marriage between a *desire to live* with a reality of *failure to live.* Without a desire to live, there will be no life, but the desire to live eventually has to give in to the greatest failure of all of death, which is the ultimate imperfection of life. But every moment of life contains smaller imperfections, since a perfect life is not competitive. Life could thus be viewed as a continued unsuccessful effort to live a perfect life, resulting in an irreversible life.

Mat: It seems that Principe Perfeito represents a new key to unlock the secret of the Arrow, a key caught in the new net of *computation* in our new age of the *computer*. But the key also may reveal some secrets of both the *real World*, since the real World is realized in some form of an analog computation or processing of information, and the *imaginary World* based on the mental computation of our thought processes or the digital computation of virtual reality and computer games.

Phil: In hinduism *Brahma* is the God of Creation and *Shiva* the God of Destruction thus playing the roles of anabolism and catabolism in the metabolism of the Universe.

Mat: Yes, creation and destruction cannot exist without the other, but creation precedes destruction and thus defines the Arrow.

Figure 6.2: Anabolism powered by catabolism.

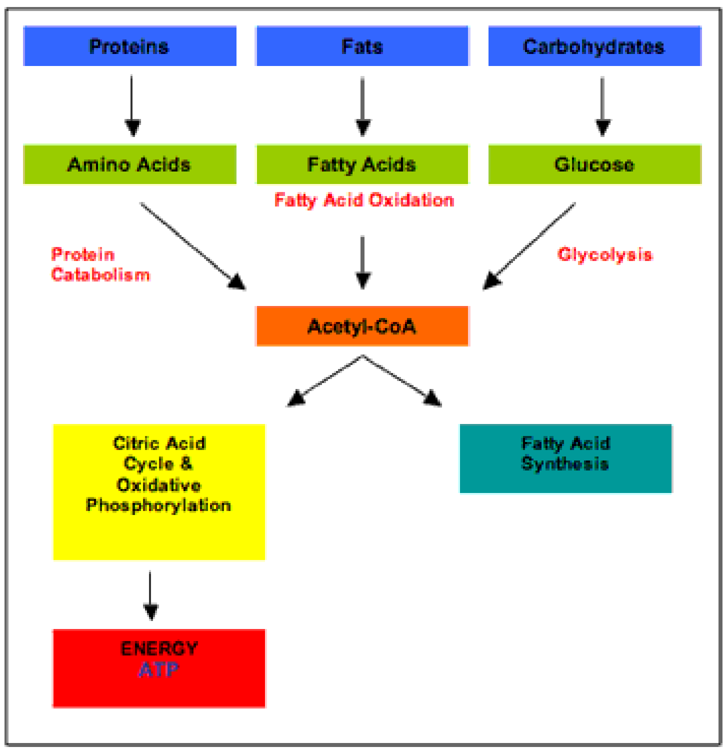


Figure 6.3: Principle of catabolism supplying energy to the cell in the form of ATP (Adenosine triphosphate).

Chapter 7

Chemical Reactions

> The meeting of two personalities is like the contact of two chemical substances; if there is any reaction, both are transformed. (Jung)

> Genius depends on dry air, on clear skies – that is, on rapid metabolism, on the possibility of drawing again and on great, even tremendous quantities of strength (Nietzsche)

> Tolstoy I know that most men, including those at ease with problems of the highest complexity, can seldom accept even the simplest and most obvious truth if it be such as would oblige them to admit the falsity of conclusions which they have delighted in explaining to colleagues, which they have proudly taught to others, and which they have woven, thread by thread, into the fabric of their lives. (Tolstoy)

Mat: Both the catabolism and anabolism of the metabolism of life are based on chemical reactions. Catabolism typically involves a process of *mixing*, which means destruction of macroscopic difference/order and correspondingly anabolism involves a process of *un-mixing*, or creation of macroscopic difference/order. Mixing does not require high precision, just stir, while un-mixing requires care and precision. In the chemical reaction of a catabolic process, the reactants are mixed so that they can meet and react. Mixing increases microscopic difference, but decreases macroscopic difference. In the chemical reaction of an anabolic process resulting in macroscopic order, the reactants are not mixed and the reaction typically takes place at a reaction front.

Figure 7.1: Mixing of ingredients to make a cake.

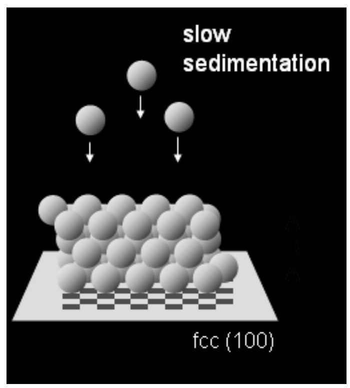


Figure 7.2: Slow growth of a crystal by sedimentation.

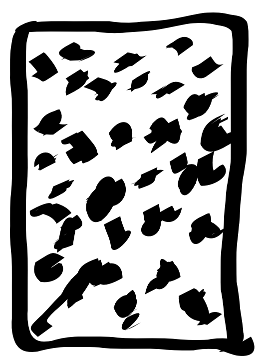


Figure 7.3: Un-mixed - small area of reaction zone - slow. Mixed - large area of reaction zone - fast.

Phil: The area of the active reaction front can be much larger if the reactants are mixed, and thus catabolic reactions can be quicker than anabolic, which explains why creation is slow, while destruction may be fast. Because of the different requirements of precision, un-mixing cannot quickly be achieved simply by reversing the quick process of mixing. Therefore a catabolic process of mixing defines an Arrow, and un-mixing cannot only be realized in a slow anabolic process.

Mat: We summarize by noting that a process of *mixing*

(m1) *decreases macroscopic difference*,

(m2) *increases microscopic difference*,

while a process of *un-mixing*

(u1) *increases macroscopic difference*,

(u2) *decreases microscopic difference.*

We understand that both (m1) and (m2) and also (u1) may be performed with low precision, while (u2) requires high precision on microscopic scales for *identification* and *separation*, which is a slow process.

Phil: In industrial processes separation can be performed by *centrifugation*, which in principle is a sedimentation process as in Fig. (7.2), with an effective gravitational force caused by the rotation of the centrifuge. With a fast centrifuge the separation can be made quickly, but biological processes do not use this principle, except possible when a dog gets rid of the water after a swim by shaking.

Mat: Why is separation sometimes a slow process? Well, it needs to be discriminating and somehow select what is to be separated, and then do it. There are many selection processes in society, like choosing a new president, and we know that these processes are very slow and complicated and they need to be precise. So selection may take time and care because high precision search is needed, but also the very separation process may take long time, as when a child separates itself from the parents, or a sediment settles. There are other forms of separation, which can go fast like ripping a paper into pieces. Such processes are difficult to reverse, because a a careful search and selection will have to be done to find the pieces which match.

Phil: Darwin's principle of *natural selection* has been a very slow process requiring billions of years for life to develop, because no centrifuge has been available for quick selection of the fittest.

Chapter 8

Life

> Dream as if you'll live forever, live as if you'll die today. (James Dean)
>
> Life is pleasant. Death is peaceful. It's the transition that's troublesome. (Asimov)
>
> Life is far too important a thing ever to talk seriously about. (Oscar Wilde)

Phil: Life processes involve growth, division and differentiation of cells formed by *photosynthesis* and/or chemical reactions from *organic* and *non-organic substances*. Life consists of both the process of creation-growth increasing difference and destruction-decay decreasing difference. Creation consumes energy and destruction produces waste. Without a drive to live there will be no life and the drive to live is a drive to differentiation, to sharpen difference, and this drive has to be controled by paying some form of interest operating on relative difference. Life thus needs a process of cell destruction, because not all cells brought to life are healthy cells, and all cells cannot be kept indefinitely. So, cell destruction is as important as cell creation. Cell destruction represents a loss or payment which is necessary for continued survival. If you do not pay this form interest, then your body will get unstable and disintegrate.

Mat: All organisms consist of small cells, typically too small to be seen by a naked eye, but big enough for an optical microscope . Each cell is a complex system consisting of many different building blocks enclosed in membrane bag. There are unicellular (consisting only of one cell) and multicellular organisms. Bacteria and baker's yeast are examples of unicellular organisms - any one cell is able to survive and multiply independently in appropriate environment.

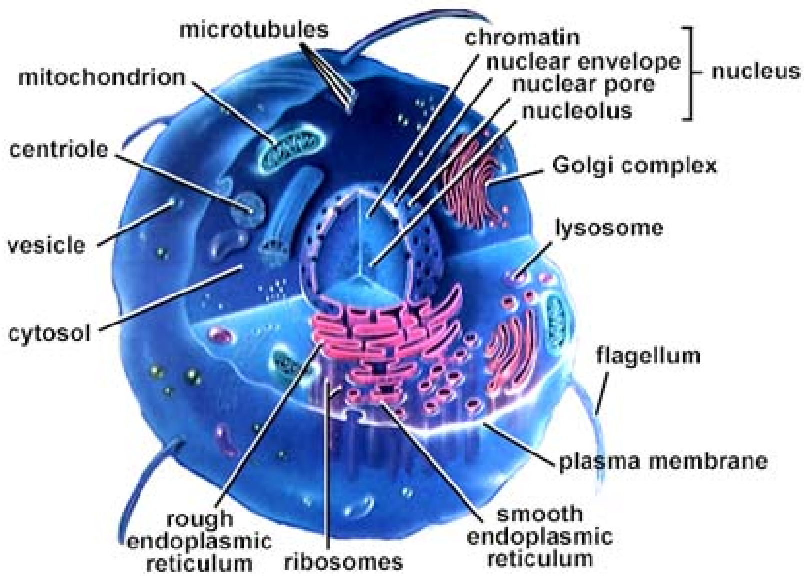


Figure 8.1: Eukaryotic cell.

Phil: There are about 10^{14} cells in a human body, of about 320 different types, such as skin cells, muscle cells, brain cells (neurons), among many others. The number of cell types is not well-defined, it depends on the similarity threshold (what level of detail we would like to use to distinguish between the cell types, e.g., it is unlikely that we would be able to find two identical cells in an organism if we count the number of their molecules). The cell sizes may vary depending on the cell type and circumstances. For instance, a human red blood cell is about 5 microns (0.005 mm) in diameter, while some neurons are about 1 m long (from spinal cord to leg). Typically the diameter of animal and plant cells is between 10 and 100 microns.

Mat: There are two types of organisms - *eukaryotes* and *prokaryotes*, and two types of cells respectively. Bacteria belong to the prokaryotes. However, most organisms which we can see, such as trees, grass, flowers, weeds, worms, flies, mice, cats, dogs, humans, mushrooms and yeast are eukaryotes. The distinction between eukaryotes and prokaryotes is rather important, because many of the cellular building blocks and life processes are quite different in these two organism types. This is believed to be the result of different evolutionary paths. Most scientists believe that life first emerged on Earth around 3.8 billion years ago. The oldest fossilized bones that have been found resembling bones from anatomically modern humans are about 100.000-200.000 years old. Nobody really knows how life emerged on Earth.

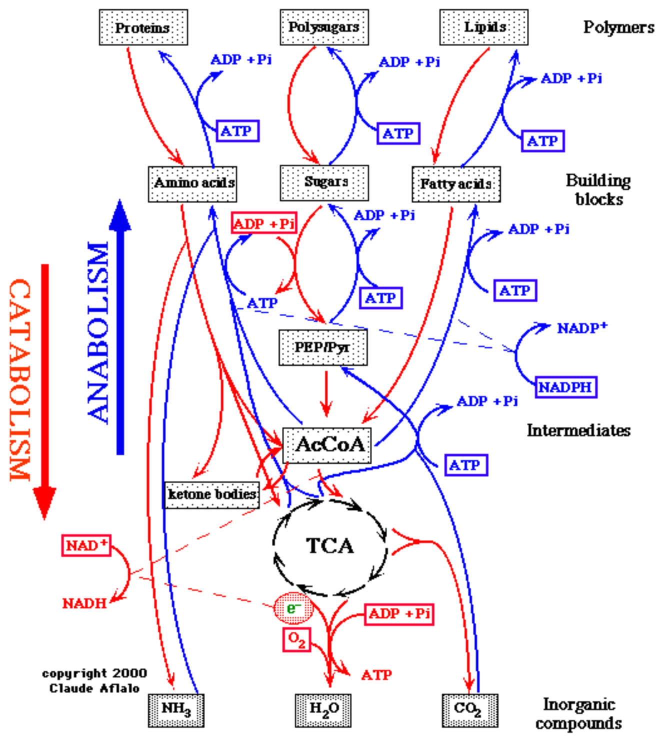


Figure 8.2: Cell metabolism.

Phil: The *metabolism* of a living cell is the set of chemical reactions of the life process, and can divided into to categories of processes *anabolism* and *catabolism*. Anabolic reactions construct cell components such as proteins and nucleic acids allowing the cell to grow and divide. Catabolic reactions break down large polymeric molecules such as proteins and polysaccharides into their constituent monomeric units such as monosaccharides, nucleotides and amino acids, offering energy and building material for the anabolism.

Mat: The metabolism of a cell thus consists of a combined process of creation-destruction. If the destruction does not work properly on the cell level, cancer develops. We understand that it is the destruction in the catabolism which makes life into an irreversible process with an Arrow. To live and create you have to destruct, and that makes life irreversible.

Phil: You find the same phenomenom on a bigger scale in the metabolism of the World.

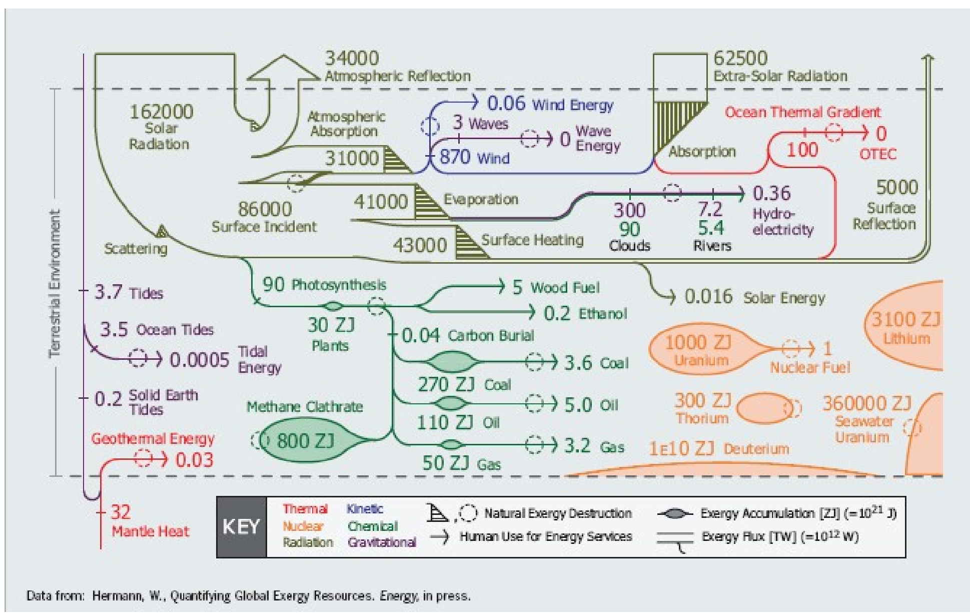


Figure 8.3: Global metabolism

Mat: To create a garden you have to put seeds to grow, but you also have to destroy weeds, and destroying weeds requires work, which you can view as a necessary loss to make to give room for the new plants. Nobody has seen a garden which does not require elimination of weeds one way or the other.

Phil: The *adaptive immune system* of a human body detects and kills *pathogens* by producing *antigenes* attaching to the pathogenes. An immune system constantly produces a palette of (millions of) different antigenes which are tested, and the antigenes which have shown to be functional are kept in an *immunological memory*, allowing faster and stronger response each time a particular pathogen is encountered. It appears that the palette of anti-genes is preset by the DNA but only the part of the palette which has once been activated is remembered. The immunological memory thus results from *eliminating* antigenes from a large collection of anti-genes, rather than *designing* specific anti-genes on order. This is like the creation of a sculpture out of a rock by elimination of everything which should not be a part of the sculpture. Writing a book this way is however not really possible: Starting with the set of all possible books, and eliminating all books which is not the correct one, does not seem to be a feasible procedure.

Chapter 9

Sexual Reproduction

> Two points of principle are worth emphasis. The first is that the usually supposed logical inevitability of the theory of evolution by natural selection is quite incorrect. There is no inevitability, just the reverse. It is only when the present asexual model is changed to the sophisticated model of sexual reproduction accompanied by crossover that the theory can be made to work, even in the limited degree to be discussed .... This presents an insuperable problem for the notion that life arose out of an a-biological organic soup through the development of a primitive replicating system. A primitive replicating system could not have copied itself with anything like the fidelity of present- day systems .... With only poor copying fidelity, a primitive system could carry little genetic information without the mutation rate becoming unbearably large, and how a primitive system could then improve its fidelity and also evolve into a sexual system with crossover, beggars the imagination. (Fred Hoyle in *Mathematics of Evolution*, 1987)

Phil: *Sexual reproduction* seems to give an advantage in the big battle for survival, since this is the primary method of almost all animals and plants Is there a connection to Principe Perfeito and finite precision?

Mat: Let's see: The standard idea is that sexual reproduction increases *genetic diversity* of the offspring. It contains two processes: *meiosis*, involving the splitting of chromosome pairs into *haploid gametes*, and *fertilization* involving the fusion of two *gametes* restoring the chromosome pairs in a *diploid* cell. During meiosis, the chromosomes of each pair usually *cross over* to achieve *genetic recombination*. But the evolution of sex is a major puzzle. The first fossilized evidence of sexually reproducing organisms is from eukaryotes of the Stenian period, about 1 billion years ago.

Phil: OK, maybe diversity is enhanced but what about fidelity and stability?

Mat: Let's see: With just one copy of a gene, there must be a relatively high probability of a serious error in reproduction by cell division, because copying genes is a process with finite precision. If a genome consists of 1000 genes and the probability of a serious error in a single gene is 0.001, thus quite small, then the probability of an error in the genome is $(0.999)^{1000} \approx e^{-1} \approx 0.3$, that is, a high risk!

Phil: That may very well be way too much. In sexual reproduction with two copies of each gene, one from the father and one from the mother, the probability that both copies of a gene are defect is 0.000001, and the probabilty that the genome is defect is then $(0.999999)^{1000} \approx 0.001$, that is, much smaller than with asexual reproduction. So sexual reproduction is not only more interesting but also more secure. Safe sex!

Mat: Yes, the big trouble in many cases of finding someone to mate with, could well be compensated by less vulnerability to finite precision. Maybe large-scale cloning does not work out. Maybe there is role for the male even when hunting and fighting is no longer necessary. With three copies of each gene the security would improve even further, but three-party mating may be too cumbersome to be competitive.

Figure 9.1: Hyperreal safe sex.

Chapter 10

Turbulence

> After the turbulence of death, moral principles and even religious proofs are called into question. (Salvatore Quasimodo)
>
> Turbulence is the most important unsolved problem of classical physics. (Richard Feynman)
>
> I am an old man now, and when I die and go to heaven there are two matters on which I hope for enlightenment. One is quantum electrodynamics, and the other is the turbulent motion of fluids. And about the former I am rather optimistic. (Horace Lamb)

Phil: So physicists claim that Newtonian mechanics in principle is reversible: If you change all velocities of a system governed by Newton's (or Schrödinger's) laws of motion at final time, then the system will return to its state at initial time?

Mat: That is correct, and this is the enigma: How can there be an Arrow in a reversible system? Let me give another example of how Principe Perfeito resolves this mystery and at the same time uncovers the secret of *turbulence*.

Phil: Turbulence? Are you kidding? This is supposed to be the major unsolved problem of classical mechanics. What is the connection to Principe Perfeito?

Mat: You know that a moving car is subject to a *drag force* opposing the motion from the flow of air around the car, which has to be balanced by a driving force from an engine. The drag force is observed to increase quadratically with the speed, and requires hundreds of horsepowers for larger speeds. *However*, the mathematician d'Alembert (with the Encyclopedia) proved in 1752 that *according to Newtonian mechanics the drag is zero*!

Phil: Amazing! I guess this is the famous *d'Alembert's paradox*; a glaring difference between theory and observation. Does it mean that Newtonian mechanics is wrong? What is the connection to Principe Perfeito?

Mat: Finite precision, my dear Watson! In an ideal Newtonian world of infinite precision the drag would be zero, but in the real Newtonian world of finite precision the drag is substantial.

Phil: What is then the difference between infinite precision of an ideal world and finite precision of a real world?

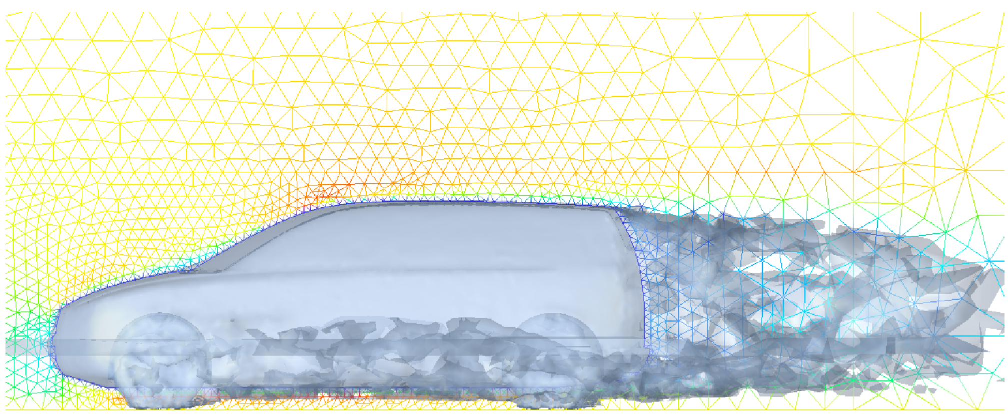


Figure 10.1: Real flow of air around a car with turbulent wake behind.

Mat: *Turbulence*, my dear Watson! In an ideal Newtonian world the flow would look the same if you reversed the motion of the car, but in the real world it changes. We have all seen that in the real world there is *behind/after* a moving car (following the flow), a *turbulent wake* of swirling flow but not before/in front. If we reverse the motion, then the turbulent wake will again occur *after/behind* the car and thus shift position. The flow is not reversible.

Phil: Yes, I am very familiar with the phenomenon of a turbulent wake behind a body moving through a fluid, and I understand that reversing the velocity will reverse the position of the wake. What about the ideal Newtonian world?

Mat: In this world there is an ideal infinite precision mathematical solution to Newton's equations, referred to as a *potential solution*. This is d'Alembert's solution which does not have a turbulent wake and it has zero drag. In particular, if the object is symmetric, then the flow is also symmetric and thus looks the same if the velocity is reversed. *However*, this ideal solution is *unstable* and with finite precision it is replaced by a non-symmetric turbulent solution, with a wake behind just as for the car.

Phil: OK, so in the real world of finite precision the ideal potential solution with zero drag, is replaced by a turbulent solution with drag. The presence of turbulence makes the flow irreversible and defines the Arrow. Neat I must say!

Mat: Yes, this resolves d'Alembert's paradox using Principe Perfeito, all according to the Wikipedia article on the paradox! Take a look!!

Phil: Amazing, you are right! Finally the paradox has been resolved, after more than 250 years of unsuccessful attempts!! This must be hot stuff.

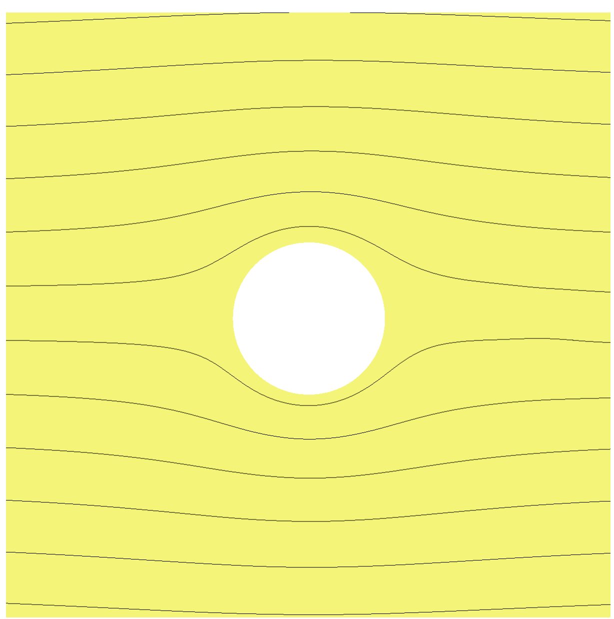


Figure 10.2: Unreal symmetric flow with zero drag.

Chapter 11

Backward in Time to Big Bang

> The appeal of the Big Bang has been more ideological than scientific. When men think about the universe, there is always a conflict between the mythical approach and the empirical scientific approach. In myth, one tries to deduce how the gods must have created the world - what perfect principles must have been used. – I have never thought that you could obtain the extremely clumpy, heterogeneous universe we have today, strongly affected by plasma processes, from the smooth, homogeneous one of the Big Bang, dominated by gravitation. (Hannes Alfvén)

> In 1981 my interest in questions about the origin and fate of the universe was reawakened when I attended a conference on cosmology organized by the Jesuits in the Vatican. The Pope told us that it was all right to study the evolution of the universe after the big bang, but we should not inquire into the big bang itself because that was the moment of Creation and therefore the work of God. I put forward the suggestion that maybe time and space together formed a surface that was finite in size but did not have any boundary or edge. – It would have neither beginning nor end: it would simply be. What place, then, for a creator? (Hawking in *A Brief History of Time*)

Phil: Stepen Hawking's bestseller *A Brief History of Time* is a tremendous success with more than 9 millions copies sold worldwide, although few seem to actually have read the book, and even fewer understood it. What is then Hawking's recipe for sales success, except that it is not understandable?

Mat: Hawking has Newton's chair in Cambridge and, has developed a theory of *black holes* based on Einstein's relativity, and is one of the prime advocates of the *Big Bang theory* stating that our Universe along with time and space was created some 13 to 20 billion years ago from an incredibly concentrated hot initial state, referred to as a *singularity*, during the first 10^{-43} seconds consisting of a soup of leptons and quarks out of which came all other elements of matter as the Universe expanded and cooled off. The idea of a Big Bang was first put forward in the famous *Alpher-Bethe-Gamov* paper by our old friend Gamov and his students. Gamow suggested that remnants should be visible as (tiny) variations in the cosmic background radiation, which was experimentally detected by the COBE-satellite and gave the Nobel Prize in 2006 to John Mather and George Smooth, and thereby also the Big Bang theory a (big bang) boost.

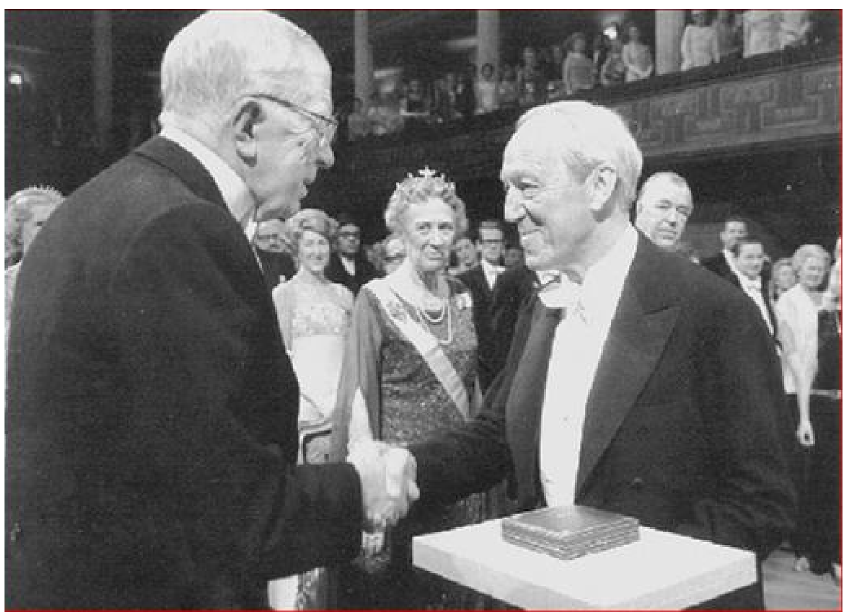


Figure 11.1: Hannes Alfvén receiving the Nobel Prize in Physics from King Gustaf VI Adolf in 1970.

Phil: Evidently, the Catholic church has embraced the Big Bang theory of creation, which may partly explain its popularity. However, Hawking has not received the Nobel Prize for his black hole theory. The Swedish skepticism towards relativity is still strong; not even Einstein got the Prize for work on relativity theory, and nobody else either. But Hawking's book is selling. Black holes evidently have a lot of attraction, he he!

Phil: Attraction? You bet. That initial state must have been a black hole, in the presence of such an enormous concentration of mass. An exploding black hole?

Mat: Hard to get a grip on this, I must admit. Today, just about everbody seems to pay worship to Big Bang. But the physicist Fred Hoyle, who coined the term in a BBC radio program in 1950, did not. He proposed an alternative *steady state model* without Big Bang, which was supported by our Swedish national hero Hannes Alfvén, who got the Nobel Prize in Physics in 1970 for his work on plasma physics, a plasma being a very hot soup of charged particles like the initial soup of Big Bang. Alfvén did not believe in Big Bang, so why should we?

Phil: Steady state without out any beginning of time, is fine for me. Big Bang with a beginning of time may suit creationists. But what is then the evidence of Big Bang?

Mat: The observation that (most) far away galaxies are *red-shifted* indicating (by an analogy for light of the Doppler effect for sound) that (most) galaxies are speeding away from us with a speed increasing with the distance. If you extrapolate backward in time, or equivalently imagine that all velocities are reversed, then galaxies would seem to get closer. Why not then assume that all of them have come out of a common singularity of the size of a needles head? This is Big Bang theory by extrapolation backward in time, or reversing time if you prefer.

Phil: OK, so Big Bang comes out from a thought experiment reversing time, or equivalently reversing all velocities and seeing what state that leads to. Like retracing your steps when you have got lost in the woods. But isn't that a pretty unstable process? And what about all that *dark matter* and *dark energy* needed to keep the model from collapsing? How can you believe in Big Bang if you have no idea of what dark matter and energy is?

Mat: Good question. Let's test another approach: We have noted that turbulence develops in potential flow, seemingly out of nothing, from a combination of instability and finite precision. Isn't it conceivable that similarly matter (and antimatter) could be created out of nothing from an instability of a gravitational potential? In fact, this was suggested by Alfvén. A gravitational potential (or gravitational field) is unstable, because the more mass concentrates, the more more local attraction there is and thus the more concentration. Mass concentration thus has a tendency to increase, and thus we expect the Universe to be very lumpy, and this is what we see.

Phil: So you suggest that our complex World has resulted from an unstable simple gravitational potential, in the same way as a complex turbulent flow comes from simple potential flow. A neat idea!

Mat: That's right!

Phil: However, evidently Hoyle lost in the big battle of scientific survival of the fittest. Since he was a man of principles, he left his position at Cambridge for a free life as a dissident. Hoyle should have received the Nobel Prize in 1983 together with Fowler for their joint discovery of the nucleo-synthesis of Carbon-12 from two Helium-4 nuclei colliding to form one Beryllium-8 which together with another Helium-4 makes one Carbon-12 nucleus. As a compensation he receieved the prestigous (Swedish) *Crafoord Prize* in 1997.

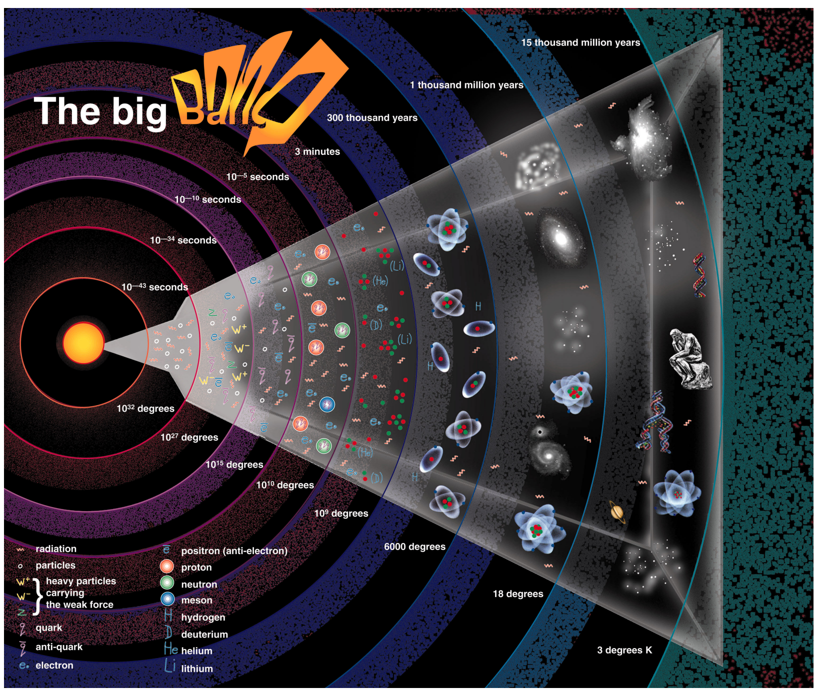


Figure 11.2: Reversing time back to 10^{-41} seconds after Big Bang from the present time of 15 billion years $\approx 10^{18}$ seconds.

Chapter 12

Sawtooth Dynamics

> Death is always and under all circumstances a tragedy, for if it is not, then it means that life itself has become one. (Theodore Roosevelt (1858 - 1919).

> Life presents itself to us as evolution in time and complexity in space. Regarded in time, it is the continuous evolution of a being ever growing older; it never goes backwards and never repeats anything. Considered in space, it exhibits certain coexisting elements so closely interdependent, so exclusively made for one another, that not one of them could, at the same time, belong to two different organisms: each living being is a closed system of phenomena, incapable of interfering with other systems. A continual change of aspect, the irreversibility of the order of phenomena, the perfect individuality of a perfectly self-contained series: such, then, are the outward characteristics–whether real or apparent is of little moment–which distinguish the living from the merely mechanical. (Henri Bergson in [1])

Phil: We have seen that the sawtooth picture in Fig. 6.1 captures an important aspect of Principe Perfeito: Motion one way is possible, the other way impossibe.

Mat: Yes, the Arrow expresses *sawtooth dynamics* of slow precise growth followed by quick imprecise decay, or slow precise build-up of tension followed by quick (brutal) release of tension. You find this dynamics in

- tragedy,
- telling a funny story,
- the sexual act,
- music,
- tennis serve,
- military action,
- winning the Nobel Prize,

or more generally in all forms of life-death processes. Note that the reversed dynamics corresponding to quick build-up is difficult to realize, and slow precise release does not make much sense. To prepare for the laugh of a funny story, or the final resolution of a crime in a detective story, or the final death of everybody in a tragedy, a slow precise build-up of tension is necessary. And then a quick (brutal) release can follow. This is one aspect of the Arrow according to Principe Perfeito.

Phil: I know: To tell a funny story backwards, is not funny! To start your life in a coffin under ground is not funny either!

Mat: The word *tragedy* is a contraction of the Greek words *tragos* (goat) and *aedein* (to sing) and refers to the tragic song proverbially sung by a goat before being led to the altar for sacrifice in ancient Greek religious ceremony. In tragedy the hero is similarly led to catastrophe by inevitable logic, just as we all are led to inevitable death by the logic of life. Tragedy thus can be seen as an aspect of Principe Perfeito. The dynamics of a tragedy is the inevitable march towards death of the individual, without possibility of repetition: When the hero is dead, he is dead. The individuality of the the hero is essential, which reflects the individuality of each human life: Everybody is ultimately alone on the road to precipice.

Phil: According to the French philosopher Henri Bergson, *comedy* arises from breaking the spell of tragedy leading the individual towards inevitable death, by allowing (i) change of identity and (ii) repetition. In a comedy, persons change identity (e.g. by changing clothes) and things get repeated (words or scences), and both (i) and (ii) seem funny and bring laughter. An appearently dead person suddenly waking up in the coffin, is irresistably funny. Time reversal is funny, because it violates cruel laws of Nature. People don't return from Hades. One way of coping with the tragedy of life, thus seem to be to pretend for a while that the laws of tragedy can be broken, and handle the contradiction of knowing that this impossible, by laughing.

Figure 12.1: Masks of comedy and tragedy.

Mat: The fundamental process of creating-releasing tension has been studied by Rudolph Arnheim (1904-) in art, film and perceptual psychology. Arnheim considers release of tension as a process towards order and equilibrium, which is in direct opposition to Boltzmann's conception of entropy as disorder with increasing entropy characterizing a process towards equilibrium. I guess we will have to return to Boltzmann, to settle this issue: Equilibrium as order or disorder? **Phil:** Thus Arnheim considers build-up of tension as a process away from equilibrium, while such a process is impossible (very improbable) for Boltzmann. I think Arnheim is closer to some truth: A life steadily moving towards equilibrium, would be no life.

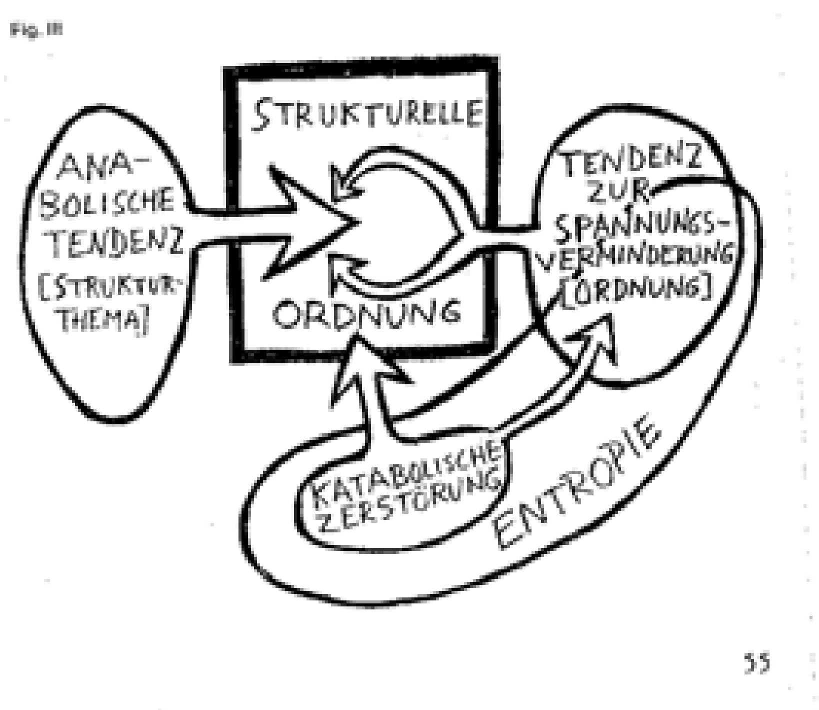


Figure 12.2: Order as tension release according to Arnheim.

Chapter 13

Free Will of a Clockwork Orange

> God is not willing to do everything, and thus take away our free will and that share of glory which belongs to us. (Machiavelli)
>
> There is no such thing as free will. The mind is induced to wish this or that by some cause and that cause is determined by another cause, and so on back to infinity. (Spinoza)
>
> Nothing is more difficult, and therefore more precious, than to be able to decide. (Napoleon Bonaparte)
>
> Freedom is nothing else but a chance to be better. (Camus)

Phil: Does Principe Perfeito relate to the old question if there can be free will in a mechanistic deterministic world?

Mat: Yes, Principe Perfeito allows expressions of free will to arise from a *combination of complexity and finite precision.* Complex systems, like a human being or any living being for that matter, are partly unpredictable because very small causes can have large effects. It may be that you were predestined to become a journalist, but your obituaries could not be predicted. And if we hadn't happen to meet at this cafe, our enlightening discussion would not have taken place. We have both lived lives of finite precision and very small changes could have made our lives very different. A single step or a single idea could have changed everything, to the worse or the better. In a sense it is a true miracle that we are still alive and are able to reflect about the nature of time.

Phil: Yes, it is a miracle. So Principe Perfeito is consistent with the idea of a free will in a mechanistic world? That is interesting. But maybe our undeniable feeling of having a free will, partly is an illusion? Evidently we (sometimes) make a decision unconsciously *before* we become aware of the fact that we have made a decision. But we cover up by pretending that we act rationally and take decisions based on logical arguments. It seems that we are skillfull illusionists able to fool both ourselves and others. We want to be seen as being rational, with a free will, even if we are not. What is upbringing, but a control of free will?

Mat: That reminds me about Stanley Kubrics film *A Clockwork Orange*, based on the novel by Anthony Burgess. The title refers to the alleged old Cockney expression "as queer as a clockwork orange" describing a mechanically responsive (clockwork) human, with "orang" being Malay for "person". Man as a clock?

Phil: Yes, that is the story about the adventures of the young man Alex who can only perform good or evil as "a clockwork orange", meaning that he has the appearance of an organism lovely with color and juice, but is in fact only a clockwork toy to be wound up by God or the Devil or the almighty state, thus without a free will of his own. Alex couldn't resist pretty girls and a bit of the old ultra-violence, was put into jail, was re-conditioned in an experimental aversion therapy developed by the government in an effort to solve society's crime problem...and came out as a different young man, or was he?

Mat: Yes, you can program a human being to a certain extent, but fortunately, not completely. It seems to me that a human being is more than a clockwork orange, the theme of many films e.g. *American Beauty*.

Figure 13.1: Alex in A Clockwork Orange expressing his free will?

Chapter 14

Emergence

> Emergence means complex organizational structure growing out of simple rules. Emergence means stable inevitability in the way certain things are. Emergence means unpredictability, in the sense of small events (possibly) causing great and qualitative changes in larger ones. (Robert Laughlin in *A Different Universe*, 2005)

Phil: What about the new code word of *emergence* or *emergent phenomena*, or more generally *holism*? Is *reductionism* out of fashion?

Mat: Yes and no. In the basics laws of both classical and quantum mechanics, time is reversible without an Arrow, and the enigma is how irreversibility can arise in a macroscopic system governed by reversible microscopical laws. A reductionist cannot explain this, because the system aspect is not taken into account. Physicists in general are extreme reductionists and concentrate on elementary particles and their properties. Turbulence is the key example of an emergent phenomenon always appearing in a fluid of sufficiently large volume depending on the viscosity of the fluid. A reductionist cannot explain turbulence because only elementary small volumes are considered. Of course you cannot understand a soccer game by looking only at an individual player. But turbulent phenomena exist as well as soccer games, and people are asking for understanding.

Phil: What are physicists doing then? They are supposed to explain the World. Or are they still stubborn reductionists?

Mat: Most are, but there are a few Nobel Laureates who, after receiving the

Prize, have started looking at complexity and emergent phenomena: *Gell-Mann* at his Santa Fe Institute in California and *Laughlin*.

Phil: Emergence connects to Leibniz idea that we live in a *Best Possible World*, which is a World with maximal complexity governed by simplest possible laws. Is there also a connection to Principe Perfeito?

Mat: Yes, of course. Let me explain: Principe Perfeito explains irreversibility as an effect of finite precision computation in a system with complex dynamics with strong point-wise sensitivity to perturbations. The effect of the finite precision is that you have to throw away information as you go along, information which is irrecoverable. We all now that it is necessary to throw old newspapers and erase data from your computers hard disk, to avoid getting bogged down by too many petty details. Living requires erasing and that makes our lives irreversible, according to Principe Perfeito.

Phil: So irreversibility is an emergent phenomenon, which comes out of complexity. Seems reasonable. But don't you find this in physics books?

Mat: Not really, only in the form of the microscopic games of roulette of statistical mechanics, which very few understand, if any. But it is easy to understand that you have to destroy information to go on living. In particular, you have to forget your failures and the in-justices you inevitably meet, to go on living.

Phil: What is the role of the number 0 on a roulette table?

Mat: Good question. If that number comes up, then the bank wins. It is a like a small interest rate making it possible for the bank to take the risk of playing, or giving a you mortgage on your real estate in the US. A basic feature of capitalism!

Figure 14.1: Emergence in flocks of birds.

Chapter 15

Finite Precision vs Statistics

> The death of one man is a tragedy. The death of millions is a statistics. (Stalin to Churchill at Potsdam, 1945)
>
> Like dreams, statistics are a form of wish fulfillment. (Baudrillard)
>
> Statistics: the mathematical theory of ignorance. (Morris Kline)
>
> What we observe as material bodies and forces are nothing but shapes and variations in the structure of space. Particles are just schaumkommen (appearances). ... Let me say at the outset, that in this discourse, I am opposing not a few special statements of quantum physics held today (1950s), I am opposing as it were the whole of it, I am opposing its basic views that have been shaped 25 years ago, when Max Born put forward his probability interpretation, which was accepted by almost everybody. — I don't like it, and I'm sorry I ever had anything to do with it. (Schrödinger about Quantum Mechanics)

Phil: What is the difference between finite precision and statistics? Doesn't statistics involve some form of finite precision? That you cannot be sure if head or tail will come up when tossing a coin?

Mat: Yes, there is a connection: The reason you cannot determine head or tail beforehand is that a very small variation in the way you throw the coin, will change the outcome. With infinite precision you could decide to get only heads, but that is increasingly difficult to realize in practice, depending on the length of the throw.

Phil: But tossing a coin very many times, you would expect to get roughly as many heads as tails. You would then say that the *probability* of head is 0.5 and the same for tail.

Figure 15.1: The famous statistician Persi Diaconis tossing a coin.

Mat: You now bring up the basic concept of statistics of an *ensemble*. By throwing a coin many times you create an ensemble of *outcomes* (head or tail), and the fraction of heads would approach 0.5 as the number of throws becomes large, if the coin is not biased in some way. The *ensemble mean value* of head would be close to 0.5.

Phil: OK, so statistics is based on ensemble mean values requiring a large number of repetitions of the same event. But suppose you toss the coin only once. What can then be said? Evidently statistics based on emsembles cannot be used.

Mat: Good point. This connects directly to the finite precision of Principe Perfeito. Throwing the coin only once you can argue like this: Imagine the coin during its flight from your hand until landing: You see it rotating many times. During each full revolution the angle of rotation changes from 0 to 360 degrees, and half of the time is between 0 and 180 (identified by heads up) and half of the time between 180 and 360 (tails up). The mean value of the angle over many rotations is 180, which is on the border between the interval $[0, 180]$ for heads up and the interval $[180, 360]$ for tails up, which you can interprete as the coin being in a vertical position, that is as much head as tail.

Phil: Oh, so you take a mean value in time instead of over an ensemble?

Mat: Exactly! That is the beauty. The advantage is that it is enough to throw the coin once and follow its motion, instead of throwing it many times without following the motion.

Phil: Is there a connection between ensemble mean value and time mean value?

Mat: Yes, in the statistics literature you find different versions of an *ergodic theorem* stating that ensemble and time mean values are equal. But this is very tricky to show and requires assumptions which are difficult to verify.

Phil: Do you mean that Principe Perfeito finite precision corresponds to throwing the coin once and following its motion, and statistical mechanics to throwing it many times and not following the motion?

Mat: You are right! This is the difference in a nutshell while the ergodic theorem indicates a similarity. The concept of ensemble is natural to use in a statistical analysis of a population of individuals, but not so for a single individual. In particular, irreversibility of a certain specific process, like smashing an expensive Chinese vase, cannot be explained by statistics of ensembles of processes. Smashing large ensembles of expensive Chinese vases would not be an option!!

Phil: So the advantage of finite precision over statistics is that you don't need to deal with ensembles and ergodicity. I appreciate this simplification!

Mat: The great advantage is that you don't have to go into statistical mechanics, which is understood by very few. The basic idea of statistical mechanics is that since there are so many atoms and molecules, it is a good idea to assume that they play games of roulette when they interact. This would be similar to basing sociology on the idea that human beings, since they are so many, play roulette when they interact.

Phil: That idea was tested by Luke Reinhardt in the his cult novel *The Dice Man*, with catstrophical consequences. Making decisions in life by throwing a dice, is not recommendable for an individual, and if everybody did so, society would break down. So how can we expect atoms and molecules to do that, just because they are so many?

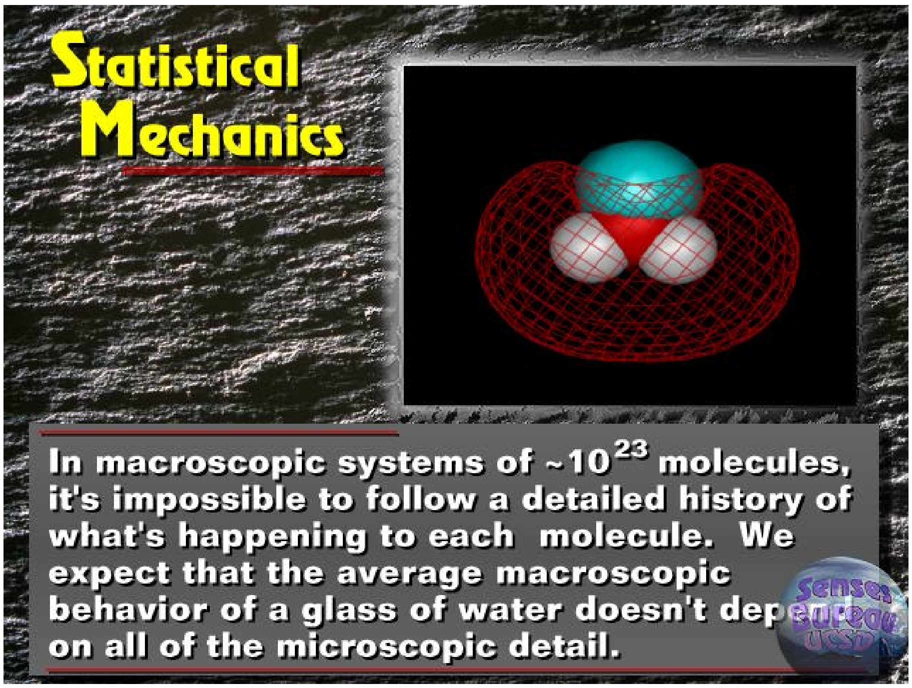


Figure 15.2: Statistical mechanics of water molecules

Chapter 16

Science vs Humanities

> Science and art have that in common that everyday things seem to them new and attractive. (Nietszche)
>
> The function of Art is to disturb. Science reassures. (Braque)
>
> Free nations are peaceful nations. Free nations don't develop weapons of mass destruction. (George W. Bush)
>
> Religions that teach brotherly love have been used as an excuse for persecution, and our profoundest scientific insight is made into a means of mass destruction. (Bertrand Russell)
>
> Nobel was a genuine friend of peace. He even went so far as to believe that he had invented a tool of destruction, dynamite, which would make war so senseless that it would become impossible. He was wrong. (Alva Myrdal)

Mat: There is a deep gap separating *science* and *humanities*, which is harmful to progress in both disciplines according to the influential pragmatic philosopher Richard Rorty (1931–), and the dividing principle is *mathematics*. Science uses the language of mathematics, and humanities uses common languages. In both cases the language is used to create models of real or imagined phenomena.

Phil: Yes, the gap is deep, and it is widening.

Mat: The mathematics of science is (primarily) *Calculus*, which is the mathematics of *derivatives* and *integrals* founded by Leibniz and Newton in the second half of the 17th century and perfected during the 18th and 19th century by many great mathematicians. The use of mathematics excludes people from understanding science, but it also excludes most scientists; only an expert scientist can master the mathematical language of a specific discipline and claim understanding. The blame for the separation thus can be put on difficult mathematics.

Phil: Is all mathematics difficult?

Mat: Of course not. Everybody understands that $1 + 1 = 2$ and so there is mathematics which can be understood by many. The great mathematician David Hilbert (1862-1943) emphasized in his address in 1900 to the 2nd International Congress of Mathematicians presenting his famous 23 Centennial Problems, with reference to "an old French mathematician": *A mathematical theory is not to be considered complete until you have made it so clear that you can explain it to the first man whom you meet on the street.*

Phil: Most scientists read novels, go to the theatre and listen to music, while most people (including also the majority of scientists) are denied access to the mathematics of statistical mechanics, relativity theory and quantum mechanics, the pillars of modern physics. Can the gap be bridged?

Mat: Let us take the Arrow as a test case. Let us see if we can use the language of mathematics and common language in parallel. Mathematical language is formalized, uses very special symbols, is sometimes very powerful, but like a Formula One racing car is difficult to handle. And without the computational power of a computer it may be as useful as a car without engine. A poem in one language can (more or less successfully) be translated to another language. Likewise, a mathematical model of a physical phenomenon can (more or less) be translated into common language and thereby be better understood.

Phil: I fear we will meet the mathematics of *thermodynamics*, which I am told is the basic area of physics concerned with the transformation between *kinetic energy* and *heat energy*.

Mat: You are not alone: Thermodynamics is viewed with fear by the majority of scientists. The group of experts claiming they understand is very small and approaching extinction. The main reason is the 2nd Law of Thermodynamics. You can make your own experiment on this issue by asking your favorite physics teacher (who may be a Nobel Laureate) to explain the 2nd

Law and carefully noticing the reaction! In any case, to understand thermodynamics, it is necessary to develop an understanding of the 2nd Law, but this is a pretty hopeless task, unless you already belong to the group of believers. This is the same Moment 22 you meet in religion with only believers being able to believe. Hilbert expressed the syndrome as: *Physics is becoming too difficult for the physicists.*

Mat: But Principe Perfeito offers an explanation of a (certain form of) the 2nd Law. What you could say to any man in street is the following: Thermodynamics is the study of transformations between heat energy and kinetic energy. The 1st Law states that the total energy, the sum of heat energy and kinetic energy, remains constant (in a closed system). Thus you can change from one kind of energy to another, but the sum remains constant, OK?

Phil: Yes, the 1st Law is easy to grasp. But the 2nd?

Mat: The 2nd law states that in any real process a significant amount of large scale kinetic energy is irreversibly transformed into small scale kinetic energy in the form of heat energy, by turbulence. Further, heat energy can be transformed into kinetic energy by expansion, e.g by letting steam in a steam engine expand and move a piston, while work by compression adds heat energy. To form a cycle, an engine has to be cooled and thereby loose heat to the exterior. We all know this too well: A car engine without cooling over-heats, and cooling means that you loose heat energy to the surrounding, which you cannot get back and which is not useful for the operation of the engine. OK?

Phil: Is this the whole story, without any mathematics, and any mentioning of entropy and statistics: Whatever you do, some of your effort goes into heat which has to be lost in cooling. But where does finite precision come in?

Mat: Good question. This is because *heat energy is small scale kinetic energy* and to reverse it back to large scale kinetic energy, you would need an infinite precision to put all the little pieces together, to coordinate the small scale kinetic energy to large scale kinetic energy. Heat energy created from large scale kinetic energy cannot all be recovered, because the required high-precision coordination cannot be realized within reasonable time.

Phil: I get the point: Smashing a vase into little pieces does not require precision and can be done very quickly, but putting the pieces back together requires extremely high precision and long time. I know this from bitter experience! Marriages require some form of smashing of china to continue. So does life and this makes life irreversible.

Mat: You've got it. Here are couple of one-liners expressing (different aspects of) Prinicipe Perfeito:

- *Time is the price you pay to live.*
- *Walking is the process of avoiding falling on your nose.*
- *Only the dead have no ambitions.*
- *Fall comes before Spring. Spring comes before Fall.*
- *Perfection kills.*
- *Difference is life, indifference is death.*

Phil: Yes, I know that writing the perfect obituary is impossible, probably because life is so complex. Maybe it is possible to write a perfect poem. Is pure mathematics is like poetry and computational mathematics like real life?

Mat: Maybe. Yes, there is a strong similarity between poetry and mathematics: It seems that the symbols, the words and the formulas, once put down on a piece of paper, start to live a life of their own, which gives the surprising result that more seems to come out than is put in. Mystical, but wonderful.

Phil: That reminds me about the old Shakers hymn describing timelessness of ecstatic dance:

Figure 16.1: Equipment for exploration of reality and fiction.

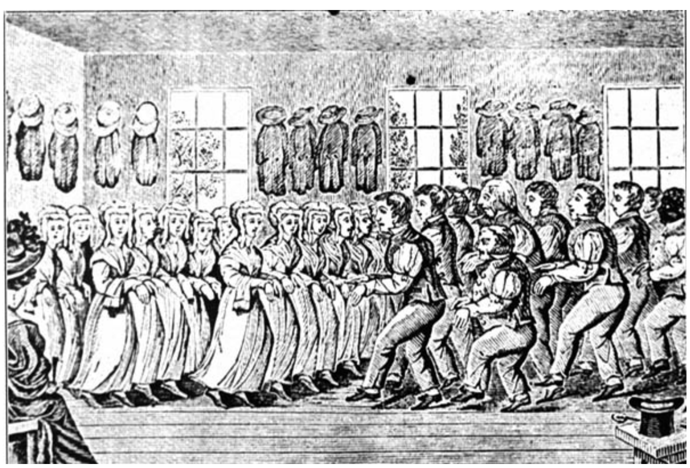


Figure 16.2: Ecstatic dancing giving shakers a feeling of timelessness: Come life, Shaker life, Come life eternal; Shake, shake out of me, All that is carnal.

Chapter 17

Postmodern Hyperreality

> The very definition of the real becomes: that of which it is possible to give an equivalent reproduction. The real is not only what can be reproduced, but that which is always already reproduced. The hyper real. (Baudrillard)

> God created man in His own image, in the image of God He created him; male and female He created them. (The Bible)

Mat: Let's take a step back and try to identify where we stand: We know that the *industrial society* emanating from the scientific revolution and the Enlightenment of the 17th and 18th century, developed in the late 19th century into the *modern society*, which has now transformed into the *postmodern information society*. The evolution from industrial to modern society is paralleled in mathematics and physics by a the development from Newtonian mechanics to quantum mechanics, and the step into postmodernity by the development of *digital computation* by computers. This couples social science to technology, and humanities to science, and thus bridges are needed, right?

Phil: Sure, and this is what postmodern French philosophers seek to build. Baudrillard (1929-2007) and Deleuze (1925-1995) describe *hyperreality* as *simulations of a non-existing reality* in a forms of *third order simulation*, with first and second order simulation representing various approximations of an existing reality. Disneyland is an example of hyperreality presenting an image of an American society which no longer exists (never existed). The objectively existing real world of the modern society, is in the postmodern world replaced by a *simulacra* of hyperreality, which according to Baudrillard masks the non-existence of a real reality and according to Deleuze is the only reality there is.

Mat: The Bible says that God created Man as his own image.

Phil: If God does not exist, would then our existence represent a form of hyperreality?

Mat: Guess so. It could be that hyperreality is more real than reality. What is intriguing is that Principe Perfeito expresses a phenomenon of *hyperreality of physics*: If exact solutions to the equations of physics had existed, they would have been reversible. But exact solutions do not exist, and the existing solutions are only approximate because of finite precision computation and therefore irreversible, because they involve an irrecoverable cost for being non-exact. In other words:

- *Hyperreality is irreversible simulation of a non-existing (reversible) reality.*

The famous computer scientist Dijkstra expresses a similiar idea:

- *Originally I viewed it as the function of the abstract machine to provide a truthful picture of the physical reality. Later, however, I learned to consider the abstract machine as the* true *one, because that is the only one we can* think*; it is the physical machine's purpose to supply a* working model*, a (hopefully) sufficiently accurate physical simulation of the true, abstract machine.*

Phil: Are you suggesting that mathematicians and physicists, usually skeptical to both French postmodern philosophy and digital simulation, will have to accept the idea that their wonderful equations of classical and quantum mechanics, do not have exact solutions. That the World is imperfect? The result of some form of finite precision computation?

Mat: Exactly! But this is what they have already done by introducing statistical mechanics with atoms playing games of roulette: All physicists are convinced that the positions and velocities of elementary particles are uncertain, according to *Heisenberg's Uncertainty Principle*, and if so how can the World be perfect with exact solutions? If atoms are jumping around as if playing roulette?

Figure 17.1: Hyperreality (masking non-existing reality?) according to Magritte.

Phil: But how can you know that exact solutions cannot exist?

Mat: Good question: To prove that the basic equations of fluid mechanics, the *Euler* and *Navier-Stokes equations*, have exact solutions is a million dollar *Millennium Prize Problem* of the *Clay Mathematics Institute*, but nobody is claiming to have a solution. Exact solutions to the Euler equations cannot exist, because if they had existed the World would have been reversible, but it is irreversible.

Phil: But isn't this very strange: Basic equations of fluid mechanics without solutions? Hyperreal mechanics?

Mat: Yes, it is remarkable, but the situation is the same in the quantum mechanics of modern physics: *Schrödinger's wave equation* cannot be solved exactly, because if it could, then the World would be reversible and the famous *Scrödinger's cat* would stay both alive and dead, in either direction of time, but nobody has seen a cat like that.

Phil: Yes, I have heard about that cat, but never seen anything like that. Can we see the phenomenon of non-existence of an exact solution in a context where it is easier to understand? Is there a parallel with the laws of our society which are not prefectly followed by everybody, not because some people simply are criminal but because it is simply impossible to follow all laws? But even so the laws have a very important role. A lawless society is no society.

Mat: Yes, the parking of cars in Stockholm over night is a problem without exact solution, since there are many more cars than parking places. People have to give up searching for a free place (usually around midnight) and break the law by parking illegally, in order to get some sleep. Just because you can write down a law, an equation, a solution does not come for free. Maybe there is no solution, because the law is asking for too much! To write down a recepee for a new cake is one thing, to actually bake that new cake following the recepee and see that it works, is another thing, right? Maybe the cake will not rise because you have put too much into the cake? This is exactly the situation in mechanics: We can write down the equations using Calculus, but there is no guarantee a priori that they can be solved exactly, and there are many indications that the Euler equations cannot. But computational approximate solutions do exist, because they can be computed, which can can be viewed as simulations of a non-existing exact solutions, in other words as hyperreality.

Phil: So Baudrillard and Deleuze are right then claiming that the existing reality is a simulation of a non-existing reality?

Mat: Seems so. Maybe it is like saying that Man created God as his own (perfect) image, instead of the other way around? Maybe this boils down to a constructive hyper-real synthesis of idealism and materialism? And maybe time is an aspect of hyper-reality?

Phil: Yes, I believe along with McTaggart that time is unreal, hyperreal. A time-line is fictional, something we construct to give the illusion of control and rationality. Evidently our egos tend to cover up irrational decisions as the results of careful logic and planning. We want to give the impression of being rational and sane. A calender is then useful, but probably models a non-existing time line, and thus is hyperreal.

Figure 17.2: The first Barbie doll. Patent definition: A small-scale anatomically improbable molded plastic figure of a human being used especially as a child's plaything. Collectable doll. Inventor: Ruth Handler (1916-2002). American, of Polish immigrant parents.

Figure 17.3: Hyperreal party in Second Life

Chapter 18

Hyperreality of Time

> Scientific American once ran a competition offering several thousand dollars for the best explanation of Einstein's general theory of relativity in three thousand words. Einstein ruefully remarked: I am the only one in my entire circle of friends who is not entering. I don't believe I could do it.
>
> I still can't see how Einstein thought about general relativity. (Feynman)
>
> Many people probably felt relieved when told that the true nature of the world could not be understood except by Einstein and a few other geniuses who were able to think in four dimensions. They had tried to understand science, but now it was evident that science was something to *believe in*, not something which should be *understood* (Hannes Alfvén).

Phil: So can we agree that our conception of time represents hyperreality?

Mat: This depends on what conception you mean. The concept of *time line* is an important part of our culture, which we learn in school. This is the spatial representation of time you find in a callender with the different days of a year nicely ordered in succession, or the line of succession of the Kingdom of Sweden with the periods of the different regents in succession, which you find at the end of your history book. When you arrange your photos, you may seek to order them in succession in the album. So the concept of a time line as an ordered sequence of images or time periods is central to human culture.

Phil: But isn't this a a construction? Can you find time lines in Nature?

Mat: Well, you don't find callenders and photo albums in the woods, but of course in cross-cuts of an old oak or sediments, you can find a nicely ordered spatial representation of a time line of years or time periods. But it would not be reasonable to identify the whole Jurassic period with all its dinosaurs with a layer in a sediment. You may also ask what use Nature has of these traces? What time lines do animals and flowers use?

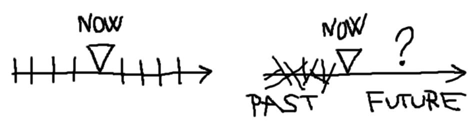


Figure 18.1: Unreal and real time-line.

Phil: Good question. I have the feeling that a lot confusion can come from mixing time with space. Or to confuse a trace with what caused the trace. Or to mix up a photo of your weddding with the wedding itself.

Mat: In relativity theory space and time are fused into *space-time* where time is viewed as a fourth space dimension. According to relativity theory we live in curved four-dimensional space-time! This is what physicists of today tell us, and what we are supposed to swallow! But the problem is that nobody can understand what the meaning is, not even Nobel Laureates in Physics including Einstein. This is easy to check by asking any physicist if he/she can think in four dimensions and solve *Einstein's equations*, the basis of general relativity. I have tried it many times always with negative results.

Phil: Of course, the idea of time travel comes from viewing time like a space dimension. Because you can travel with your eyes along the lines of your calender, you may get the impression that actually you could displace yourself out of the present *now* to some other time in the past or the future. This is a popular idea in science-fiction supposed supported by relativity theory. The travelling twins aging a different rates, and all that stuff.

Mat: Yes, this kind of confusion is propagated by physicists. I have just read *The Fabric of Reality* by the physicist *David Deutsch*, winner of the Paul Dirac Medal and Prize. It is gold mine of strange statements:

- *There is no such thing as flow of time. Yet the idea of it is pure common-sense. We take it so much for granted that it is assumed in the very structure of our language.*
- *Space-time does not change, therefore one cannot, within spacetime physics, conceive of causes, effects, the openness of the future or free will. In reality we make no choices.*
- *Relative to space-time, nothing ever moves.*
- *The reason why the common-sense theory of time is inherently mysterious, is that it is inherently nonsensical.*

The message is that we should give up common-sense and believe in four-dimensional space-time, also referred to as *block-time* with all instants stacked together into a solid block of space-time. Your life is then represented by a *world-line* in block time:

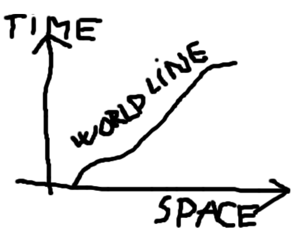


Figure 18.2: Phil's world-line.

Phil: OK, I see a space axis and a time axis spanning a plane of block-time and it is clear that in this picture time is given a spatial representation: The time axis looks just like the space axis. My world-line seems to be "frozen" into a plane of block-time, and I see no Arrow on my world-line. But language makes a clear distinction between space and time. If you confuse "here" with "now", then your life will be a mess. Likewise if you confuse "yesterday" with "tomorrow" on a world-line without Arrow.

Mat: Yes, if someone asks you to give up common-sense and rationality, you may expect that there is a hidden agenda. Of course common-sense could be wrong and then should be replaced by some better common-sense, but to give up common-sense completely for some form of abstract mysticism, isn't it against the principles of the Enlightenment? Can really the structure of language be so "wrong"? What does the common-sense of a practical man like Robinson Crusoe say?

Chapter 19

Robinson Crusoe

> Your memory is a monster; you forget - it doesn't. It simply files things away. It keeps things for you, or hides things from you - and summons them to your recall with a will of its own. You think you have a memory; but it has you! (John Irving)

Mat: Robinson Crusoe expresses his struggle to record time as follows:

Figure 19.1: Robinson Crusoe making a Calendar.

- *Do you wonder how I have kept an account of the time? I will tell you. A few days after the ship wreck it came into my mind that I should lose track of the days and the seasons. For I had neither almanac nor notebook. It would be hard always to remember the days of the week and I might even f orget when it was Sunday....So I set up a large post by my door. At the top of this post I cut in large letters these words:*

  I CAME ON SHORE HERE SEPTEMBER 30, 1659.

- *Every morning I cut a little notch on the side of the post under these words. Every seventh notch was twice as long as the rest, and this showed me that the day was Sunday. Every thirtieth notch was longer still and broader. This showed me that a full month had gone by. It was thus I made my calendar. One morning I found, on counting up, that there were three hundred and sixty-five notches on the post. I knew, therefore, that it was just one year since my landing. I kept this day as a solemn fast. Having now been on the island a whole year, I had learned that the seasons there were not the same as in England. They were not to be spoken of as spring, summer, autumn, and winter. They were rather to be called the wet season and the dry season. Indeed, there were two wet seasons and two dry seasons, in the year.*

Phil: I think this gives a pretty clear image of how you can count the flow of time as the days go by following the motion of the Sun until sunset and through the night until the new day is born... You also understand that a process like your life, or vacation period on a lonely island like Robinson, has a beginning and an end. You have also learned that you should not pose the question where you where before your conception, because it is childish. Likewise, it is believed that universal time was started at the Big Bang, and the question what happened before Big Bang cannot be posed.

Mat: I recall that we agreed to give (the flow of) time an operational definition as what you measure with a clock, which could be the Sun, a *Sun dial* or the beating of your heart. With this definition time is one-dimensional and ordered, because the readings of a clock are.

Mat: Yes, this is the old idea of Aristotle of time is an aspect of change which you can measure by numbers. This means that time is one-dimensional and can be represented as a *line of numbers*. We can order the numbers in magnitude like the *natural numbers* $0, 1, 2, ...$, starting with 0 without end,

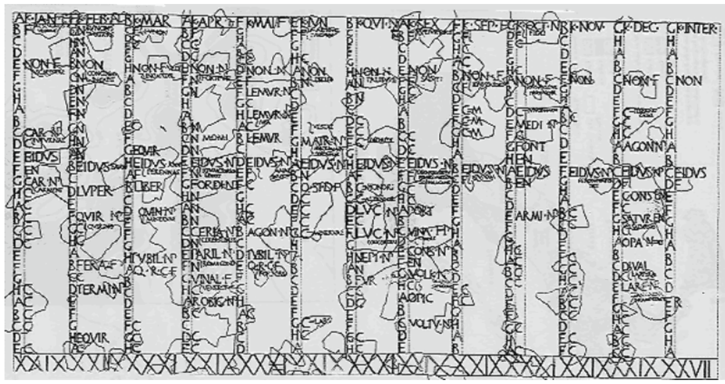


Figure 19.2: Spatial representation of time in a Roman calendar.

or like the *integers* $..., -2, -1, 0, 1, 2, ...$ without beginning and end. We can fill in with the *rational numbers* as quotients of integers, or the *real numbers* as all (possibly infinite) decimal expansions. We can then measure time by anything which changes in position or configuration, like the height of the Sun for the time of the day, or the maximal height of the Sun over a day for the time of the year, length of your finger nails or hair if you let them grow without cutting, or the color of your hair as the years go by. Or you can simply watch the arms of your analog watch change position, or the change of the digits on your digital clock. You then understand that a digital clock shows granular time, where the smallest time unit may be a second, 1/10 or 1/100 of a second. For an analog clock there is theoretically no absolutely smallest time unit, but in practice there is, because you will not be able to distinguish two times if they are sufficiently close. This is a well-known difficulty of deciding who is the winner in a 100 meter sprint race, if the race is close.

Phil What remains is then the question if time has a direction or if there is an Arrow of Time. This is the most interesting and intriguing question about time, and accordingly I suggest we devote our main time to this question. Let us meet again *next week* at the *same time*, if you understand what I mean?

Chapter 20

Tensed vs Tenseless Time

> Existence really is an imperfect tense that never becomes a present.
> (Friedrich Nietzsche)
>
> The line it is drawn
> The curse it is cast
> The slow one now
> Will later be fast
> As the present now
> Will later be past
> The order is
> Rapidly fadin
> And the first one now
> Will later be last
> For the times they are a-changin. (Bob Dylan)

Phil: Recall that the basic concepts of the McTaggart's A-theory are past-present-future, and those of the B-theory are earlier-later.

Mat: Yes, I recall that. What is really the difference?

Phil: The A-theorists accept the idea of becoming or fleeting present, while the B-theorists deny the existence of any such objective passage of time and only consider an increasing series of clock times as real. You refer to the A-theory as a *tensed* view of time, as opposed to the *tenseless* view of the B-theorists. Becoming is tensed while being is tenseless.

Mat: So the use of the word "now" is tensed, while "at 3 pm" is tenseless?

Phil: Exactly. The B-theorists consider past-present-past to be a subjective illusion, which we resort to in language and thought, but is just a shadow of *token-reflexive* temporal indicators, such as "now", "yesterday" and "tomorrow", or more generally "me", "you" and "here". A token of a word is a specific instance of its use, and an expression is said to be token-reflexive if the context of its use plays a key role in its interpretation. Thus a given token of "here" refers to the place where it is expressed.

Mat: Can you translate tensed expressions into tenseless expressions?

Phil: Probably not. As little as you can speak without using words like "I" and "you". The B-theorist like Spinoza would like to view the world *sub specie aeterenitatis*, from the perspective of eternity. This would be like saying that I should not care specially about *my* children, rather than someone else's, unless I believed there was something objectively special about me (or my children).

Mat: Clearly the use of "now" is required for synchronization. Even without clocks that works fine. Using only tense-less expressions would seem to require access to a common absolute time, which has been out of reach so far. With GPS now available to everybody, the utopia of absolute time is becoming a reality, but it remains to be seen if this will make expressions like "here" and "now" obsolete...

Mat: What about if I say "one plus one is two". Do I then use "is" in a tense-less sense?

Phil: In a timeless or eternal sense: one plus one is *always* two.

Mat: To me "tensed" means to "have tension", like the string of a bow. To have tension, to be tensed, means that you are ready for action, ready for change. The present is tensed, because the present present is ready to change to the next present, because it has tension which seeks to be released. A tense-less string has no tension and no potential to change. But what do we mean by *eternity*? Any clue?

Phil: Sure. Eternity often simply means existing for limitless amount of time, while philosophers have used it to refer to a timeless existence altogether outside time. Aristotle, attempted to prove that matter, motion, and time must have existed eternally. Augustine of Hippo wrote that time exists only within the created universe, so that God exists outside of time; for God there is no past or future, but only an eternal present. An atheist mathematician can maintain that numbers and the relationships among them exist outside of time, and so are in that sense eternal. Another facet of eternity is that it is permanent; nothing can happen.

Mat: I recall that eternity is often symbolized by the image of a snake swallowing its own tail, known as Ouroboros The circle is also commonly used as a symbol for eternity. There is a folk story called *The Shepherd Boy* by the Brothers Grimm where a wise shepherd boy is brought to a king to answer three questions. The third question the king asks is 'how many seconds of time are there in eternity?' To which the shepherd boy replies:

- *In Lower Pomerania is the Diamond Mountain, which is two miles and a half high, two miles and a half wide, and two miles and a half in depth; every hundred years a little bird comes and sharpens its beak on it, and when the whole mountain is worn away by this, then the first second of eternity will be over.*

Phil: According to Buddhism and Zen, the law of Karma, or law of cause and effect, is so powerful that it governs everything in the universe, that is, except the one who is Enlightened. Upon Enlightenment, the round of cause and effect loses its significance, just as Samsara, or the round of birth and death. This probably means that time stops.

Mat: Einstein claimed that in curved space-time the past and future exist alongside the present, as events in curved space-time, without anything particular with the present events. A partly comforting but partly very distressing idea. But of course Einstein was very absent-minded, so maybe he did not really live in the present? Like many theoretical scientists.

Figure 20.1: A tensed present.

Chapter 21

Facta! Ja Facta Ficta!

Time is an eternal loss of instant moments. (Beckett)

A careful analysis of the process of observation in atomic physics has shown that the subatomic particles have no meaning as isolated entities, but can only be understood as interconnections between the preparation of an experiment and the subsequent measurement. Quantum physics thus reveals a basic oneness of the universe. The mathematical framework of quantum theory has passed countless successful tests and is now universally accepted as a consistent and accurate description of all atomic phenomena. The verbal interpretation, on the other hand, i.e. the metaphysics of quantum physics, is on far less solid ground. In fact, in more than forty years physicists have not been able to provide a clear metaphysical model. (Fritjof Kapra, 1975)

Phil: Nietzsche states in his *Morgenröthe*:

- *Facta! Ja Facta ficta. - Ein Geschichtsschreiber hat es nicht mit dem, was wirklich geschehen ist, sondern nur mit den vermeintlichen Ereignissen zu thun: denn nur diese haben gewirkt. Ebenso nur mit den vermeintlichen Helden. Sein Thema, die sogenannte Weltgeschichte, sind Meinungen über vermeintliche Handlungen und deren vermeintliche Motive, welche wieder Anlass zu Meinungen und Handlungen geben, deren Realität aber sofort wieder verdampft und nur als Dampf wirkt, - ein fortwährendes Zeugen und Schwangerwerden von Phantomen über* *den tiefen Nebeln der unergründlichen Wirklichkeit. Alle Historiker erzählen von Dingen, die nie existirt haben, ausser in der Vorstellung.*

- *A historian is not concerned with what actually has happened, but only with supposed events, since only those can have effects. His theme, the so-called World History, consists of views on supposed actions and their supposed motives, however quickly dimmed into phantom waves over the deep mist of reality. All historians tell about things that have never existed, except in the imagination.*

Mat: This is hyper-reality, isn't it? Did actually Julius Ceasar say *Iacta alea est?* Or is it only a fictional event fitting into the glorious story of his take-over? Isn't history the history of the survivor, because the dead cannot write. And did really Stanley utter the famous: *Dr. Livingston, I presume?*. Or was it just good journalism?

Phil: Is this cynicism, or only realism?

Mat: I think this is realism. Only the present exists, while the past and future represent (different forms of) imagination and (re)construction. Evidently, we all have a tendency to reconstruct and rewrite our past so that our actions appear to be rational, because we are allowed to behave irrationally only when we are drunk.

Figure 21.1: Victory of Karl XII of Sweden at the Battle of Narva in 1700, painting by Gustaf Cederström in 1910. Reality or hyperreality?

Chapter 22

Time in Nature and Society

> Henceforth space by itself and time by itself, are doomed to fade away into mere experience shadows, and the only kind of union of the two will preserve an independent reality. (Hermann Minkowski, 1908)

Phil: Our modern (and postmodern) society is based on *automated mass production* of material goods by machines and *automated processing* of *information* by *computers*. In an automated process, material in the form of *physical matter* or *information* is being modified following a given step-by-step sequential scheme, *flow chart*, *algorithm* or *computer program*, which is repeated over and over with new material each time the program is executed. The concept *sequential* reflects the Arrow of Time, in the sense that the steps of a sequential scheme are performed one after the other following the Arrow of Time, like the sequence of steps we go through when we bake a cake. The *order in time* of the steps expresses the aspect of being sequential (in time), and of course can be essential: If we forget *mixing* the ingredients *before* putting them into the oven, then there will be no cake to eat.

Mat: We can number the steps in a *sequential process* by the natural numbers $1, 2, 3, ...$, and then follow the *ordering* of the natural numbers during execution of the process. We can then view the process as a form of *clock* measuring the *flow of time*: If each step takes about one second, then we can say that the total time for executing a process consisting of 10 steps is about 10 seconds. This represents *taylorism* as developed by Fredrick Taylor in the late 19th century for the automation of e.g. car manufacturing, with the time duration of each step carefully measured by a *time study specialist* equipped with a clock, following the mantra of the industrial society of *saving time* (but not energy). The time study is also necessary for *coordination* (in time) of processes so that *queeing* is avoided (and time is saved). Not everything has to be performed sequentially in time. There are tasks that can be done in *parallel processing* by executing many copies of the same program with different data. For example, you can hire 10 bakers to bake 10 cakes in 10 ovens simultaneously, all working independently, and deliver 100 cakes by the end of the day. Instead of hiring one baker to bake 100 cakes in 1 oven requiring 10 days. Parallel processing is essential for mass production.

Phil: I think it is important to make a distinction between the role of time in Nature and in Society. The water molecules in a water wave are not equipped with clocks (as far as we know), yet they do just the right thing at the right moment (as far as we know). The flowers and the birds do not have any watches either, but follow the variations of the seasons just as homo sapiens were doing during all the hundreds of thousands of years before the industrial society developed starting in the 17th century and the information society of our time. In our developed human societies clocks are necessary to coordinate the actions of many people, and for navigation. The GPS system is based on measuring the time it takes for a light signal to pass from a satellite to a receiver on the Earth, and requires synchronization of all satellite clocks and and receiver clocks on the ground. The GPS system works remarkably well, which shows that it is possible to set up a system of synchronized clocks around the Earth, and probably in our Solar system when the need from space travel arises.

Mat: Algorithms for automation are *deterministic* in the sense that the steps follow according to specified rules with effects of *randomness* or *chance* made as small as possible. A deterministic algorithm encodes a sequence of cause-effect events, expressing the essence of a *rational materialistic mechanistic* world view, as opposed to an *irrational idealistic magical* view allowing things to happen “out of the blue”, by chance or by the influence of *ghosts* of some form. The order in a sequential cause-effect process defines an Arrow of Time, with the cause occuring *before* the effect. The challenge is to explain what makes certain processes irreversible in the sense that they cannot be run backwards in an effect-cause manner. The challenge is thus to explain what makes the cause to be the cause in a cause-effect process, and not the cause the effect and the effect the cause. This is the objective of this book.

Chapter 23

Operational Definition of Time

> Let us draw an arrow arbitrarily. If as we follow the arrow we find more and more of the random element in the state of the world, then the arrow is pointing towards the future; if the random element decreases the arrow points towards the past. That is the only distinction known to physics. This follows at once if our fundamental contention is admitted that the introduction of randomness is the only thing which cannot be undone. I shall use the phrase "times arrow" to express this one-way property of time which has no analogue in space. (Arthur Eddington in *The Nature of the Physical World*, 1928)

Mat: I suggest we agree on the following *operational definitions* of *space* and *time* is made in terms of the units for *measuring* length and time. Length is then what you measure as length and time what you measure as time. Simple and clear! According to the presently generally adopted *1983 SI standard of Conference Generale des Poids et Measure* the *time unit* is *seconds s* with one second equal to 9192631770 cycles of a cesium clock (more precisely the duration of that number of periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom at rest at temperature 0 Kelvin). The *length unit* is *meters m* with one meter being the distance traveled by light in 0.000000003335640952 seconds or 9192631770/299792458 cycles of a cesium clock. Equivalently, the length standard can be chosen as *lightsecond* or 299792458 meters.

Phil: Great! Do we have to say more? Time is what you measure with a cesium clock, and length what you measure in lightseconds.

Mat: Yes, we have to say more, because it does not show us what the Arrow of Time is. We do not have any operational definition of entropy, because we do not know what entropy is, and thus we do not how to measure it, and even less why it can only increase.

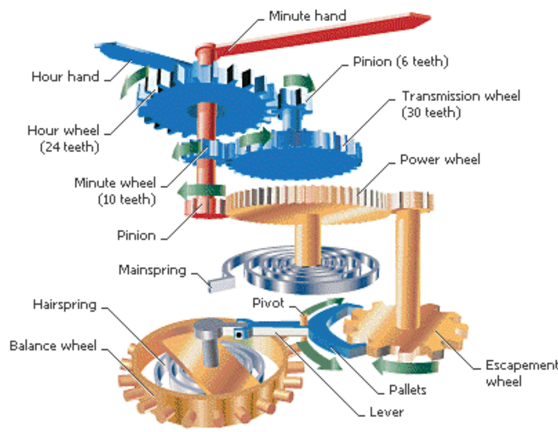


Figure 23.1: Principle of a mechanical clock.

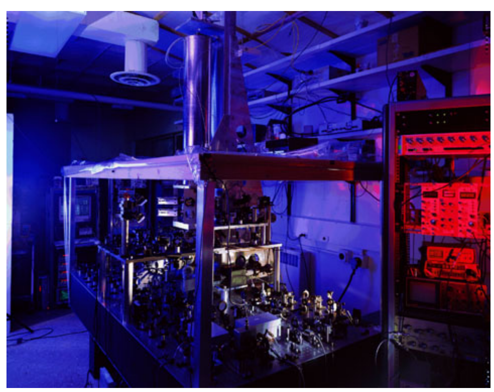


Figure 23.2: The cesium fountain atomic clock at the NIST laboratories in Boulder, Colorado, USA, defining Coordinated Universal Time UCT, the official world time. The precision is less than a second over 60 million years.

Chapter 24

A World of Computation

> All physical systems can be thought of as registering and processing information, and how one wishes to define computation will determine your view of what computation consists of. (Seth Lloyd)
>
> Every physical system registers information, and just by evolving in time, by doing its thing, it changes that information, transforms that information, or, if you like, processes that information. (Seth Lloyd)

Phil: Since we live in the beginning of the *information age*, we are led to view any process in the the real or the virtual World as a sequence of transformations of data or processing of information by some form of analog or digital computation. In each step input is transformed into output, which serves as input in the next step. The complete process may be described in a flow chart specifying input and output in each step. A flow chart defines a (local) Arrow of Time for each step in the sense that the input information has to be available *before* output data can be produced. In natural processes the scheduling of events in time is automatic: The lion awaits the appearance of the prey at the water-hole, and the tennis player waits for the right moment to hit the ball. In industrial processing of material goods or digital computation timing and scheduling serves an important function to reduce waiting time.

Mat: The idea of the World as a computer performing a massive computation has been put forward by the physicist *Seth Lloyd* (1960–):

- *I have not proved that the universe is, in fact, a digital computer and that it's capable of performing universal computation, but it's plausible that it is.*

- *In order to figure out how to make atoms compute, you have to learn how to speak their language and to understand how they process information under normal circumstances.*
- *It's been known for more than a hundred years, ever since Maxwell, that all physical systems register and process information.*
- *Merely by existing and evolving in time - by existing - any physical system registers information, and by evolving in time it transforms or processes that information.*
- *Nothing in life is certain except death, taxes and the second law of thermodynamics.*
- *Of course, one way of thinking about all of life and civilization is as being about how the world registers and processes information. Certainly that's what sex is about; that's what history is about.*
- *One of the things that I've been doing recently in my scientific research is to ask this question: Is the universe actually capable of performing things like digital computations?*
- *Science consists exactly of those forms of knowledge that can be verified and duplicated by anybody.*
- *Similarly, another famous little quantum fluctuation that programs you is the exact configuration of your DNA.*
- *So science is basically, at it most fundamental level, a public form of knowledge, a form of knowledge that is in principle accessible to everybody.*
- *That is not to say that these three processes don't have fringe benefits: taxes pay for roads and schools; the second law of thermodynamics drives cars, computers and metabolism; and death, at the very least, opens up tenured faculty positions.*
- *Thinking of the universe as a computer is controversial.*

Phil: The *clock rate* is the fundamental rate in cycles per second (Hertz or Hz) at which a computer CPU performs its most basic operations such as adding two numbers or transferring a value from one processor register to another. The original IBM PC from 1981 had a clock rate of about 5 MHz (5×10^6 cycles/second), Intel's Pentium from 1995 ran at 100 MHz, and the Pentium 4 from 2002 at 3 GHz (3×10^9 cycles per second), thus with almost a factor 1000 over 20 years, roughly corresponding to Moore's Law of doubling each 18 months. The rate of a cesium clock is about 10^{10} Hz which may be the clock rate of the CPU of the World, and thus microprocessor clock rates cannot continue to increase according to Moore's Law. Nevertheless, the computing power seems to continue to double each 18 months, but now by increasing the number of processors combined with more efficient computational algorithms.

Mat: *Knowledge* appears as a particular form of information in Lloyd's paradigm, and has an important role in Paul Romers extension to the Information Society of Adam Smith's classical analysis of the economy of the Industrial Society in *The Wealth of Nations*, as outlined by David Warsh in *Knowledge and the Wealth of Nations* [27]. The computer game industry is today booming offering new possibilities to human experience and interaction. Second Life is one of the many new virtual worlds with a rapidiy increasing population of virtual citizens. Virtual reality instead of real reality, e.g in the form of video-conferences or virtual tourism, saves energy and may be the feasible way of handling the threat of global warming.

Phil: You know *Kurzweil* has identified 2045 as the time of the *Singularity*, when according to Moore's law the information society will develop infinitely fast towards an unlimited complexity and intelligence. We are quickly approaching this year and only Global Warming can prevent the Singularity to develop.

Chapter 25

Fiction and Non-Fiction

> Horologium, solo naturae motu, atque ingenio, dimetiens, et numerans momenta temporis, constantissime aequalia. (A clock that, by natural motions alone, indicates regularly equal divisions of time, Mateo de Alimenis Campani (1678)).

> There is a concept which corrupts and upsets all the others. I refer not to the Evil, whose limited realm is that of ethics; I refer to the infinite. (Borges)

Mat: From my experience running a hardware store, I know how important precision and quality is. Japanese cars have better precision than American and are therefore steadily taking new market shares. But even a Toyota has finite precision. Infinite precision belongs to fiction and so does infinite sets such as *the set of all natural numbers* $\{1, 2, 3, ...\}$. I think, along with Aristotle and the great mathematician Gauss, that it is better to view the natural numbers rather as some kind of *potential*, where you can always get a bigger number by adding 1 to whatever you have, but you *have to do it*; it is not already done. so to speak. Like here at Atomic Clock Cafe: You can always get another cake, but you have to order it, and pay for it! And this does not mean that the owner of the cafe, Mr. Brouwer, has stored infinitely many cakes somewhere. They are baked on demand.

Phil: Yes, of course. Storing infinitely many cakes would be very costly, infinitely costly in fact. Borges *Library of Babel* containing all possible books, as all possible strings of letters, is also infinite. You are describing a difference between fiction and non-fiction. In fiction you are free to play with concepts like the set of all natural numbers, as if it exists, while in plumbing you have to constructively join one pipe to another. Now, are there constructive aspects of time? If so, then time would maybe exist in this constructive sense?

Mat: Yes, I believe so. Of course, you first have to make a distinction between *physical time* and *psychological time*, which you may view as a distinction between *objective time* and *subjective time*, or between *constructive time* and *fictional time*.

Phil: OK, what is then objective or constructive time? For sure, we will get back to subjective time, the sooner the better.

Mat: Well, I think I have to change the question to instead a question about *change of time* or *time flow* or *rate of time*, or *stream-of-consciousness* as in the famous *Ulysses* by Joyce. You can then say that change of time or time flow or rate of time is what you measure with a *clock*. This is an *operational definition* if I tell what a clock is in a constructive sense. You could then claim that rate of time exists in a material sense, even if time itself does not exist.

Phil: What is then a clock? Is it material?

Mat: Well, a clock is a mechanical or digital *repetitive* or *periodic* material device with the period controlled by the material oscillation of something like a pendulum or a quartz crystal. The most precise clock is an *atomic clock* with the rate controlled by the vibrations of cesium atoms. This is the clock here at the *Atomic Clock Cafe*, which defines *Coordinated Universal Time UTC* and is the time of the *GPS* system. The precision of this clock is astounding; almost 10 digits!

Phil: It seems to me that there are two types of clocks: the metronome type of clock, or *time rate clock*, only showing the rate of time or the *tempo* or *pulse* or *beat*: tick–tick–tick..., and the usual clock, or *time clock*, showing accumulated or integrated time: 12.00.00–12.00.01–12.00.02....

Mat: That is right. You can view the metronome time rate clock to be the basic type of clock, like your heart beat. If you have a time rate clock, then you get a time clock simply by counting the beats. But there is no device in your body counting the number of beats of your heart. Or maybe there is: It seems that the number of heart beats during a life time of different animals, from small birds to large elephants, is roughly the same. Small bird: quick beat–short life. Elephant: slow beat–long life. If we know in principle how the heart keeps a beat as a time rate clcok, the biological clock of aging remains mysterious. Evidently, there is some mechanism for counting the heart beats, or the number of cell divisions, or something that makes us grow older and older until it is all over.

Phil: Yes, that is intriguing, but let's for the moment at least, forget about the limited number of heart beats. Now, is really the clock rate of an atomic clock always the same? Everybody knows that according to Einstein's theory of relativity, clocks are supposed to be slowed down if they are moving, so how can an atomic clock here at Atomic Clock Cafe define an objective clock rate? Is it the same at the Atomic Clock Cafe in the Andromeda Galaxy 2.5 million light years away, which is approaching us at a speed of 300 kilometers per second?

Mat: Good question. But you have to understand that nobody really understands relativity theory, not even Einstein claimed to do that, and thus we have to stay away from that if we are going to have a meaningful conversation. It also is very natural to do so, since clock rates are only (supposed to be) affected at speeds close to the speed of light, which can never be attained by humans or human-made equipment. Even the speed of the Andromeda Galaxy is only 1/1000 of the speed of light, so clocks there run at basically the same speed as here, if this is something you worry about. Isn't it relatively meaningless to speculate about the rate of a clock in a very far away galaxy speeding away from us at nearly the speed of light?

Phil: I guess so. What a relief to stay away from relativity. I never understood it either. In fact this was the reason I choose not to become a physicist. I thought you would have to understand the theory of relativity to qualify, but maybe this is asking too much, if you are right that nobody really understands it.

Figure 25.1: The Infinite Library of Trinfinity College in Dublin

Chapter 26

Is Presentism Solipsism?

> 'How sad it is!', murmured Dorian Gray, with his eyes fixed upon his own portrait. 'How sad it is! I shall grow old, and horrible, and dreadful. But this picture will remain always young. It will never be older than this particular day of June...If it were only the other way! (Oscar Wildein *The Picture of Dorian Gray*).
>
> Since *absolute simultaneity* cannot be ascertained, science must remove this concept from its system. (Max Born)

Phil: OK, so we measure time flow or rate of time with an atomic clock. We can then assume that everybody is equipped with an atomic clock running at the same rate and defining an objective (rate of) time flow. But what then about time itself, and the notions of past, present and future, and the question of what the meaning of *now* is?

Mat: Well, I believe that only the present *exists* in a material way, while the past and future only exists in a non-material way, in the form of images, memories or expectations. Therefore I believe in *Carpe Diem* or *Seize the Day.* Thus, the idea of ordering events along a time line, which you can imagine, belongs to fiction. Neither, the past nor the future exists in a material way. Only the present exists. But the present changes in a material way, just as the pendulum of a clock changes position, and the rate of change of the present, is measured in comparison with the rate of change of an atomic clock or with respect to normalized time flow. The now is then the same as the present.

Phil: Carpe Diem? You know, this is nothing but *presentism*, or the *R-theory*, the belief that only the present exists and the future and the past are unreal or belong to fiction. The opposite of presentism is *eternalism*, which is the belief that the time-line of all events ordered into earlier and later, exits in some sense, which is also referred to as the *B-theory*. Presentism can also be used more loosely to refer to a narrow focus on the conditions of the moment. St. Augustine proposed that God is outside of time and present for all times, in eternity, while we as human beings so to speak would have access (in a material way) only to the present. Stcherbatsky, leading scholar of modern Buddhist philosophy, writes: *Everything past is unreal, everything future is unreal, everything imagined, absent, mental... is unreal... Ultimately real is only the present moment of physical efficiency or causation.* Are you a Buddhist?

Mat: Never thought of myself that way, but maybe in some sense. In fact, I now recall that in Indian Buddhism time consists of *replaced present moments*, something like the stream of images on a movie screen, one replacing the other. I get the distinct feeling that this may be pretty deep and I would like to explore this idea.

Phil: Yes, that may be constructive, but don't you here run the risk of getting into a vicious circle when you speak about replaced present moments? Isn't replacement a form of change and can you speak about change without speaking of time? You speak about change of position of a pendulum, right?

Mat: Yes, I do. I see the pendulum change position. For the moment I do not seek to explain *how* change of position can come about. I have some new ideas on this old subject, which I will return to, if you allow me. No, it does not lead to a vicious circle to define time rate through a material device, like a vibrating atom, as long as you you don't have to explain what an atom is. For now, I suggest that we simply assume that atoms exist and vibrate and that the vibrations can be observed. Just like a swinging pendulum, or the shifting seasons, can be observed, as a sequence of replaced presents.

Phil: OK, I accept that. Buddhism may be more scientific than Christianity, which always has been in conflict with science. In fact, it seems that quantum mechanics connects to Buddhist views on the nature of the material world, or vice versa.

Mat: Yes, it does, but so does also Leibniz *Monadology* with the *monads* representing some form of elementary waves/particles. Speaking of the present and science, we know too well the scientist is an *absent-minded* ill-dressed professor with upright hair and thick glasses, like Einstein, a person who does not know what time it is, where he is and where he is going, a person without any feeling for the present or change.

Phil: Some people believe this is a typical male syndrome, with women in general being more aware of the present. Maybe something genetic. Maybe the vision of science is to find eternal unchangeable truths rather than the truth of the day?

Mat: Could very well be.

Phil: But there is something I have to tell you about presentism, a not so nice aspect: It leads to *solipsism*: If you deny the past and the future moments real existence, what reason do you have to believe that any other human being than yourself exists, has existed or will exist? Radical presentism by necessity has the consequence that the world as you know it is a present representation in your mind – and that representation can hardly take place anywhere but in your mind, whatever that can be. Schopenhauer saw this consequence and that is why his central work is called *The World as Will and Representation*. Are you like Schopenhauer?

Figure 26.1: Solipsism.

Mat: Hope not. I have heard that he was not overly pleasant. Anyway, you don't have to be a self-occupied solipsist, with the World only inside your mind, just because you are a presentist. You have your present and I have mine, and sometimes we share the present, for example when we sit here at the Cafe having this nice conversation. We share the present when we are *interacting*, but only then. When we don't see each other, or interact over the net, that is when we don't interact, then your present is yours and mine is mine. So there are as many presents as there are minds. This is a form of *many-minds* view, which I have found rather appealing. It connects to the *post-modernity* of our *multi-cultural society* with many different *perspectives* and *interpretations*.

Phil: Many-minds? Post-modernity? Yes, why not? I guess our discussions is a a form two-minds hopefully postmodern adventure, and yes, we only share the present when we interact, fortunately I must say!

Mat: I agree. Of course, when we share the present, it is *simultaneous*.

Phil: But everybody knows that according to Einstein, the concept of *simultaneity* has to be abandoned. It does not work! That is one of the many convictions we have to give up according of Einstein's theory of relativity. It is tough, yes tough, but we have to free ourselves from such superstition as simultaneity. The great Max Born, life-long friend of Einstein, says so!

Mat: Oh, so you are back to relativity? Didn't we agree to leave that out? Do you believe that the *twin paradox* is not a paradox? That each one of two clocks moving with respect to each other, will be slow as compared to the other? Like each of two persons looking at each other at distance claiming that the other is half as tall (while they in fact are equally tall.) Do you believe that this is profound science, and not just trivial confusion, which you free yourself from at the age of two? Of course, we can speak about simultaneity when we interact. We share simultaneity when we interact, but not necessarily when we do not interact. Then the issue does not arise. It is a no-issue. There is not necessarily any common simultaneity for everything everywhere, just as there not two persons with the same opinion about everything.

Phil: But I have to insist: Assume that a runner sets a new world record on 100 meter. That means that his passing the end line is simultaneous with a particular oscillation in a harmonic oscillator. If that moment is the moment of our observation, with your interpretation of now or the present moment the runner is passing the end line now. What is happening on an earth-like planet in the Andromeda Galaxy now? Could an event on that planet take place now? Or is now a word devoid of meaning, used in that context?

Mat: Andromeda Galaxy? How can we interact with any supposed cousins there, if they do exist? Did you mean that the new record was a *Universal Record*? That runners also in Andromeda took part in the race? Simultaneously?

Phil: No kidding. Of course not. I see what you mean.

Mat: I am happy to hear that. Shall we agree to meet here at the Cafe next week at the same time? Or shall we leave it open and simply say that we will meet again when we meet again, here at the Cafe or somewhere else? What is sure is that when we meet, it will a simultaneous event We will meet at the same time, right? Or will you first meet me, and then I you? It would seem to me that we would then run the risk of missing each other?

Phil: I prefer that that we decide on a time to meet. I like to view myself as rational being, and not just a person following the laissez faire of "whatever happens happens, whenever it happens", which seems to be your melody.

Mat: Sort of. It has its advantages.

Phil: *James Boswell* (1740-1795) relates in his biography *The Life of Johnson* of Samuel Johnson (1709-1784), often referred to simply as *Dr Johnson*, the English essayist famous for his great wit and prose style. Boswell describes a discussion with Dr Johnson about Bishop Berkely's solipsistic theory of the non-existence of the material world, a theory considered difficult to refute. Dr Johnson then kicked a large rock and said as his foot rebounded: *I refute it thus.* Convincing?

Mat: Believe so. If you hit your head (hard) against a wall, you will get evidence of an external material world.

Figure 26.2: One mind or many minds?.

Chapter 27

Imaginary Books and Reality

> It is a laborious madness and an impoverishing one, the madness of composing vast books setting out in five hundred pages an idea that can be perfectly related orally in five minutes. The better way to go about it is to pretend that those books already exist, and offer a summary, a commentary on them... A lazy man, I have chosen to write notes on imaginary books. (Borges in *Collected Fictions*)

> But here, as in so many other cases, Germany, learned, indefatigable, deep-thinking Germany comes to our aid. It is, after all, a blessing that, in these revolutionary times, there should be one country where abstract Thought can still take shelter; that while the din and frenzy of Catholic Emancipations, and Rotten Boroughs, and Revolts of Paris, deafen every French and every English ear, the German can stand peaceful on his scientific watch-tower; and, to the raging, struggling multitude here and elsewhere, solemnly, from hour to hour, with preparatory blast of cow-horn, emit his 'Höret ihr Herren und lasset's Euch sagen'; in other words, tell the Universe, which so often forgets that fact, what o'clock it really is. (Thomas Carlyle in *Sartor Resartus*)

Mat: It seems that we can agree, for the moment at least, that only the now exists in a material way, like the pendulum at a certain position. The rest is fiction. In this sense, only the rate of change of time exists, but not time itself as the integrated rate of change. You can thus say that time flow exists reflecting the changing material existence of the present, but time itself does not exist in a material sense, only in a fictional sense. Does that make sense?

Phil: In a way, yes. But what about thinking of a *time line* as a row of books ordered on shelf, which each book representing an event and the order of the books representing the order of events? A particular book would then represent the now, with the books to the left (say) representing the past, and the books to the right the future. Or the numbered pages of a book, one page after the other, like in a biography accounting for the time line of a person. This is the B-theory. Can we dismiss it?

Mat: I think a time line like a shelf of books or the pages of a book, is not a good model of time, because it gives you the false impression that all the time instants represented by books or pages, exist, in some sense, and that one of them is chosen to represent the present. It is then better to think of a film screen, where picture after picture is displayed, but only one at a time, and where the pictures already shown have been erased and those yet to come are neither displayed. A sequence of replaced presents. In this case the shelf of books would correspond to the whole film itself rolled up in the projector, but the reality would be the picture on the screen. When you watch a movie, you do not think of the entire film rolled up in the projector, but you get the impression that *one image leads to the next* following the logic of the story. Like in a real life dialogue with one statement following the other, without all the statements having been written down beforehand like in a theatre play. With this perspective, the film in the projector would be non-existing; the only existing thing would be the picture on the screen, which would generate a new picture while disappearing. Like an old generation of professors educating a new generation and disappearing. Or like the modern *e-book*, which you read on your computer screen replacing one page by a new page by repeatedly pressing a button.

Phil: OK, I agree. The book shelf or book analogies can be misleading if you interprete them to represent reality. Our future is not already written down on the pages of the *book of our lives*; one day will follow the previous day, and that is all. Yesterday is gone and tomorrow not yet here. The idea of one picture generating a new and disappearing, is not bad. Like a step in a computer code such as $x = x + 1$, where the old value of x is updated by adding 1 to give a new value of x while the old value is erased. If the World is a computer, this would be the way it functions, in principle. But as a presentist you will have to answer the question of the "duration of the present"?. Is it 1/16 seconds like in a film showing 16 images per second?

Mat: Good question. Of course, any attempt to give a direct answer can be questioned on good grounds. If I answer 0.01 seconds, or 0.0001 seconds, you will ask why, and I will be unable to give a convincing motivation. Even if I say that the vibrations of atoms have a period of femtoseconds (10^{-15} seconds), which ought to be the duration of the present or "length of a moment", you will bring up *Planck time* of quantum mechanics (10^{-44} seconds) and so on...This makes me feel that I have to instead circumvent the question by showing that it cannot be posed. This is because, the changing present in a way is eternal or permanent. Just like *love*, which is eternal although its subjects change.

Phil: OK, so the changing present would so to speak represent the reality, and thus exist? The rate of time would exist in a material way, but not time itself?

Mat: Yes, something like that. I have the feeling that this way we can get around one of the main mysteries of the concept of time, namely the *nature of change*. If the change of the present or time flow is what we perceive as reality, and not the present or time itself, then we can use an operational definition of time flow as what you measure with a clock, and then view time as something non-material resulting from integrating the material change of time. It must connect to the *Fundamental Theorem of Calculus*, that is that the integrated velocity is the distance. It is like traveling in a cabriolet: You directly feel the wind through your hair, that is the velocity, but the distance traveled only indirectly by looking at the trip meter or road signs. Or you feel physically the pressure on your lips when kissing from a repeated firing of neurons, a sequence of replaces presents, while the conception of the kiss itself as the integral of the kissing, is a mental illusion. What do you think?

> Finnegans Wake, long considered literature's grandest experiment in deliberate linguistic morphology, simmered in the global stew of languages and media advances for some ninety years before its effects were fully felt. The culmination of several generations of thought about the experiment did not blossom until early this century. Icaro Canto of Bellona here surveys the full efflorescence of the Wake experiment in a multitude of writers in the early part of this century. It should be noted that the book intentionally comes in two editions, one with the apostrophe in the title, one without; there is no other

Figure 27.1: Perception of reality as velocity in 1939.

difference between the versions. By the first decade of the 21st Century, authors the world over had come to understand Joyce in their own ways, and in their own languages. It has been said that their brains caught up with his, now that they were immersed in the globalizing media of the times. What had been a foresighted work on his part, a torch thrust ahead into the darkness, was now an accepted form of the emergent art of deliberate linguistic morphology. Authors raised new questions, beginning with the translations of Joyce's Wake, full-length works in Gaelic, Urdu, Swahili, Chinese, Thai. Fully half the world's language groups are represented here, with page samples from each. Unfortunately, the trend pushed itself over its edge by witnessing new translations into invented and imaginary languages: Esperanto, Ebonics, Klingon. (Review of *The Wake's Wake* by Icaro Canto, 2067, Imaginary Book Review)

Figure 27.2: Waiting line representation of time.

Chapter 28

Becoming vs Being

> The American lives even more for his goals, for the future, than the European. Life is for him always *becoming*, never being. (Einstein)
>
> As far as we can discern, the sole purpose of human existence is to kindle a light in the darkness of mere being. (Jung)

Mat: In presentism the concept of *becoming* is central. Becoming is dynamic indicating change, while the concept of *being* is static indicating permanence.

Phil: Evidently, our sensory system reacts to becoming more than being. When you take a bite of that wonderful chocolate cake, then you get a strong feeling of pleasure, but you cannot be in that state of happiness for very long. It is a dynamic state of becoming, which you cannot turn into static permanence.

Mat: This suggests that change of time or time flow is more fundamental than time itself, that becoming is more essential than being. That we are more apt for falling in love than being married?

Phil: Yes, I quickly get bored and want change. Or my wifes do. I have been married six times but I am maybe now becoming too old to continue like that. Maybe it is time for change...

Mat: Greek philosophy tended to depreciate becoming and exalt mere being, and as was consistent, to depreciate relativity and exalt independence or absoluteness. Aristotle summed it up when he held that what was altogether immutable and hence immune to influence from others was superior to that which in any way changed or depended upon other things. Medieval natural theology never explicitly deviated from this attitude.

Phil: Yes, Aristotle denied that God could have knowledge of changing things, arguing that knowing cannot be independent of what is known. But of course Christian and also most Jewish and Mohammedan theists felt obliged to affirm God's knowledge of the changing world. This glaring inconsistency forced Spinoza to deny change not only in God but in the world which God knows, because the known is in the knowing, and if there change in the former, then there is also in the latter.

Mat: It seems that in this view, genuine becoming is impossible. The truth, the reality, is eternally there, spread out to the divine gaze, though our present experience, being localized in the eternal panorama, cannot behold most of it. This is the book shelf again, which amounts to *spatializing time* according to Bergson.

Mat: On the other hand, in Buddhism becoming is the universal form of reality, of course connecting to Herakleitos, while *substance* including the *soul* as substance is rejected. The momentary experiences are the primary realities, and these do not change, they simply become, and what is called change is the successive becoming of events having certain relationships to their predecessors. The soul or the *self-identical ego* is merely the relatedness of experiences to their predecessors through memory and the persistence of various qualities or personality traits. The first great meta-physician in the West to hold this view clearly was Whitehead in the form of *process philosophy*.

Phil: One can also read a sort of process philosophy into Hegel and Schelling, who doubtless helped to do away with the classical metaphysics of being

Mat: I guess that when we say that "the weather changes", we do not mean that that there is some form of substance called "the weather", which changes. Right?

Phil: Probably! But, when you say "I am getting older" do you mean that there some form of substance called "I" which is changing and getting older?

Mat: Do you want me to describe what I mean by "I"? I am not sure I can.

Figure 28.1: Becoming.

Mat: Well, take your time. It is not that easy. But recall that in European language the most concrete realities to which abstractions are to be applied, the real *subjects*, which have *predicates*, are things, individuals which change from one actual state to another, a person, a tree, a mountain, a star, not happenings. But there is something more concrete than an individual "I", and that is the actual history of the individual, the succession of *states*, for instance, experiences, which constitute the reality of the individual through time. Is it not clear that the entire actuality of the individual is in one's states, bodily and mental? Don't we have to admit, with the Buddhists and Whitehead, that individuality is somewhat abstract, compared to an actual event-sequence. Isn't it the person now, the person in his/her present actual state, that *has* the person as the same individual from birth to death, not the same individual that *has* the present actual state. We speak of someone as being *in a state*, not of the state as being in the individual. To see a person as always the same entity, we must abstract from what is new in the individual at each moment.

Mat: OK, so personal identity through experiences is a property of the experiences, not a property of the identity, or of the ego. It took European philosophy over two thousand years to think through this issue, an issue which Buddhism thought through long ago.

Phil: How do we even know that things have passed away, if not by preserving in memory at least something of what they have been? In memory, past happenings are still somehow with us. Moreover, in perception also, past happenings in a fashion linger on in present experience. We now hear the explosion which in fact took place some seconds ago; we see a stellar explosion which took place years in the past. Memory and perception both somehow embrace the past and preserve something at least of its character. In human memory and perception this "immortality of the past" is faint and fragmentary; but then all human capacities are imperfect, limited.

Mat: We have here taken human experience as the model of reality? Is this not suspiciously anthropomorphic? Shouldn't we ask ourselves what it would like to be an amoeba or a molecule?

Phil: To Leibniz, everything including an amoeba and a molecule has a certain form of more or less primitive soul. I think, the wave-function of quantum mechanics can be viewed this way as an ever-changing becoming "I". Metaphysics has always tended to reach this result. Northern Buddhism illustrates this, but so does Hinduism and it is only a little below the surface in Plato and Aristotle.

Mat: Neoclassical metaphysics as process philosophy is a fusion of idealism or psychoalism with a full realization of the primacy of becoming as self-creativity or creative synthesis. (See *The Development of Process Philosophy*, Philosophers of Process, ed. Douglas Browning (Random House, 1965)).

Phil: Can we couple being to an aristocratic attitude, and becoming to a democratic?

Mat: Guess so. Martin Heideggers *Being and Time* has been connected to the repressive authoritarian society of National Socialism. I think Putin views himself as *being* the leader of Russia, while Hillary Clinton views herself as *becoming* the leader of the US.

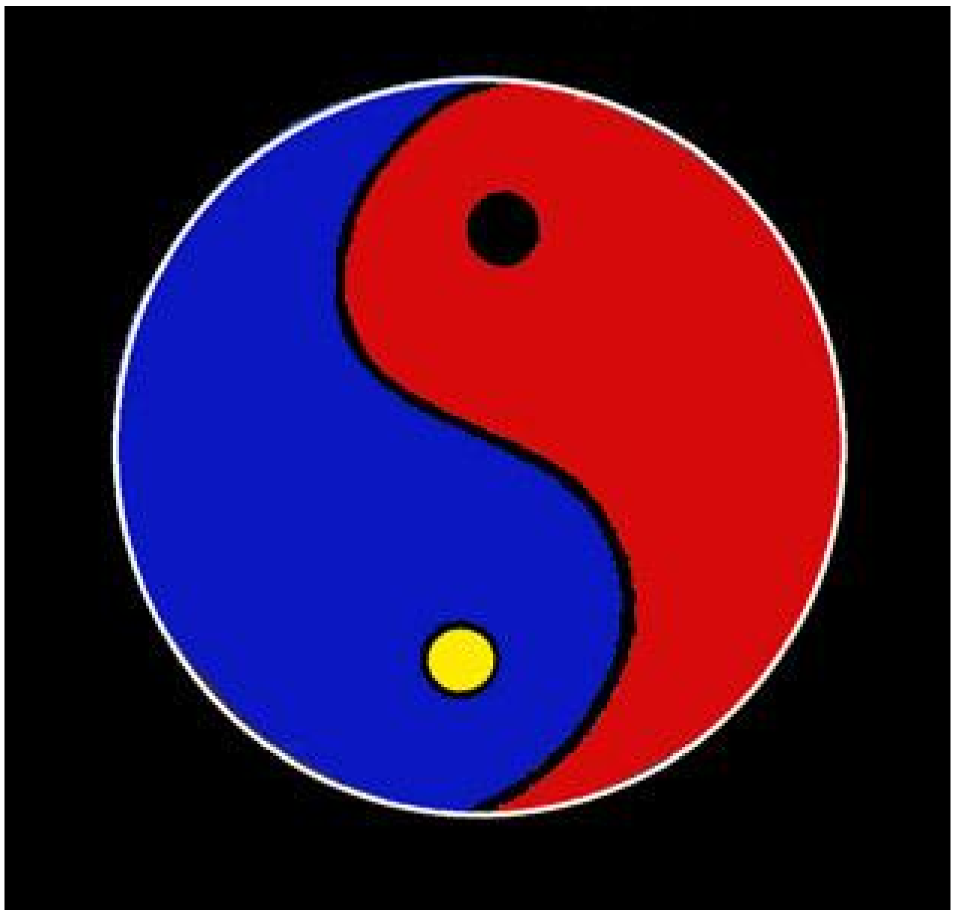


Figure 28.2: Being-in-Becoming.

Chapter 29

Triumph of Mathematics

> Perhaps it would be necessary now to try to invent places for teaching and research outside the university institutions. – Still today, I cannot cross the threshold of a teaching institution without physical symptoms, in my chest and my stomach, of discomfort or anxiety. And yet I have never left school. – Why is it the philosopher ho is expected to be easier and not some scientist who is even more inaccessible? – As soon as there is language, generality has entered the scen. – Whoever said that one was born just once? – (Derrida)
>
> A photograph is always invisible, it is not it that we see. (Barthes)

Mat: Viewing rate of time to be more fundamental than time, connects to the post-modern *deconstruction* of the constructive idealism of modernity. In mathematical terms, time results from *integration* of rate of time, which is a constructive *cumulative process adding little increments* of time to get *global time*. Similarly, integrating velocity over time you get the distance, recalling that velocity is the derivative of distance with respect to time. You may view rate of time as a deconstructed version of time; when you deconstruct you break down into pieces, and when you construct you put pieces together.

Phil: This is like viewing the whole as being the sum of the pieces, or (equivalently), the sum of the pieces being the whole. Summing is like integrating.

Mat: Yes, this is the meaning of the Fundamental Theorem of Calculus: Integrating the derivative of a function, you get back the function. Or equivalently, differentiating the integral you get the integrand (what you integrate).

Thus you can view integration and differentiation as inverse operations: If you first integrate and then differentiate, (or vice versa), then you get back what you started with; the integrand (the integral). You learn this in high school: The derivative of the integral of an integrand, is the integrand. The integral of a derivative of a function, is the function.

Phil: Then deconstruction is like taking the derivative, breaking down into pieces, and construction would be like putting pieces together. It is natural to view the pieces as being more fundamental, more basic to our understanding, while the the result of a constructive process of putting pieces together is less fundamental in the sense that it requires a construction, a summation, an integration, to be performed. When baking a cake the ingredients are basic and the cake is the integrated result of putting the pieces together. Collecting ingredients may be trivial, while baking a cake can be an art.

Mat: The whole of mechanics can be viewed this way. The basic equations of motion are rate of time laws such as Newton's second law $ma = F$, where m is *mass*, a is *acceleration*, which is the derivative with respect to time of the velocity, which is the derivative of the distance, and F is *force*. By integrating these rate of time equations of motion, you can determine the velocity and distance traveled of an object of mass m acted upon by a given force F. For instance you can compute the future position and velocity of the planets in our solar system, knowing their positions and velocities at an initial time, by integrating the equations of motion.

Phil: We know that *Calculus* was developed by Leibniz and Newton as a language to express equations of motion, in the form of *differential equations* involving derivatives, such as Newton's second law. The all-time high of mathematics was reached when Newton solved the *two-body* problem with a small body orbiting a big body under gravitational attraction, like the Earth orbiting the Sun, and showing that the trajectory is an ellipse, thus in one shot proving *Kepler's laws*:

- *The orbit of the small body is an ellipse with one foci at the big body.*
- *The radius joining the bodies sweeps equal areas in equal times.*
- *The square of the period is proportional to the cube of the mean distance.*

People were amazed to see Newton play the role of God telling the planets how to move.

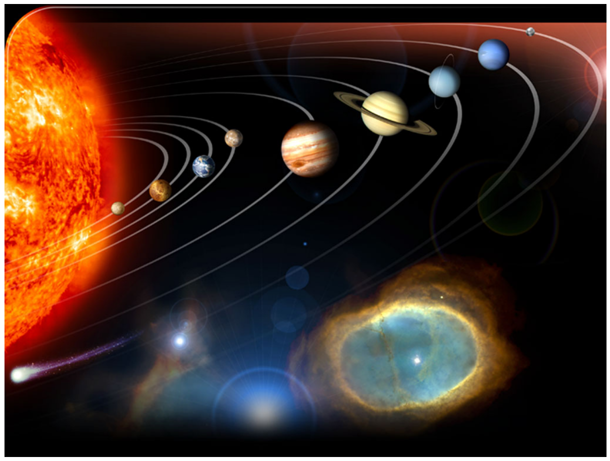


Figure 29.1: Our Solar system

Mat: Newton's formidable unpresedented success forstered a *Dream of Calculus*, which has carried mathematical analysis into our time, to solve differential equations by analytical techniques of integration writing formulas on pieces of paper. But that dream of Calculus has remained a dream, because analytical integration is possible in simple model problems. What is remarkable is that today the Dream is being fulfilled: The computer can solve any differential equation by carrying the necessary summation simply by computing, adding one increment to the next to get the desired integrated quantities. This way you can today simulate complex phenomena. The outstanding open problem of turbulence is just now being solved that way. I can inform you about this later. I am sure you are all ears.

Phil: Solving the mystery of turbulence by computation? Yes, that should be possible. After all what can the World be but some form of computational process, where the new present is computed from the previous present in an eternal time-stepping.

Mat: On May 10, 1933 - an event unseen since the Middle Ages occurs as German students from universities formerly regarded as among the finest in the world, gather in Berlin and other German cities to burn books with "unGerman" ideas, a form of deconstruction or rather destruction. Books by Freud, Einstein, Thomas Mann, Jack London, H.G. Wells and many others go up in flames as they give the Nazi salute. In Berlin, Nazi Propaganda Minister Joseph Goebbels gave a speech to the students, stating...

Figure 29.2: Deconstruction/destruction in 1933

- *The era of extreme Jewish intellectualism is now at an end. The breakthrough of the German revolution has again cleared the way on the German path... The future German man will not just be a man of books, but a man of character. It is to this end that we want to educate you. A s a young person, to already have the courage to face the pitiless glare, to overcome the fear of death, and to regain respect for death - this is the task of this young generation. And thus you do well in this midnight hour to commit to the flames the evil spirit of the past. This is a strong, great and symbolic deed - a deed which should document the following for the world to know - Here the intellectual foundation of the November (Democratic) Republic is sinking to the ground, but from this wreckage the phoenix of a new spirit will triumphantly rise...*

Over a hundred years earlier, the German-Jewish poet, Heinrich Heine, had stated: *Where books are burned, human beings are destined to be burned too.*

Chapter 30

Initial Value Problems

> Only by taking infinitesimally small units for observation (the differential of history, that is, the individual tendencies of men) and attaining to the art of integrating them (that is, finding the sum of these infinitesimals) can we hope to arrive at the laws of history. (Leo Tolstoy)

> We may regard the present state of the universe as the effect of its past and the cause of its future. An intellect which at a certain moment would know all forces that set nature in motion, and all positions of all items of which nature is composed, if this intellect were also vast enough to submit these data to analysis, it would embrace in a single formula the movements of the greatest bodies of the universe and those of the tiniest atom; for such an intellect nothing would be uncertain and the future just like the past would be present before its eyes. (Laplace)

Phil: Let us sum up: We have the A-theory of past–present–future, the B-theory of earlier-later, and the R-theory of the present.

Mat: Yes, and in particular the R-theory connects to the great mathematician Laplace's idea that if you know the positions (and velocities) at a certain moment of all the atoms in the World, then you can (in principle) predict their positions (and velocities) in the next moment, and so on into the future.

Phil: I see: Newton's law $ma = F$ determines the acceleration, the rate of change of the velocity, which allows you to time-step the velocity and then the position. The basic law $ma = F$ thus is a *rate law* for the velocity in terms of the force, in which there is no need of accumulated time, or history: All you need to know to take a step into the future is the present, and the past plays no role (if the force only depends on the present position).

Mat: Yes, mathematically this comes out as describing the World as an *initial value problem*, where the future is determined from the present, and not from the past. This is how a *weather prediction* is made by computing temperature, velocity and pressure of the air one time step after the other using Newtonian mechanics starting from measured present values.

Phil: OK, maybe the material World results from a finite precision solution of an initial value problem. But in a world of fiction or thoughts, the past can seem to influence the future. However, the past may have to pass through the window of the present to have an impact on the future. The pictures in your photo album may change your decisions today, if you look into the album today, or remember the pictures today, but if you don't, then the mere existence of the photos or the memories cannot change anything tomorrow; they are inactive so to speak until they are brought into the light of a (transfixed) present.

Mat: Yes, the light upon the actor on the scene is only temporary. Suddenly, the curtain falls... The present is like a window to the future through which everything somehow has to pass by time-stepping, in order to have an impact. This aspect is very obvious as concerns the data on your hard disk; to keep it to coming generations you have to continually redo the storage. Only the present hard disk exists in a material sense. The data on a crashed hard disk does not exist, neither the storage device of tomorrow.

Phil: So what aspects on an initial value problem determine an Arrow of time?

Mat: Good question. Principe Perfeito gives an answer based on a certain form of stability referred to *edge stability*, something between stable and unstable. In an edge stable problem little causes may have large pointwise effects in both forward and backward time, but certain mean-values are stable only in forward time which determines and Arrow.

Phil: Edge-stable? Can you give an example?

Mat: Sure: When you stir milk into your coffee the exact distribution of specific little volumes of milk is impossible to control or predict, but the

Figure 30.1: Irreversible process of stirring a soup.

result of the stirring of a brownish mix is very stable. No matter how you stir, the result is a cafe latte. And the reverse process of un-stirring is very unstable. So there is one aspect, the stability of mean-values, which defines the Arrow. The evolution of the weather is also seems to be edge-stable, partly predictable partly not.

Phil: Waiter, coffee and milk please! We are going to make an experiment!

Figure 30.2: Edge stability by Zorn.

Chapter 31

Clocks

> Nevertheless be it remarked, that even a Russian steppe has tumult and gold ornaments; also many a scene that looks desert and rock-bound from the distance, will unfold itself, when visited, into rare valleys. Nay, in any case, would Criticism erect not only finger-posts and turnpikes, but spiked gates and impassable barriers, for the mind of man? It is written, 'Many shall run to and fro, and knowledge shall be increased.' Surely the plain rule is, Let each considerate person have his way, and see what it will lead to. For not this man and that man, but all men make up mankind, and their united tasks the task of mankind. How often have we seen some such adventurous, and perhaps much-censured wanderer light on some out-lying, neglected, yet vitally momentous province; the hidden treasures of which he first discovered, and kept proclaiming till the general eye and effort were directed thither, and the conquest was completed;–thereby, in these his seemingly so aimless rambles, planting new standards, founding new habitable colonies, in the immeasurable circumambient realm of Nothingness and Night! Wise man was he who counselled that Speculation should have free course, and look fearlessly towards all the thirty-two points of the compass, whither-soever and howsoever it listed. (Thomas Carlyle in *Sartor Resartus*)

Phil: Thinking of clocks and time-keeping, what is our modern society, but a sequence of coming, meeting and parting, intermixed with some time for sleep, all regulated by clocks? If you are not at the right spot at the right time, you'll miss the train. If we agree to measure time flow by clocks, then the construction of a clock might tell us something about time. What is then a clock?

Mat: Well, that can be debated of course, unless we simply say that it is the standard cesium clock here at Atomic Clock Cafe. But more generally, we can say that any repetitive procedure can be viewed as a clock: your heart beat, your foot steps, your breathing, the rotation of the Earth, the Seasons, you name it.

Phil: Fine, but what is then a *repetitive process*?

Mat: Well, it seems to me that such a process comes out of som form of *dissatisfaction with status quo*. We know that life here at the cafe is a repetitive process: eat a cake–digest a cake–desire a new cake–eat a cake–digest a cake.... So it goes , cake upon cake, day after day. You never get really satisfied for good. You can also say that this form of cake addiction represents a vicious circle: you always get back to where you started.

Phil: Yeah, another example is *walking*, putting one foot foot ahead of the other, in a continued effort not to fall on the nose, because equilibrium is never satisfied since you are leaning slightly forward. Of course, in this process you are advancing forward, but the position of your feet is repeated.

Mat: Similarly, you can view the motion of a pendulum swinging back and forth as an endless process resulting from the dissatisfaction of staying in either top position or the bottom position.

Phil: OK, so let us now look into the construction of a mechanical clock. We all know that *mechanical clocks* go by periodic ticks, regulated by some sort of *oscillator* like a pendulum, one tick at a time, one tick per second for example. Thus a mechanical clock is really digital showing a sequence of discrete instants of time which can be digitally *numbered* one after the other in hours, minutes and seconds: 12:00:00, 12:00:01, 12:00:02 et cet. *Digital clocks* are controlled by an oscillating quartz crystal, and also show digital time. From this perspective time flow seems to be discrete, seemingly jumping from one second to the next.

Mat: Of course there are clocks also showing fractions of a second, but still they are discrete or digital. The most precise digital clocks have a period of nano-seconds (0.000000001 seconds), like the cesium clock here at Atomic Clock Cafe. The GPS system requires clocks of this precision, and we know that it works amazingly well.

Phil: The incentive to develop mechanical clocks in the 18th century, came from the necessity of keeping track of time to determine your longitude at sea.

The British Parliament offered a huge sum (6 million Pounds in todays value) for its solution, and half of it was eventually awarded to John Harrison, the inventor of the famous *maritime chronometers* named H1-H4. You can follow the development of an ever finer time chopping in track sports: When Oxford and Cambridge met in March 1864 for the world's first dual track meet, the races were timed in quarter seconds. In the 1912 Olympics in Stockholm, experiments were made with photographic-electric timers clocking tenths of a second, and in the 1924 games in Paris, instruments were introduced capable of resolving hundreds. But not until the 1960 Rome Olympics were hand-held times abandoned and electric results accepted as official. Today, it is not uncommon that two runners in a 100 m dash, get the same time in hundreds of a second, so the next step will be thousands, allowing you to crown the winner by the thickness of the dental enamel.

Mat: It is clear that the modern industrial democratic society requires the actions of millions of people to be coordinated, in time and space, and this can only be accomplished by supplying each individual with a clock. To learn to read the clock, and follow it, is a most essential element of education, which you are confronted with during your first school years, and then struggle with, more or less, the rest of your life. Today, everybody has a digital clock, but to get the industrial revolution going, hand-held clocks had to be invented, an invention of maybe the same dignity as the wheel.

Phil: In ancient time you had sun-dials, water clocks (clepshydra), sand clocks (hourglasses), which are all different forms of *analog clocks*, where a continuous flow or motion of some material is used to measure the flow of time. Such clocks are imprecise and impossible to offer to the masses in the form of hand-held clocks. Su Song, renowned Chinese statesman, astronomer, cartographer, horologist, pharmacologist, mineralogist, zoologist, botanist, mechanical and architectural engineer, and ambassador of the Song Dynasty (960-1279 AD) designed and let build a huge clock, 40 feet high, powered by a special water wheel. Buckets around its rim were filled, one at a time, by a steady flow of water. When each bucket was heavy enough to trip a mechanism, it fell forward – carrying the bucket behind it into place under the water spout. And the process repeated. The weight of the buckets exerted enough force to activate all sorts of displays. Su-Sung's wonderful clock, with its tick-tock motion, was quite accurate. It looked a little like the mechanical clock which wasn't invented for another 200 years in Europe. Su-Sung's clock was stolen when invading Tatars put an end to the Sung dynasty in 1126.

The Tatars weren't able to get it running again, and the high art of Chinese clock-making completely disappeared. But even before the Tatar invasion, Taoistic reformers had come into power. They saw fancy clock-building as part of the older regime and did little to sustain it. Su-Sung's book on the operation of his clock didn't surface in the West until the 17th century. By then, of course, the Western mechanical clock was light-years ahead of it.

Mat: Yes, the mechanical clock helped the Western World to take the lead in the industrial revolution. The basic principle is a *gear train* of wheels and pinions combined with an *oscillating device* controlling the motion of the gear train in a stop-and-go fashion, referred to as the *escapment* or *Zeit-normal*. This is a form of digital clock with a tick-tack motion of the gear train controlled by an oscillator. The essence is of course, the design of the escapement keeping a steady beat. The first *anchor escapement* used in a mechanical clock was designed by Robert Hooke (1635-1703) around 1657, in London, which catalyzed a rapid succession in clock and watch escapement designs over the next 50 years that revolutionized timekeeping. The development of the escapement by generations of horologists was largely an empirical trial-and-error process. Even today, the understanding of the dynamics of linkages under impact, friction, and other realistic effects, is incomplete. An escapement mechanism is a speed regulator, and it uses feedback to obtain precision operation despite imperfect components. The presence of feedback is realized by the interaction between the escape wheel and the escape arm, which interact according to their relative position and velocity. This interaction can be seen in Fig. 31.1 displaying a verge-and-foliot escapement. The control mechanism consists of an oscillating device (foliot) that prevents the gear train (verge) from rotating, except at specific intervals, when it releases one tooth of the last gear in the train. By controlling the rate of rotation of the gears, it is possible to use this device to measure time by incorporating an indicator and a scale at the end of the shaft of one of the gears.

Phil: The basic mechanism to set the pace is a *pendulum*. Galileo found that the period of oscillation is approximately independent of both the amplitude of vibration and the weight of the pendulum, and only depends on the length L and the acceleration of gravity g: The period is

$$T = 2\pi\sqrt{L/g},$$

so that a pendulum 23 cm long has a period of 1 second. Christiaan Huygens was the first to make a practical pendulum clock, by allowing the verge to

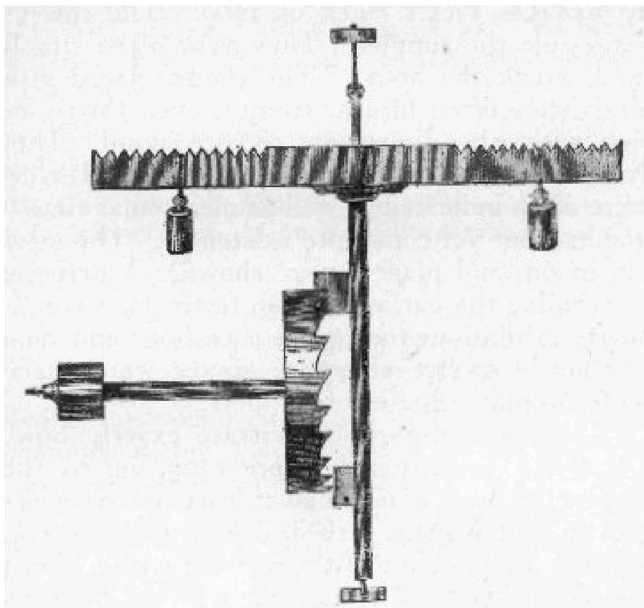


Figure 31.1: Verge (toothed wheel) escapement with foliot (horisontal arm).

drive a pendulum instead of a foliot. The pendulum clock is a stationary clock, and some other oscillator had to make the clock truely portable by a person. Robert Hooke invented the *balance wheel* and *hairspring*, which oscillated reliably even while being moved about (Huygens' invention of 1675 was probably independent). This was really a development of the foliot, rendered oscillatory by the spring.

Phil: Of course the subject of mechanical clocks is endless, and very interesting, but for the moment I hope that we can stick to principles: The period of a pendulum is determined by its length and the force of gravity, and thus can be used to set an objective rate of time. That is enough for me. But of course I would like to understand how you can derive the formula for the period? It includes both pi and a square-root and looks pretty complicated. Is it?

Mat: No it is not. It will be a true pleasure to present the proof, very neat, short and simple. But I will have to keep you in suspension for some time...we have to go step by step very carefully...

Chapter 32

Walking

> Me thinks that the moment my legs begin to move, my thoughts begin to flow. (Henry David Thoreau)

Mat: I have the feeling that the dynamics of walking tells us something about time.

Phil: Could be. Do you mean that the fact that you are advancing forward when you walk, may represent that time is moving forward?

Mat: Yes, that may the connection. The essence of walking is of course to advance, and I guess you do that by slightly leaning forward, so that you tend to fall on your nose, which you compensate by repeatedly taking a step forward.

Phil: You might say that there is a tendency, by the inequilibrium resulting from leaning forward, to move forward, to take another step forward to seek to balance the in-equilibrium. Can you similary see a step forward in time as resulting from a need to balance some form of in-equilibrium? That so to speak the present is leaning forward and to compensate time takes a step forward in search of equilibrium?

Mat: Yes, that is not a bad idea. You can connect it to Principe Perfeito by coupling the idea of easy forward step and a difficult backward step, with the idea that the present is leaning forward. And the in-equilibrium with dissatisfaction. The present is not satisfied, is not in equilibrium, and thus takes a step forward in time in search of equilibrium, and so on.... Yes, what is life but a fruitless search for equilibrium, for satisfaction... until the urge is gone...

Phil: I think we are touching something essential here... By the way, it seems an urge is growing in me, an urge to take another cake. What about you?

Figure 32.1: Principle of walking by (slightly) leaning forward

Chapter 33

Change

> All changes, even the most longed for, have their melancholy; for what we leave behind us is a part of ourselves; we must die to one life before we can enter another. (Anatole France)

Mat: I read in the newspaper that we live in a time of change. Everything is changing, the global climate, telecom, fashion, life styles, moral, you name it. Swedish people are supposed to be particularly open to change.

Phil: Yes, apparently we are living in a changing world, and then it may seem paradoxical to ask, *how* on Earth is change possible. But we should then remember that we were hiding in the caves for about hundred thousand years, before anyone got the idea that anything could be changed. Maybe change after all is something quite delicate?

Mat: You may be right. Maybe perpetual change is in a way contradictory. But we have agreed that time and change are closely related; without change there is no time. So how is it then possible for the arms of a clock to change position indicating that time is passing with one present being replaced by a next present without end?

Phil: This must be the most essential question of all to answer. If we are not capable of changing the way we live, how are we going to cope with the threat of global warming? Or of global terrorism?

Mat: We have said that a system which is not in equilibrium, will have a tendency to change so as to find equilibrium. Everything is seeking equilibrium. Why? Is this a general principle? Probably so, a sort of trivial principle based on semantics. If you are in equilibrium, then you are satisfied and do not seek to change anything, while if you are not in equilibrium then there is something with which you are not satisfied with and since you are a rational being, you will seek to do something about it. If you are not satisfied with the way you look, you will get a face lift done, right? You will seek to change your weary looks. When the apple is no longer satisfied hanging in the air, it will fall to the ground. How can you reduce the energy consumption when at each moment nothing happens?

Phil: But I am quite satisfied. I am in equilibrium. I don't want to change anything. I am perfectly happy.

Mat: Congratulations! But not everyone is as satisfied as you are. There will always be people who are not satisfied and who will seek change.

Phil: I guess you are right. And we have to do something about global warming. So we have to solve Zeno's paradox asking how an arrow can move when it at each instant stands still? How is change possible, when at each instant nothing changes?

Mat: Yes, we will have to come back to that. Right now I feel we have to get some fresh air and open our minds to some fresh input.

Figure 33.1: Possibilities of change.

Chapter 34

Information

> The evidence about Saddam having actual biological and chemical weapons, as opposed to the capability to develop them, has turned out to be wrong. I acknowledge that and accept it. I simply point out, such evidence was agreed by the whole international community, not least because Saddam had used such weapons against his own people and neighboring countries. (Tony Blair, 2004)

Mat: It is natural to view any process as some form of *information processing*. In particular, it is natural to expect a connection between thermodynamics and information theory. This idea was pursued by Claude Shannon (1916-2001) when forming a theoretical basis for *information theory* in his *Mathematical Theory of Communication* from 1948. Shannon gave the concept of *entropy* in thermodynamics an interpretation as a measure of disorder of a string of information to be communicated. Information with a lot of entropy would then require more effort to communicate in terms of signal band-width and/or time.

Phil: Of course, Shannons information theory used the notion of *finite precision of digital information* directly measured by the number of digits in digital representation (like the number of pixels in an image), with a direct connection to the cost of communication.

Mat: The physicist *Rolf Landauer* (1927-1999) stressed the necessity of erasing finite precision digital information, in order not to get drowned by digits, and made an interpretation of the erasure of information as an irreversible increase of entropy. We all know that without erasure, our hard disk will get full, so we understand that Landauer said something important. If you erase information it is will not be possible to recover, so be careful with this operation. But is it really necessary to erase information. Can't you just get a bigger hard disk?

Figure 34.1: The irreversible process of a wave breaking on the shore.

Mat: In an edge stable process, on the border between stability and instability,

(i) *small-scale information* is necessarily produced,

(ii) small-scale information has to get erased.

The novelty is the inevitable production of small-scale information, which reflects the weak stability of an interesting system. This reflects our mantra of "finite precision computation and stability". And small scale information is costly to store because it requires many digits because of the small scales. Get the idea?

Phil: Sure. We know that there are many interesting processes in Nature, and according to our mantra such processes will have to involve erasure of small-scale information in order not to get bogged down and simply stop functioning: The show must go on and cannot be stopped by petty details.

Mat: The braking of a wave on a shore illustrates both (i) and (ii): When a big beautifully shaped wave approaches a shore, it gets steeper and steeper until it finally tips over, and breaks into turbulent mess of small vorticies which "disappear" as the wave recedes.

Phil: Every living creature creates waste, a household produces waste, a society produces a lot of waste, and all this seems impossible to avoid. Life produces waste, and waste consists of small-scale pieces of junk. You have to throw old newspapers not to get drowned in paper, or use them to heat your house, and when you do that you destroy information, irreversibly. Life is an irreversible process because it creates information by destroying information. That is the 2nd Law. In Plato's perfect society, no waste is produced, but this society does not exist. Only the existing society exists, and cannot exist without producing waste. This is an existential question.

Figure 34.2: Recycling of waste

Chapter 35

Capitalistic Economy

> The forces in capitalist society, if left unchecked, tend to make the rich richer and the poor poorer. (Jawaharlal Nehru (1889-1964), Indian Premier Minister)

> The inherent vice of capitalism is the unequal sharing of blessings; the inherent virtue of socialism is the equal sharing of miseries. (Winston Churchill (1874-1965))

> The importance of money flows from it being a link from the present to the future. (John Maynard Keynes)

> Entrepreneurs and their small enterprises are responsible for almost all the economic growth in the United States. (Ronald Reagan)

Phil: We all know that you have to pay interest on a loan, but why is this necessary?

Mat: Because the bank takes a risk lending you money; some great ideas show to be not so great and businesses go bankrupt and some loans are not paid back. We can also make a *reversibility test*: Suppose we change the direction of time in your morgage plan for your house. Then you would *receive the interest* instead of paying it! Wonderful, but you probably say that would be a bit too good to be realistic. It would be like having a *negative interest rate*. The Japanese economy has been approaching zero interest rate, but the rate has remained positive. With a negative interest rate, you would earn more the more debts you would have, which would lead into an exploding spiral of debts and revenues. An economy with negative (or zero) interest rate would be unstable, and thus can not exist over long time.

Phil: So the Arrow of an economy is defined by positive interest rate!

Mat: Yes, a *capitalistic economy* works that way, as compared to a *socialistic plan economy* where the interest rate is zero. In a capitalistic economy individuals or groups of individuals can make money from a (more or less) unique product or service, that is, by *differentiation*. This is Adam Smith's *free-market* system with its *invisible hand*, through which the pursuit of private interest promotes the public good. In a socialistic economy nothing of this is possible, because everybody is equal and differentiation is not allowed.

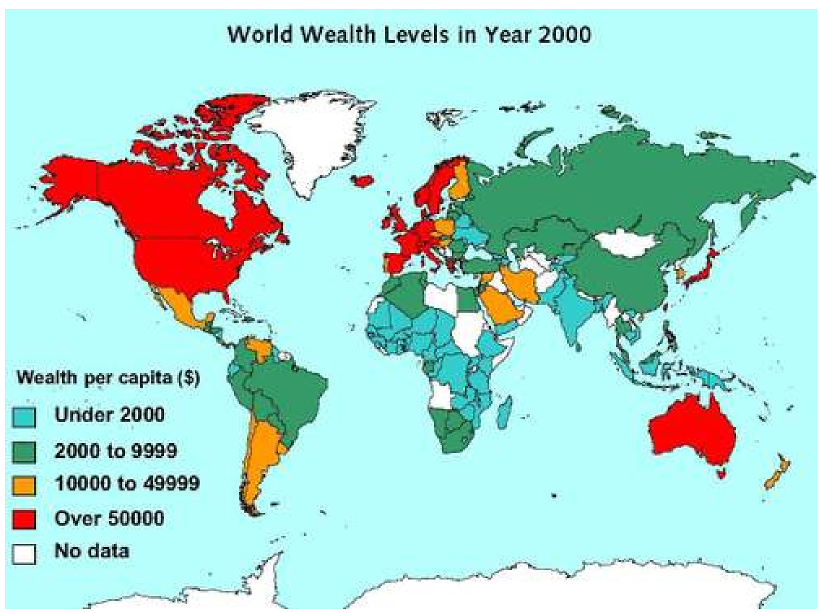


Figure 35.1: World distribution of wealth.

Phil: A capitalistic economy can grow by differentiation through division of labor and specialization, making some people very rich. But stability is an issue.

Mat: The Federal Reserve Bank of New York monitors the interest rate with the aim of generating a steady stable growth. A lower rate will accelerate the economy and a higher rate will slow down the economy, and a zero or

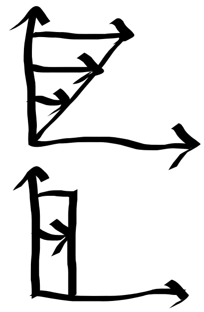


Figure 35.2: Capitalistic vs socialistic economy.

negative rate is not allowed. A capitalistic economy is *edge stable* in the sense that it allows differentiation and controls it by tax and interest. Similarly, the Swedish state allows consumption of alcohol, to make society go round, but seeks to control it by taxes. There is also an aspect of finite precision related to the degree of differentiation which is allowed, which could be measured e.g. by comparing the salary of a CEO with that of an ordinary employee. A capitalistic economy thus is an example of a process combining finite precision and edge stability.

Mat: Differentiation results by increasing initial small differences or fluctuations over time, typically by *migration* or *mixing*. Consider the following basic example: Let us line up 8 runners transversally on a track for a 100m dash, according to their respective speeds, with the fastest runner on track 1 and the slowest on track 8, with a linear distribution in between with 0.1 seconds difference in final time between nearby runners, see Fig. (35.4). Start the dash and assume the runners stay on their tracks. They will then line up at the end with the same linear distribution of speed transversally. If the runners are no longer required to stay on their tracks, a slight displacement during the race can change the transversal ordering at the end, so that the fastest runner ends up next to the slowest. If this happens, then the differentiation has been sharpened from 0.1 to 0.7 seconds by migration only, and not by changing the speeds of the runners. We thus understand that differences may get sharpened by migration. Sharpening of difference can arise by migration from one population into another, of people, goods or ideas. But the sharpness of the difference has to be limited by tax and interest in an open society, and by a Berlin Wall in a closed society.

Phil: So difference feeds difference, or more precisely, large scale difference

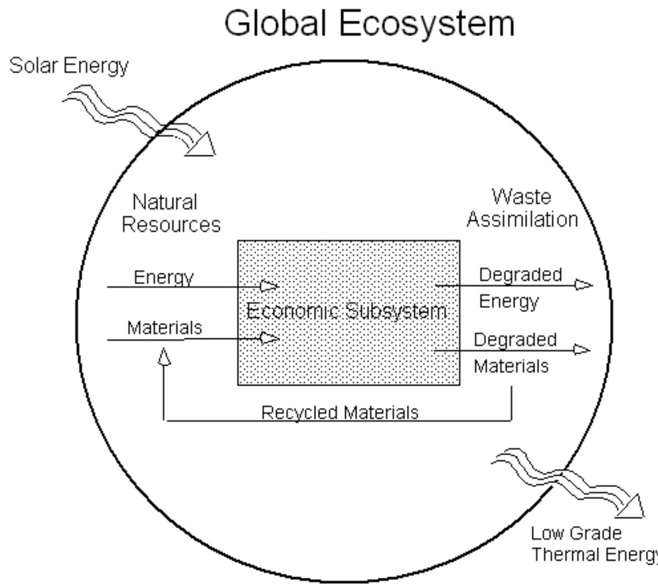


Figure 35.3: Economy as a subsystem of a global ecosystem.

Figure 35.4: Capitalism: Runner 1 to 8 lined up for a 100m dash ordered according to speed, with the fastest runner on track 1 and the slowest on track 8, and with a difference of 0.1 seconds in total time between two consecutive runners and 0.7 seconds difference between runner 1 and 8.

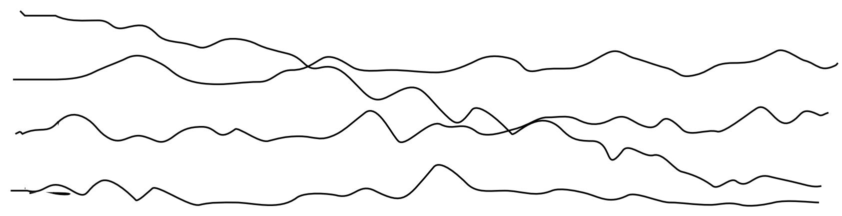


Figure 35.5: Principle of migration: track on top slowly approaches track at the bottom and the relative difference is increased.

opens the possibility of smaller scale difference which opens the possibility to smaller scale difference. A big company is surrounded by a range of of smaller companies all the way down to one-person companies, with each company feeding on the next bigger company in the scale. But there is a limit to the smallness of a company, because at the bottom end just sweat and frustration will come out.

Mat: Yes, big vortices generate smaller vortices on a range of scales down to smallest vortices representing heat.

Chapter 36

Time-Periodic and Cyclic Processes

A *time-periodic* is a process which returns to a previous state after some time and then repeats itself. The seasons variations is a time-periodic process. In a *cyclic process* a substance is moving in a closed loop and returns to a previous location after some time. There are many cyclic processes including

- the flow of money in an economy, see Fig. (36.1),
- the carbon-oxygen cycle, see Fig. (36.2),

The losses in a cyclic or time-periodic process define the Arrow of Time of the process. A lossy periodic or cyclic process is thus irreversible, although it repeats itself. Of course this requires interaction with the environment to compensate for the loss. A closed system, without any interaction with any environment, cannot be both irreversible and period/cyclic, but an open system with interaction can.
Mat: A time-periodic process may be viewed to represent *circular time*, like a classical clock with a period of 12 or 24 hours, while a digital clock can be viewed to represent *linear time* always increasing and never returning.

Phil: You may (conventionally) connect linear time with the psychology of a result-oriented male always seeking to come to a final conclusion at the end of a line, and periodic time with female psychology understanding the dynamics of birth, life, death and new life in a circular process.

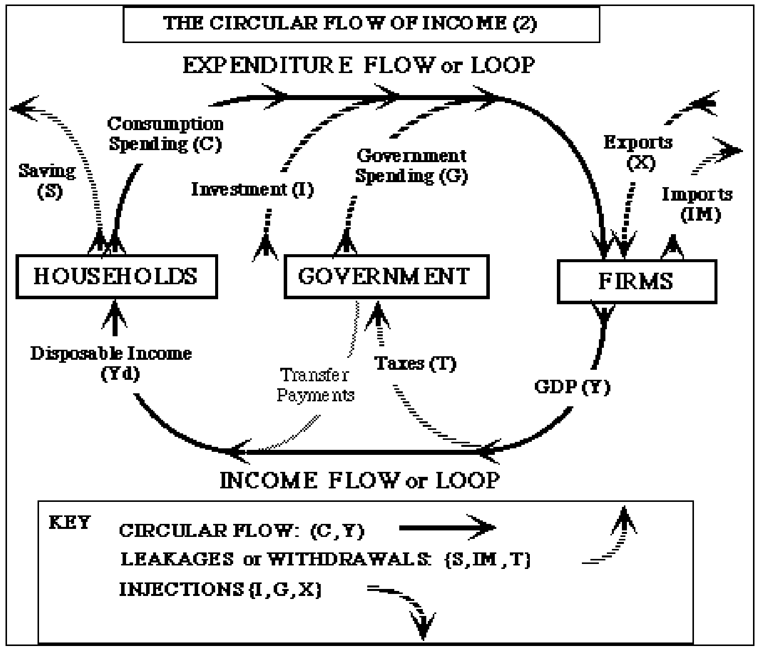


Figure 36.1: Cyclic flow of money.

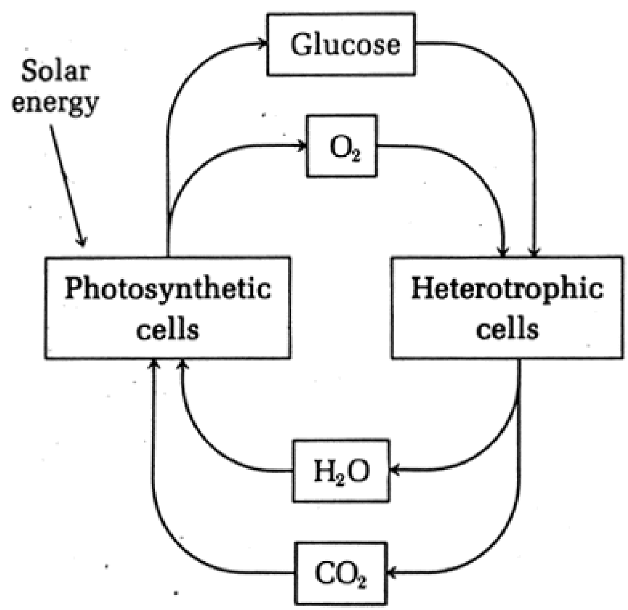


Figure 36.2: The carbon-oxygene cycle

Figure 36.3: Female conception of time.

Figure 36.4: Male conception of time.

Part II

Psychology

Chapter 37

Stream of Consciousness

> In its entirety, probably, it follows us at every instant; all that we have felt, thought and willed from our earliest infancy is there, leaning over the present which is about to join it, pressing against the portals of consciousness that would fain leave it outside. (Henri Bergson)

Phil: Presentism, or eternal presentism, connects to the literary style of *stream of consciousness* also referred to as *interior monologue* pioneered by James Joyce. It is characterized by a flow of thoughts and images, which may not always appear to have a coherent structure or cohesion. The plot line may weave in and out of time and place, carrying the reader through the life span of a character or further along a timeline to incorporate the lives (and thoughts) of characters from other time periods. Writers who create stream-of-consciousness works of literature focus on the emotional and psychological processes that are taking place in the minds of one or more characters. Important character traits are revealed through an exploration of what is going on in the mind.

Mat: Yes, the concept of stream of consciousness was used by William James in 1890 to describe the unbroken flow of thought and awareness of the waking mind, and then got used to describe a special mode of narration that undertakes to capture the full spectrum and the continuous flow of a character's mental process, sense perceptions mingle with conscious and half-conscious thoughts and memories, experiences, feelings and random associations, without resorting to objective description or conventional dialogue. Eduard Dujardin's *Les lauriers sont coupé* is credited by Joyce as the first example of this technique.

Phil: Its forerunner was the psychological novel as exemplified by Marcel Proust's *Remembrance of Things Past*, which had an enormous influence on many such novelists. Another forerunner was Henry James, brother of William James, who created what he called a "central consciousness" or a governing intelligence, a character that he would stay with throughout a story or novel and whose mind we would thus be limited to in our perception of the action of the novel. The subject of these novels often was precisely the inner thoughts and emotions of the character rather than any external events. Long passages would be devoted to the rendition of these inner states of mind, such as in the famous fireside scene in James's *Portrait of A Lady* wherein Isabel must consider her choices.

Mat: The shift in emphasis to the inner lives of characters during the late Victorian period and in the modern period has often been said to be related to a growing shift away from a belief in an independent, absolutely verifiable external reality. The breakdown of religious faith after Darwin and in certain forms of scientific certainty after Heisenberg, Einstein, et al. also paralleled these gradual shifts of emphasis in the arts. A loss of confidence in absolutes, in political authority, scientific authority, religious authority, or indeed even the authority of a unified subject or identity (with the rise of psychology during the 1920s) all can be related to some extent to the shifting practices and innovations in artistic and literary form. Quite a few novels used interior monologue or the free indirect style in their rendition of a central character's perceptions of the world and inner thoughts in response.

Phil: The difference in stream-of-consciousness is that the attempt is to render the thoughts "as they fall" upon the mind (see Woolf's "Modern Fiction"). These thoughts as they fall, in random, free, unstructured, chaotic, and even inchoate or nonverbal form–these are the purest fragments or moments of sensation and being. The novelist using stream-of-consciousness seeks to create the illusion that we are overhearing the flood of sensations and uncensored, pre-rational thoughts within a character's mind before the character has ordered them into any coherent form or shape. Thus the novelist will dispense with grammar, with logic, with neat, orderly sentences and predictable pauses. Joyce lets Molly Bloom run on for one extended sentence of 64 pages in Ulysses. Woolf refers to this aspect of stream of consciousness when she talks to the reader in "Character and Fiction" and says that

- *...in the course of your daily life this past week you have had far stranger and more interesting experiences than the one I have tried to describe.*

You have overheard scraps of talk that filled you with amazement. You have gone to bed at night bewildered by the complexity of your feelings. In one day thousands of ideas have coursed through your brains; thousands of emotions have met, collided, and disappeared in astonishing disorder.

I say "illusion" because the novelist of course does shape this collection of thoughts into the appearance of shapelessness. Woolf in her novels tries to suggest this flood of the daily internal experiences of any ordinary person, an experience wherein *thousands of ideas have coursed through your brains; thousands of emotions have met, collided, and disappeared in astonishing disorder*. Stream of consciousness is the rendition of the astonishing disorder of our minds. I would argue that perception itself becomes the focus of these novels.

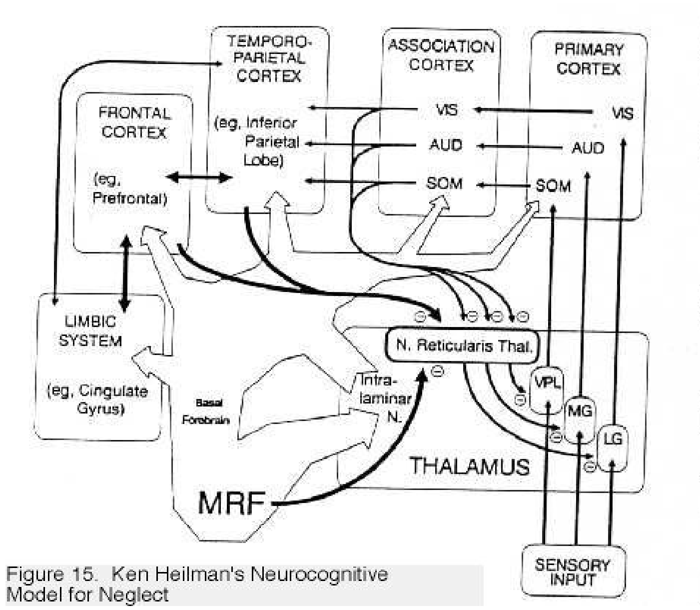


Figure 37.1: Stream of consciousness.

Chapter 38

Memory

> Memory is deceptive because it is colored by today's events. (Einstein)
>
> Memory... is the diary that we all carry about with us. (Oscar Wilde)
>
> Every man's memory is his private literature. (Aldous Huxley)
>
> It's a poor sort of memory that only works backwards. (Lewis Carroll)
>
> I do have a blurred memory of sitting on the stairs and trying over and over again to tie one of my shoelaces, but that is all that comes back to me of school itself. (Roald Dahl)
>
> Their memory's like a train: you can see it getting smaller as it pulls away And the things you can't remember Tell the things you can't forget that History puts a saint in every dream. (Tom Waits)
>
> The life of the dead is placed in the memory of the living. For what is man's lifetime unless the memory of past events is woven with those of earlier ... (Marcus Tullius Cicero)
>
> Memory is the real name of the relation to oneself, or the affect of self on self. (Deleuze, Foucault)

Mat: I think of a memory somehow stored in my brain as some form of image or representation or scent of a *frozen moment* kept to a later time, like a photo kept in a photo album. Or some form of time-sequence of images like a clip of video. It can also be a funny story about a family event kept in

Figure 38.1: Memory allocation of character attributes

the collective memory of the family. To record and store memories, in your brain and your computers hard disk, or more generally information, requires both work and physical space. To maintain stored information requires more work, because stored information has a tendency to degrade. To secure that your hard disk will be kept into the future requires attention.

Phil: Yes, you are right. More precisely, *individual memory* can be viewed to consist of:

- *personal memory* of events in the past, which figure significantly in our self-descriptions, also called episodic memory,
- *cognitive memory* of things we learned in the past, also called semantic, or categorical memory,
- *habit-memory* of capacities to reproduce performances, like riding a bicycle, also called procedural memory.

Collective memory is found in myths, books, images, films, songs.

Mat: Most people do not seem to embrace a offer to relive life very enthousiastically. Why?

Phil: Don't know really. Maybe, simply because it is impossible. If you have any hopes in that direction, you should give it up. But H.G Wells' (1846-1946) *Time Traveller* delivers the following breath-taking report in *The Time Machine*:

- *I am afraid I cannot convey the peculiar sensations of time travelling. They are excessively unpleasant. There is a feeling exactly like that one has upon a switchback–of a helpless headlong motion! I felt the same horrible anticipation, too, of an imminent smash. As I put on pace, night followed day like the flapping of a black wing. The dim suggestion of the laboratory seemed presently to fall away from me, and I saw the sun hopping swiftly across the sky, leaping it every minute, and every minute marking a day. I supposed the laboratory had been destroyed and I had come into the open air. I had a dim impression of scaffolding, but I was already going too fast to be conscious of any moving things. The slowest snail that ever crawled dashed by too fast for me. The twinkling succession of darkness and light was excessively painful to the eye. Then, in the intermittent darknesses, I saw the moon spinning* *swiftly through her quarters from new to full, and had a faint glimpse of the circling stars. Presently, as I went on, still gaining velocity, the palpitation of night and day merged into one continuous grayness; the sky took on a wonderful deepness of blue, a splendid luminous color like that of early twilight; the jerking sun became a streak of fire, a brilliant arch, in space; the moon a fainter fluctuating band; and I could see nothing of the stars, save now and then a brighter circle flickering in the blue.*

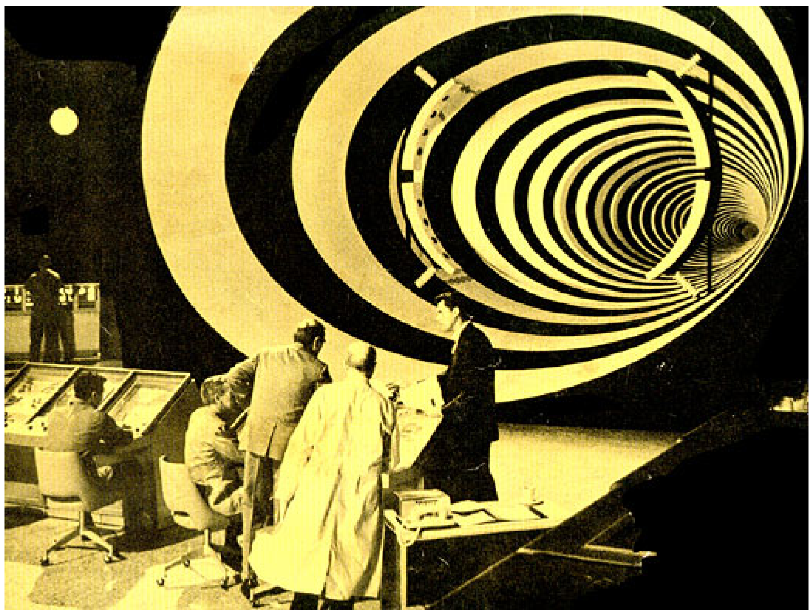


Figure 38.2: Entrance to The Time Travel Machine

Time and memory are true artists; they remold reality nearer to the heart's desire. (John Dewey)

Life is all memory, except for the one present moment that goes by you so quickly you hardly catch it going. (Tennessee Williams)

Yesterday's just a memory, tomorrow is never what it's supposed to be. (Bob Dylan)

The heart's memory eliminates the bad and magnifies the good. (Gabriel Garcia Marquez)

Although computer memory is no longer expensive, there's always a finite size buffer somewhere. When a big piece of news arrives, everybody sends a message to everybody else, and the buffer fills. (Benoit Mandelbrot)

Chapter 39

Duration of the Present?

> The story of life is quicker then the blink of an eye, the story of love is hello, goodbye. (Jimi Hendrix)

Phil: What is the duration of the present? 1 second, 0.1 seconds, the blink of an eye, or something else?

Mat: Yes, you can pose this question, but it does not make sense at least not in a metaphysical sense for a presentist. The present in a metaphysical sense is duration-less or eternal, and is not a snapshot with a certain shutter speed. The present is like a comet dragging along a tail into the past and the length of the comet with tail is endless. A common mistaken argument against presentism is that since our phenomenal present seems to a temporal breadth, so too does the metaphysical present. But this argument conflates the distinction between content and its bearer. A written token of "loud" represents loudness, but the bearer of this content is not itself loud. In the case that interests us, even if we think that the content of our phenomenal present represents past and present things as co-existing, it remains an open question whether our phenomenal present qua bearer of this content has metaphysical extension. A presentist can claim that the bearer is metaphysically duration-less.

Phil: But can't we think of the present as a worm of finite length constantly gaining a segment at one end while losing one at the other. The length of the worm would then be the duration of the present?

Mat: But this is not the way consciousness works; you carry a tail of (more or less bleak) memories from your youth, so the length of your worm is like the tail very long, and thus in a sense duration-less.

Phil: Guess so. Let's talk about something else.

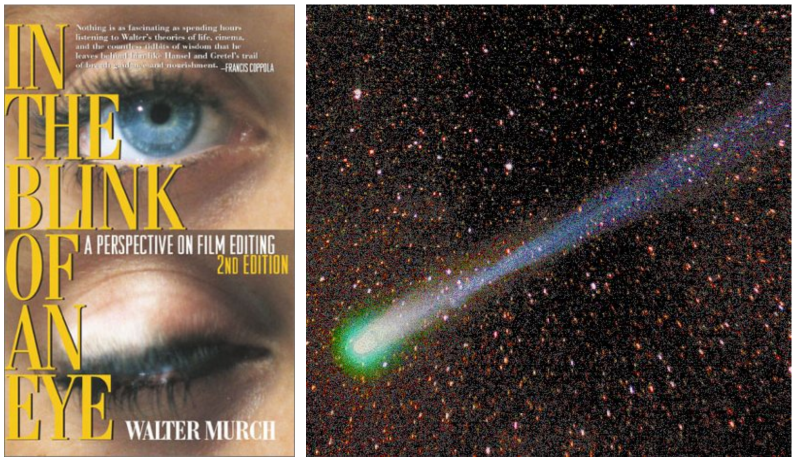


Figure 39.1: The blink of an eye and Hale-Bopp comet with tail.

Figure 39.2: Durationless worm.

Chapter 40

Perceptions of Perception

> To begin with, our perception of the world is deformed, incomplete. Then our memory is selective. Finally, writing transforms. (Claude Simon)

Phil: We get our *perceptions* or *sense impressions* from neurons firing nerve impulses to the brain. When sailing we feel the wind pressure from the impact of air molecules hitting receptors in our skin sending nerve signals into the brain. We see the light of the setting Sun from the stream of photons or light waves entering through the cornea, pupil, lens and vitreous humor, hitting our retina sending electric signals through the optic nerve along the visual pathway to the occipital cortex at the back of the brain, where the electric signals are interpreted as an image. We hear the opera aria as the variations in air pressure generated by the soprano travel through the auditorium into our ears setting through the membrane tiny hair fibres in the inner ear into vibration sending electrical signal to the brain.

Mat: Yes, our senses are marvelous inventions! In all cases it seems as if the "pressure" or intensity of the impression is what we sense. An "impression" is clearly a form of "pressure". It supports the idea that what we directly sense, is the rate of time, rather than time itself.

Phil: True, but of course, our body also contains biological clocks counting accumulated time and not just rate of time. When time passes between meals, we get hungry on some kind of absolute scale, and when we drink alcohol, it is not just the rate of consumption, but also the total consumption and associated level of intoxication, which counts. No doubt about that.

Mat: Yes, this is certainly supported by direct experience. But in jazz music for example, the intense feeling of time flow or “swing” or “groove”, is at best some kind of timeless experience, at least for the listener, if not for the soloist who has to keep track of the number of beats (modulo 12 in a blues) to keep pace with the other musicians.

Phil: The compound eyes of an insect like the fruit fly are made up of repeating units, the ommatidia, each of which functions as a separate visual receptor. Each ommatidium consists of a lens (the front surface of which makes up a single facet), a transparent crystalline cone, light-sensitive visual cells arranged in a radial pattern like the sections of an orange, pigment cells which separate the ommatidium from its neighbors. The pigment cells ensure that only light entering the ommatidium parallel (or almost so) to its long axis reaches the visual cells and triggers nerve impulses. Thus each ommatidium is pointed at just a single area in space and contributes information about only one small area in the field of view. There may be thousands of ommatidia in a compound eye with their facets spread over most of the surface of a hemisphere. One may wonder what perception of reality a fruit fly has, with its multifaceted 360 degree view?

Figure 40.1: Compound eye of *Drosophila melanogaster* (fruit fly).

Chapter 41

Flow

> Got my mojo working, but it just won't work on you
> I wanna love you so bad till I don't know what to do
> I'm going down to Louisiana to get me a mojo hand
> I'm gonna have all you women right here at my command
> Got my mojo working, but it just won't work on you
> Play on!
> Got my mojo working, but it - uh uh - just won't work on you.
> (Got My Mojo Working, Muddy Waters)

Mat: The concept of time is intimately connected to the concept of *flow*. In psychological terms this is described as a state of mind of being completely involved in an activity for its own sake, with the ego fading away with at feeling that "time flies". Every action, movement, and thought follows inevitably from the previous one, as in playing tennis or improvising jazz music, or may playing a computer game. Your whole being is involved, and you're using your skills to the utmost.

Phil: Yes, this is a wonderful state of mind, when you are completely absorbed into something with a strong feeling of fulfillment and satisfaction. Not too easy, not too hard, just at the right level, so that you can use your potential fully without feeling pressed. Something with the endorphins probably.

Mat: Of course, giving the students experiences of flow must be the goal of every teacher. An important aspect in flow is *feed-back*. You are in flow when the feed-back is just right. But you need feed-back. Therefore computer games can put you into a flow experience, while listening to tedious lectures cannot.

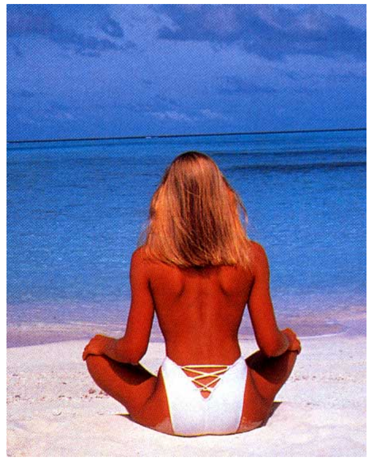


Figure 41.1: Feed-back.

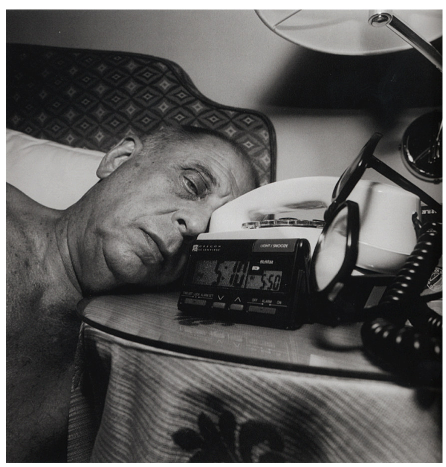


Figure 41.2: Time awareness

Part III

Philosophy

Chapter 42

Parmenides and Herakleitos

> If everything when it occupies an equal space is at rest, and if that which is in locomotion is always occupying such a space at any moment, the flying arrow is therefore motionless. (Aristotle, Physics VI:9, 239b5)

Phil: The debate on time goes back to early Greek philosophy, where you find two radically different views: *Heracleitos* argued for *perpetual change* or *panta rei*, including *time change*, while *Parmenides* maintained there was *no change* and thus neither time nor motion. You can connect Herakleitosperpetual change with Demokritos atomistic theory underlying modern physics. More generally with a "democratic" attitude, where a poor man can get rich and vice versa, and Parmenides no-change with an aristocratic attitude with the noble family forever in control of their castle, land and servants. Aristotle essentially took the position of Herakleitos, and it is logical that Aristotle carefully studied aspects of democracy.

Mat: *Zeno of Elea* (490-430 BC), member of the pre-Socratic Eleatic School founded by Parmenides, questioned the concept of *change* and *motion* in his *arrow paradox*: How can it be that an arrow is moving, when at each time instant it is still? Parmenides and Zenon were followed by Plato seeking a timeless reality without a flow of time towards death. Parmenides argued that if there was Becoming, a thing must grow from nothing into something, which he regarded to be logically impossible. Herakleitos took a different more constructive attitude claiming that

- *All things are in flux.*

- *Becoming is the very essence of life.*
- *You cannot step twice into the same river, for fresh waters are ever flowing in upon you*
- *The sun is new every day.*
- *For it is death to souls to become water, and death to water to become earth. But water comes from earth; and, from water, soul.*
- *The bow is called life, but its work is death.*
- *Time is a child playing draughts, the kingly power is a child's.*
- *Mortals are immortals and immortals are mortals, the one living the other's death and dying the other's life.*
- *God is day and night, winter and summer, war and peace, satiety and hunger; but he takes various shapes, just as fire, when it is mingled with different incenses, is named according to the savor of each.*
- *Fire lives the death of earth, and air lives the death of fire; water lives the death of air, earth that of water.*
- *All things are exchanged for Fire, and Fire for all things as wares are exchanged for gold, and gold for wares.*
- *The beginning and the end are common (to both paths).*
- *It is cold things that become warm, and what is warm that cools; what is wet dries, and the parched is moistened.*

Phil: Evidently, Herakleitos was surprisingly clairvoyant, while Parmenides idealistic denial seems a bit barren. Herakleitos expressed the following profound thruths about science:

- *Dogs bark at every one they do not know.*
- *Nature loves to hide.*

Mat: Yes, you are right. Parmenides no-change idea was abandoned with the scientific and industrial revolution starting with Leibniz' and Newton's *Calculus* in the 17th century, which is the *mathematics of change*. In the industrial society new machines deliver increasing output every year offering ever increasing material wealth to the people, thereby opening to democracy. Democracy without change is impossible, and without (hope of) change to the better, democracy risks to collapse. If seems that the capitalistic system is based on growth of the economy, just like a life without growth is inconceivable.

Phil: On the other hand, and this is what we are facing today in the threat of *global warming*, anything that has the capability to grow also runs the risk of growing too much so that it suffocates. We know that today everybody sings the song of controled growth, not too much and not too little, but very few sing about no-growth.

Mat: In Einstein's theory o relativity theory, developed in the beginning of 20th century as democratic Europe collapsed in the 1st World War, space and time are joined into *space-time* and in space-time there is no real change in time, only seemingly motionless space-time configurations. Thus Parmenides has come back in our time in relativity theory viewed as one of the corner stones of modern physics. The other corner stone is *quantum mechanics*, which rather connects to Herakleitos perpetual change: The *wave functions* of quantum mechanics satisfying *Schrödinger's equation* describe the perpetual motion of electron waves around atomic kernels. Thus modern physics harbors the contrasting contradicting views of Parmenides and Herakleitos, by many witnessed as a crisis.

Phil: Modern physics contradictory? Haven't we already discussed this hang-up of yours? But if you are right, then it is shocking! I thought physics was the science par excellence, certainly without contradictions.

Mat: Yes, this is shocking and in a sense unbelievable. But there is only one possibility: We have to go for democracy with perpetual change, and we must believe that physics can be given a rational foundation. This is our only chance in a hostile and cold Universe under the threat of global warming.

Phil: Speaking about contradictions, we have to address *Zeno's Paradox* of the moving arrow, which at each instant does not move. It is obviously completely basic to our discussion: If the arrow moves or flies, then we may say that *time flows* or *time flies*, and if the arrow stands still, so does must time.

Mat: You are right, the first thing we have to do is to solve Zeno's Paradox. Fortunately, I have a feeling that it can be solved. This is at least what my friend Prof. Dr. Leibschnitzel tells med. Do want to hear?

Phil: Sure, but first another coffee. Waiter, please!

Figure 42.1: *Nude Descending a Staircase* by Marcel Duchamp caused a scandal when first shown in the Armory show in 1912: At each moment the nude is at a fixed position, yet she is descending the stairs.

Figure 42.2: Panta rei.

Chapter 43

Resolution of Zeno's Paradox

> But maybe that is our mistake: maybe there are no particle positions and velocities, but only waves. It is just that we try to fit the waves to our preconceived ideas of positions and velocities. The resulting mismatch is the cause of the apparent unpredictability (Stephen Hawking 1988)

Mat: OK. This is what Prof. Dr. Leibschnitzel has told me: To come to grips with Zeno's paradox, we have to understand what *motion* is.

Phil: So what is it?

Mat: Well, we can say that motion is *change in position* or *change in configuration*: When you lift your coffee cup from the table to your mouth, the cup changes position. You can only take a sip of coffee with the cup at your lips. But yet you say: At each instant the cup stands still, so how on Earth can it move from the table to my lips? That is a tricky question, but it can be answered. To do so we have to go to quantum mechanics of course, since ultimately the question is how on Earth the atoms of the cup with coffee can move in space from the table to your lips? Since quantum mechanics concerns wave functions, we have to understand what the characteristics of a *wave* are.

Phil: It so seems, so what is then a wave? I am really curious!

Mat: Well, you have certainly watched waves in the sea approaching a shore or you have felt waves approaching you when you are swimming or sailing. What is really intriguing about water waves, is that you see a wave moving

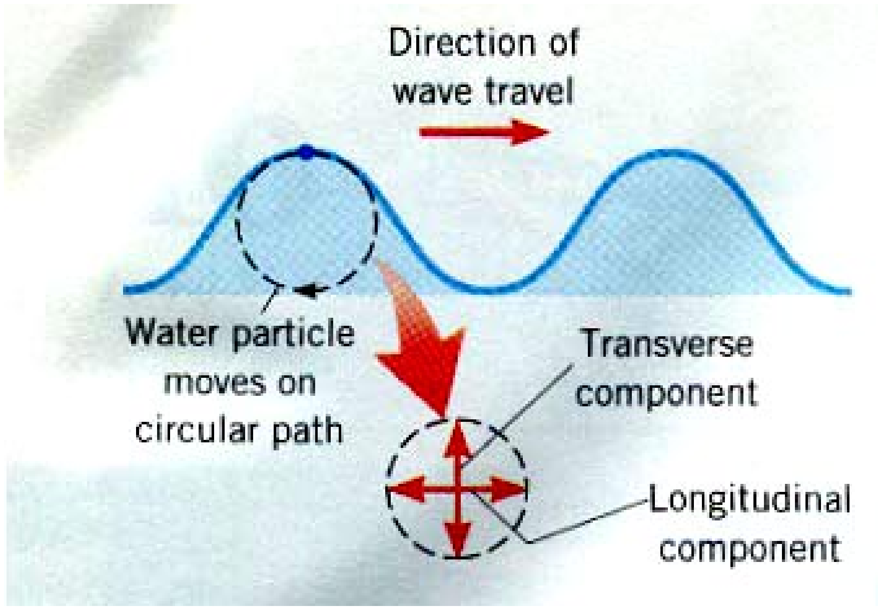


Figure 43.1: A water wave is generated by circular motion of the water molecules. The wave can propagate to right or left without loosing its form.

horizontally, while the particles of water making the wave do not move along with the wave. You may even know that each water particle has a small vertical circular motion, more or less up and down on the spot, and thus does not move horizontally with the wave, see Fig. 43.1. The wave seems to be moving across the surface of the water, but the fluid particles are not moving along with the wave. Motion without motion.

Phil: Yes, I am familiar with this phenomenon: If you fasten one end of a rope to a wall, stretch the rope and shake it quickly, you will see a wave progressing along the rope from your hand towards the wall, and of course no part of the rope itself moves along with that wave: The material of the rope moves up and down a little, more or less like the water particles in a water wave, but the wave moves horizontally. Physics is really quite fascinating, when you get that good feeling that you understand something!

Mat: If we now go back to the quantum mechanics of the atoms of a coffee cup, we can understand that if atoms with their electron clouds are described by a form of wave mechanics, and thus behave like waves, it is conceivable that the motion of an atom would be like the motion of a sea wave and thus not really require any motion of any material, whatever material is. With this perspective atoms would thus move like waves without any corresponding material motion. We thus get by without explaining what material motion is, and that is the beauty of a wave theory like quantum mechanics. Could we thus agree with Parmenides and say that material motion is maybe not possible, or rather that we do not need it and thus do not have to explain it, because a wave can move anyway and thus wave motion is possible?

Phil: OK, I understand what you say, more or less, and of course this suggests a resolution of Zeno's Paradox: The arrow viewed as a wave is moving while the material of the arrow is not moving. It suggests that the arrow rather "appears" at different positions, just as the wave "appears" at different spots, without corresponding motion of material, whatever the meaning of that can be. In a sense the arrow thus "is born" anew at each spot, then dies away, and gets reborn at another spot. The impression we get is that the arrow moves. As a metaphor one could think of an expanding ring of mushrooms above ground carried by an invisible *mycel* below ground. It could then appear as if the mushrooms were moving, but in reality they would not, because the apparent motion would come from new mushrooms appearing at some spots and disappearing at other spots. I think this is a beautiful resolution of Zeno's paradox. Really neat! I like mushrooms.

Mat: So we can agree that change of position is possible in the sense that the arrow can appear at different positions. To connect to the concept of time, we now recall that Aristotle claimed that time is change of position or configuration or rather

- *Time is an aspect of change which can be measured by numbers.*

Thus you can measure time by the change of position of the arms of a clock. A growing child can measure time by his/her length in centimeters, an old male philosopher by the length of his beard, a farmer by the height of the corn in the fields. The time of the day by the height of the Sun et cet. We are thus led to the following operational definition:

- *Time (flow) is what you measure with a clock.*

Phil: OK, let's agree on that for the moment. Another aspect of change of location without material motion, is *teleportation*, in which a material body is somehow "decomposed" into electromagnetic waves which are transmitted over long distance and then "assembled" to the same material body. This is a common way of transportation in science fiction, which has not yet made its way into the tourist industry. Some practical details are still to be resolved.

Mat: Yes, that is a fascinating idea, and maybe it will help on cutting down on energy for transportation in our age of global warming. Of course, there are variants of teleportation which already work very nicely: We can transfer a book from one location to a another quickly and cheaply, by making an electronic copy of the book, sending that copy electronically, and printing it at the destination. Similarly, in principle you can by cloning teleport (a copy of) a living organism by transmitting its genetic code and letting it express itself at the new location.

Phil: So maybe the idea of change of position without material motion is not so crazy after all? This reminds me of the sculpture *Unique Forms of Continuity* from 1913 by the futurist sculptor Umberto Boccioni illustrating the interaction of a moving object with the surrounding space, which Boccioni termed *plastic dynamism: the simultaneous action of the motion characteristic of an object (its absolute motion), mixed with the transformation which the object undergoes in relation to its mobile and immobile environment (its relative motion).*

Mat: I think it is now time for a refreshing walk: Let's take it as an opportunity to study motion and plastic dynamism!

Figure 43.2: Plastic dynamism according to Boccioni.

Chapter 44

Aristotle

> All men by nature desire knowledge. – Change in all things is sweet. – In all things of nature there is something of the marvelous. – Plato is dear to me, but dearer still is truth. – The gods too are fond of a joke. – The secret to humor is surprise. (Aristotle)

Phil: Aristotle ties time to movement or change and tries to find out what in a movement is time. He argues that time manifest itself in the change of things but the change itself is not time: *So time is either change or some aspect of change; and since it is not change, it must be some aspect of change....not only we measure the movement by the time, but also the time by the movement, because they define each other.*

Mat: At first sight this arguments seems of little use: that we measure movement with the aid of time is well known e.g. when measuring speed. Also we record time in terms of movement. The change of the hands of a clock tells us the elapsed time. Aristotle is of course aware of his circular argument. What is then the change that determines time? He argues that there is slow and fast movement but time is the same. The main idea of Aristotle consist in singling out a concrete "bounded" motion: *Now there is locomotion, and as a kind of locomotion, circular motion, and since each thing is counted by one thing of the same kind, and therefore time too by some definite time, and since, as we said, time is measured by change and change by time ...then uniform motion is most of all measure...*

Phil: But which circular motion?

Mat: Aristotle answers: *This is why time is thought to be motion of the celestial sphere, because the other changes are measured by this one, and time by this change.* Aristotle introduces 53 heavenly spheres to explain the motion of the celestial bodies. For him time is defined by the motion of these spheres. Especially by the fix-stars. Without this time can not be measured and therefore there is no time. In a generalized sense one could say that it is the motion of the bodies in the universe which determine time. Not bad as a definition I think.

Phil: Aristotle believed that there was a fifth element beyond earth, air, fire, and water known as *aether*, which rotates around the center of the universe (the Earth) along with the stars thus defining time.

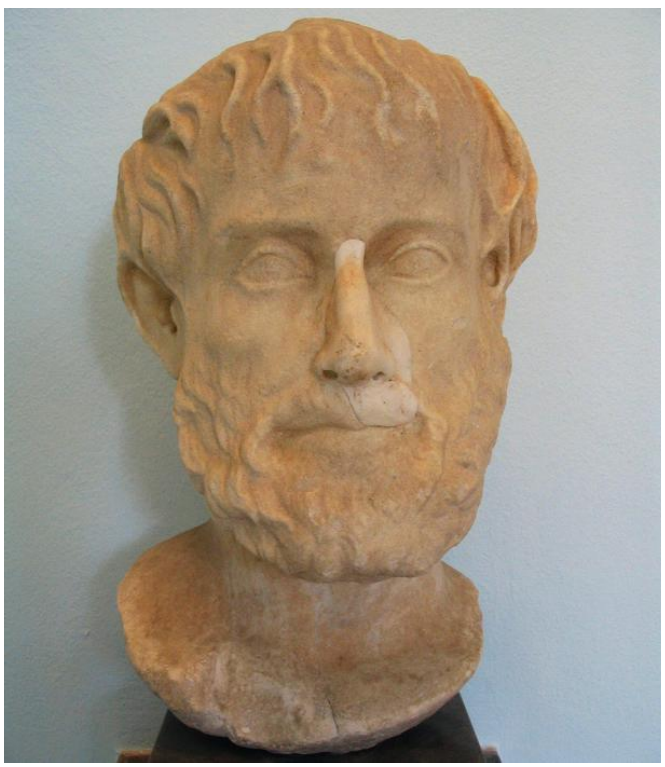


Figure 44.1: Aristotle (Archaeological Museum, Palermo).

Chapter 45

Lucretius

> I teach great things,
> I try to loose men's spirit from the ties,
> Tight-knotted, which religion binds around them.
> The Muses' grace is on me, as I write
> Clear verse about dark matters. This is not
> A senseless affectation; there's reason to it.
> Just as when doctors try to give to children
> A bitter medicine, they rim the cup
> With honey's sweetness, honey's golden flavor,
> To fool the silly little things, as far
> As the lips at least, so that they'll take the bitter
> Dosage, and swallow it down, fooled, but not swindled,
> But brought to health again through double-dealing,
> So now do I, because this doctrine seems
> Too grim for those who never yet have tried it,
> So grim that people shrink from it, I've meant
> To explain the system in a sweeter music,
> To rim the lesson, as it were, with honey,
> Hoping, this way, to hold your mind with verses
> While you are learning all that form, that patter
> Of the way things are. (Lucretius)

Phil: Lucretius' (100-55 BC) *On the Nature of the Universe (De Rerum Natura)* is a remarkable exposition of the materialistic philosophy of Epicuros. Concerning time Lucretius writes in *Book I Matter and Space*:

- *Similarly, time by itself does not exist; but from things themselves there results a sense of what has already taken place, what is now going on and what is to ensue. It must not be claimed that that anyone can sense time by itself apart from the movement of their restful immobility.*

Mat: This is the idea of Aristotle.

Phil: Yes, and Lucretius continues:

- *If there had been no matter and no space or place in which things could happen, no spark of love kindled by the beauty of Tyndareus daughter would ever have stolen into the breast of Phrygian Paris to light that dazzling blaze of pitiless war; no Wooden Horse, unmarked by the sons of Troy, would have set the towers of Ilium aflame through the midnight issues of Greeks from its womb. So you may see that events cannot be said to* **be** *by themselves like matter or in the same sense as space. Rather, you should describe them as accidents of matter, or of the place in which things happen.*

Mat: So Lucretius makes a clear distinction between space and time. Events in time do not *exist* in the same sense as something material *exists* in space. I guess this is an important point.

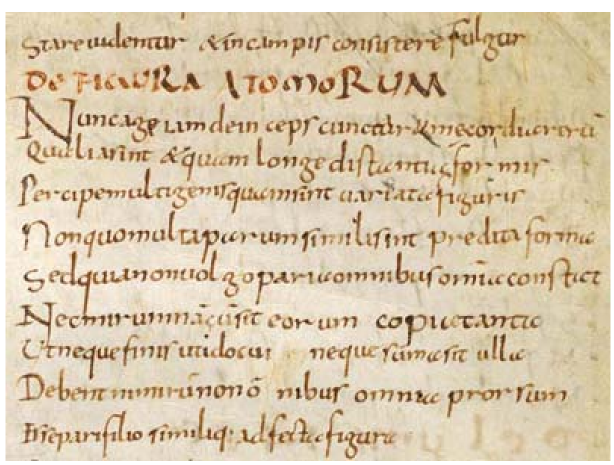


Figure 45.1: De Rerum Natura 2.332-41, as preserved in the 9th century fragmentum Gottorpiense (= codex G).

Phil: Yes, it think so too. In *Book IV Sensation and Sex* he gives the following materiaistic account of love:

- *The one stimulus that evokes human seed from the human body is a human form. As soon as this seed is dislodged from its resting-place, it travels through every member of the body, concentrating at certain reservoirs in the loins, and promptly acts upon the generative organs. These orphans are stimulated and swollen by the seed. Hence follows the will to eject in the direction in which the tyrannical lust is tugging....So when a man is pierced by the shafts of Venus, whether they are launched by a lad with womanish limbs or a woman radiating love from her whole body, he strives towards the source of the wound and craves to be united with it and transmit something of his own substance from body to body.*

Mat: Yeah, I guess this is the way it is, still two thousand years later.

> Nothing can ever be created by divine power out of nothing. – Nature resolves everything into its component atoms and never reduces anything to nothing. – Material objects are of two kinds, atoms and compounds of atoms. – To say, as Herakleitos does, that everything is fire, seems utterly crazy. – What can be a surer guide to the distinction of true from false than our own senses? – If you take a little trouble, you will attain to a thorough understanding of these truths. For one thing will be illumined by another, and eyeless night will not rob you of your road till you have looked into the heart on Nature's darkest mysteries. So surely will facts throw light upon facts. (Lucretius)

Figure 45.2: Copy of De Rerum Natura for Pope Sixtus IV in 1483. De Rerum Natura was long dismissed as the work of an atheist and lunatic, but after the discovery of an early manuscript in 1417 by the humanist and papal secretary Poggio Bracciolini, it circulated widely in Italy.

Chapter 46

St Augustine

> Modo, et modo, non habebent modum. (By-and-by has no end). (St. Augustine)
>
> You mean now? (Yogi Berra, being asked what time it was)
>
> How can you think and hit at the same time? (Yogi Berra)

Phil: The clever St. Augustine criticises Aristotle in his autobiographical *Confessions* referring to the battle of Joshua against the Amorite in the Old Testament:

- *I have heard a learned person say that the movement of the sun, moon, and stars in themselves constitute time. Why should time consist rather of movement of all physical objects? If the heavenly bodies were to cease and a potters wheel were revolving, would there be no time?....Let no one tell me then that time is the movement of heavenly bodies. At a mans prayer the sun stood still, so that the battle could be carried through to victory. The sun stopped but time went on.*

Mat: Yes that is a clever question. But any motion would do to define flow of time, right? Even if the Sun stood still?

Phil: Let me cite from Chapter XIV of Book XI of *Confessions*:

- *There was no time, therefore, when thou hadst not made anything, because thou hadst made time itself. And there are no times that are coeternal with thee, because thou dost abide forever; but if times should abide, they would not be times.*

- *For what is time? Who can easily and briefly explain it? Who can even comprehend it in thought or put the answer into words? Yet is it not true that in conversation we refer to nothing more familiarly or knowingly than time? And surely we understand it when we speak of it; we understand it also when we hear another speak of it.*
- *What, then, is time? If no one asks me, I know what it is. If I wish to explain it to him who asks me, I do not know. Yet I say with confidence that I know that if nothing passed away, there would be no past time; and if nothing were still coming, there would be no future time; and if there were nothing at all, there would be no present time.*
- *But, then, how is it that there are the two times, past and future, when even the past is now no longer and the future is now not yet? But if the present were always present, and did not pass into past time, it obviously would not be time but eternity. If, then, time present– if it be time–comes into existence only because it passes into time past, how can we say that even this is, since the cause of its being is that it will cease to be? Thus, can we not truly say that time is only as it tends toward nonbeing?*

Mat: This is all quite confusing, but probably representative of classical ideas about time and the Arrow.

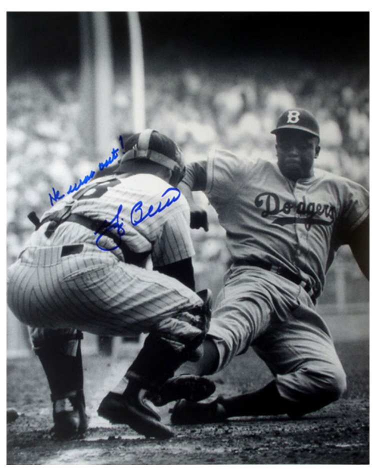


Figure 46.1: Too late, according to Yogi Berra.

Chapter 47

Newton's Absolute Time

> I can calculate the motion of heavenly bodies, but not the madness of people. – I have studied these things, you have not. – Every body continues in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed upon it. – There is one thing stronger than all the armies in the world; and that is an idea whose time has come. (Newton)

Mat: Newton writes in his *Philosophiae Naturalis Principia Mathematica*:

- *Absolute, true, and mathematical time, in and of itself and of its own nature, without reference to anything external, flows uniformly and by another name is called duration. Relative, apparent, and common time is any sensible and external measure (precise or imprecise) of duration by means of motion; such a measure - for example, an hour, a day, a month, a year - is commonly used instead of true time.*

- *It may be that there is no thing as an equable motion, whereby time may be accurately measured. All motion may be accelerated and retarded, but the flow of absolute time is not liable to change.*

Phil: Yes, besides absolute time Newton introduces the concept of absolute space with respect to which motion and rest may be defined unambiguously. For more than 200 years Newtons concept of absolute time served as a fundament for describing physical aspects of nature. Especially in classical celestial mechanics, like the description of the planetary orbits, the prediction of solar and moon eclipses and for describing gravitationally bounded system in general, observations were in excellent agreement with Newton theory of gravity.

Mat: But questions were emerging: In *Mechanik, in ihrer Entwicklung , historisch kritisch dargestellt* from 1883, Ernst Mach argues that Newton does not comply with his own idea to only study the factual:

- *This absolute time can not be read off from any motion, therefore has no practical and scientifically value...we are completely incapable to measure the change of objects with respect to time. Time is an abstraction to which we arrive at by the change of objects because we do not rely on a concrete measure since all are interconnected.*

Thus Mach views absolute time to be a useless construct, but still admits that the interplay of all the components in the universe could respresent some form of universal time.

Mat: Mach is interesting since he is *both* a physicist and philosopher. The *Mach number* measures velocity vs the speed of sound: The supersonic airplane Concorde reached *Mach 2*, that is twice the speed of sound, about 2000 km/hour.

Phil: Mach was only the beginning. A radical revision of the classical concept of time was initiated by Lorentz and Poincaré followed by Einstein combining the previously separated concepts of space and time into the new concept of *space-time* presented to the World by the mathematician Hermann Minkowski at the meeting of the Versammlung Deutscher Naturforscher und Ärzte in 1908:

- *The view of space and time which I wish to lay before you have sprung from the soil of experimental physics, and therein lies their strength. They are radical. Henceforth space itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality.*

Minkowski was inspired by Einstein's 1905 article on *special theory of relativity* putting forward the following two contradictory facts:

- *We have to consider that all our judgments in which time plays a role refer to simultaneous events.*

- *We cannot attach any absolute significance to the concept of simultaneity.*

Einstein thus claims that absolute simultaneity is meaningless and thus also absolute time is meaningless. Newton was crushed.

Phil: Einstein apologized in his famous *Newton forgive me*, but a collapse of absolute time was seen as just one aspect of the general collapse of traditional values during the 1st World War, and the emergence of a new era of *modernity* out of the ashes. A modern man should not believe in absolute time, only in space-time, whatever that meant.

Mat: But the break-through only came after the end of the 1st Worlds War. Initially Einstein was ignored by the scientific community, and Einstein having difficulties in finding an academic job, raised the bet to *general relativity*, which took fire on Dec 6 1919, when Eddington at the Royal Academy of Sciences presented experimental evidence from a Solar eclipse. People went crazy over night for the curved space-time of general relativity.

Phil: But the skepticism to relativity theory was strong into the 1950s, while today it is believed to form the corner stone of modern physics along with quantum mechanics. And general relativity and quantum mechanics seem impossible to combine. Very few claim they understand general relativity, if any.

Mat: General relativity is condensed into *Einstein's equations* equating space-time curvature with mass-density. The idea is that space-time curvature tells mass how to move, and mass tells space-time how to curve. But the equations seem more or less impossible to solve, because of their implicit form, with everything tangled up with everything. To make a prediction using general relativity, you have to solve Einstein's equations, but the equations are virtually impossible to solve and accordingly there are very few predictions which can be checked by experiments. One prediction is the existence of *gravitational waves*, but no such waves have been detected.

Phil: If you find Newton's concept of absolute time difficult to defend, do you then have to accept curved space-time of general relativity, even if you cannot understand it?

Mat: In fact, it seems that absolute time is back again, in the form of *Absolute Time Corrector (ATC)*, which is an award-winning program available on the web, which allows you to synchronize your local PC time using NIST

(National Institute of Standards and Technology) Internet Time Service or LAN time servers. Absolute Time Corrector queries NIST timeservers using Internet and then compares NIST time to the time set on host computer. If there is a disparity, ATC automatically adjusts the computer's time to reflect NIST time. Once set up, the host computer can serve as a timeserver for network of any size. The host can be set to check NIST time as often or seldom as desired, and each computer in the network can likewise be set to check time on the host computer as often as deemed necessary by the network administrator.

Phil: OK, so I don't have to believe in curved space-time, on the ground that there is no absolute time. Evidently, absolute time is today available on the web, while it was not in 1905. That changes the game I guess, and so Newton seems to be back in business. Further, Einstein connects with Aristotle since relativity theory ties the space-time geometry of the Universes to matter and energy, and for Aristotle time is the movement of the celestial spheres. Long live Newton!

Mat: There is an strong element of heroism in the requirement of giving up absolute time. The monumentality of the sacrifice is supposed to guarantee its scientific value and truth. Abstaining from any kind of pleasure, must be admired, because if not it is not worth the sacrifice. Logical?

Figure 47.1: Stephen Hawking: *Newton's law of motion put an end to the idea of absolute position in space. The theory of relativity gets rid of absolute time.*

Chapter 48

Nietzsche

All things are subject to interpretation whichever interpretation prevails at a given time is a function of power and not truth. – Every man is a creative cause of what happens, a primum mobile with an original movement. – Existence really is an imperfect tense that never becomes a present. – It is my ambition to say in ten sentences what others say in a whole book. – Mystical explanations are thought to be deep; the truth is that they are not even shallow. – No one lies so boldly as the man who is indignant. – Of all that is written, I love only what a person has written with his own blood. – People who have given us their complete confidence believe that they have a right to ours. The inference is false, a gift confers no rights. – Plato was a bore. – The best author will be the one who is ashamed to become a writer. – The doer alone learneth. – The man of knowledge must be able not only to love his enemies but also to hate his friends. – The surest way to corrupt a youth is to instruct him to hold in higher esteem those who think alike than those who think differently.– There are no facts, only interpretations. – There are various eyes. Even the Sphinx has eyes: and as a result there are various truths, and as a result there is no truth. – There is more wisdom in your body than in your deepest philosophy. – Thoughts are the shadows of our feelings - always darker, emptier and simpler. – We have art in order not to die of the truth. – Without music, life would be a mistake. – Words are but symbols for the relations of things to one another and to us; nowhere do they touch upon absolute truth. (Nietzsche)

Phil: Nietzsche has influenced post-modern French philosophers such as Derrida, Foucault, Deleuze and Lyotard as concerns emphasis on interpretation and perspective, on becoming and process over being and ontology, and on links between power and knowledge.

Mat: For Nietzsche the question is no longer wether a perspective is "true" or "false", but if the perspective enhances life.

Phil: His *Will to Power* has influenced in particular Foucault to a highly sophisticated analysis of power focussing on *power relations*, the relations of force that operates within social practices and systems. Will and desire play an integral role in directing the relations of power. Deleuze focusses on the willing of power – desire, and introduces a concept of *desiring machine* as a functionalist translation of Nietzsche's will to power.

Mat: What is a desiring machine?

Phil: Something like a functional assemblage of a desiring will and the object desired. Deleuze uses the word *machine* to avoid the personification/subjetification in a substantive will, ego or self. So doing he recognizes that desire and the object desired arise together. Thus desire does not arise in response to a perceived lack, as in Plato's *Symposium* or in Freud's psychoanalysis, but is part of the infrastructure. Desire is productive preceding and producing objects *as* desirable.

Mat: Can we couple this to a desire of the present to change, to move on, to the next present?

Phil: Guess so. That is a dynamic view on time as a form of becoming, from a desire to become. When you were little you always met the question: What will you become when you have grown up? And maybe you answered: I want (desire) to become a scientist, or writer.

Figure 48.1: Nietzsche: *All truly great thoughts are conceived by walking.*

Chapter 49

Kant

> Experience without theory is blind, but theory without experience is mere intellectual play. – Intuition and concepts constitute... the elements of all our knowledge, so that neither concepts without an intuition in some way corresponding to them, nor intuition without concepts, can yield knowledge. – What can I know? What ought I to do? What can I hope? (Kant)

> The idea of time does not originate in the senses but is presupposed by them...Time is not something objective. It is neither substance nor accident nor relation, but a subjective condition, necessary owing to the human mind, of the coordination of all sensibles (experience stimuli) according to a fixed law...(Kant)

Mat: Kant claimed that time is part of our perception of the world programmed into our genes in the struggle for survival. Time is both subjective and objective as a social construction.

Phil: Yes, Kant proposed that the construction of our brain somehow reflects the physical world, and therefore we may, by pure reflection (without a posteriori observation) just using our brains, discover some truth about the physical world. This is referred a *synthetic a priori truth*, while an *analytic truth* results from logic only and does not concern the physical world.

Mat: Of course, our perception of time and the way we may think of time, must be influenced by the design of our brain used for perception and thinking. Kant says that there may be synthetic a priori judgments about time which turn out to be true. Kant is thus led to consider the flow of time as a subjective perception, which may be difficult to rationalize by objective science.

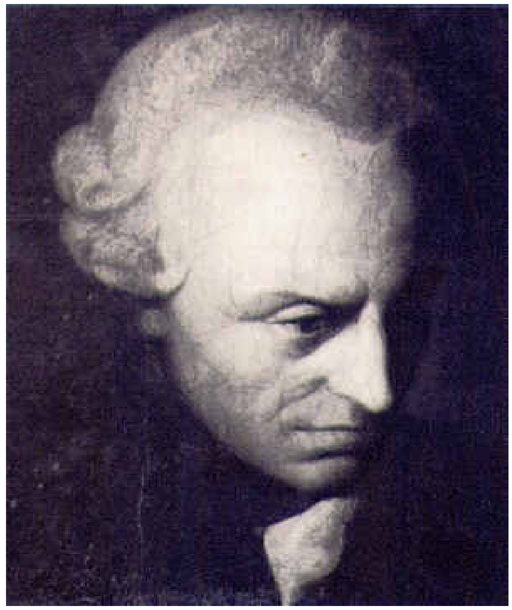


Figure 49.1: Kant: *All our knowledge begins with the senses, proceeds then to the understanding, and ends with reason. There is nothing higher than reason.*

Phil: Yes, the design of our brain with only *one* consciousness per brain, representing some form of tip of an ice-berg of all sorts of unconscious brain activities, of course restricts our conception of time to be (essentially) one-dimensional. It is true that we can listen to the radio, watch the television and talk in our mobile telephone all at the same time, possibly following different time zones, but our conception of this productive activity is (probably) that we *swap* from one medium to the other, and do not really have three independent minds working in parallel. Or? If we believe that we are just one person, and thus do not have a split personality, then we would naturally perceive time as being sequential. This insight could represent a true a priori synthetic judgement.

Mat: Kant's goal in his metaphysical exposition is to show that the presentation of time is not an empirical concept or a discursive concept, but rather is a *pure form of sensible intuition*. If time were a universal concept, then the fact that different times cannot be simultaneous could not be proved by analysis of the concept, since it is a synthetic principle. Kant notes that we can present a sequence of times using the spatial analogy of a line. He draws the conclusion that the presentation of time is an intuition from the fact that it can be presented in space, which has already been established as an intuition.

Phil: Recall that the purpose of a transcendental exposition of a concept is to show how synthetic principles may be based on it a priori. For space, these principles are those of geometry. Time has its own special *axioms of time* such as that time is one-dimensional and that unlike the parts of space, which exist simultaneously, the parts of time exist only sequentially. Kant adds some further principles which depend on time as a form of intuition. These are the concepts of change and motion. Without the presentation of time, we would never be able to form these concepts at all. A change is the combination of two opposed predicates in the same object, something that is forbidden by the principle of contradiction if we cannot assign the having of these predicates to different times. Motion is change of place, so its concept depends on the intuition of time as well.

Mat: Kant says: Arithmetic attains its concepts of numbers by the successive addition of units in time. Kant appeals to the use of five fingers to add five to seven in order to arrive at twelve: Thus, in that image of mine, I gradually add to the number 7 the units that I previously gather together in order to make up the number 5. In this way I see the number 12 arise.

Phil: Difficult to not agree. Kant: As with space, time is said not to be a self-subsistent thing or *a determination or order attaching to things themselves*. As with space, we are told that the only viable account of time is that it is only a *subjective condition* which makes intuition possible. The a priori presentation of space is only a condition for outer intuition, the presentation of spatial objects through the senses. In contrast, the a priori presentation of time is a requirement for all intuition, inner and outer. (Inner intuition is the presentation of our *empirical self*, that is, our mind as it is given to itself, as an object.) Our inner self is presented only in time, while outer objects are presented in space and time.

Mat: Kant claimed that time is ideal in the same sense in which space is ideal. Time does not *attach to things absolutely, as a condition or property*. It is *nothing, if we abstract from the conditions of sensible intuition*. Thus time is a feature of appearances but not things *as such*. It *has objective validity only with regard to appearances, because these are already things considered as objects of our senses*.

Phil: Fair enough. Let's go on.

Chapter 50

Schopenhauer

> After your death you will be what you were before your birth. – All truth passes through three stages. First, it is ridiculed. Second, it is violently opposed. Third, it is accepted as being self-evident. – Buying books would be a good thing if one could also buy the time to read them in: but as a rule the purchase of books is mistaken for the appropriation of their contents. – Music is the melody whose text is the world. – The fundament upon which all our knowledge and learning rests is the inexplicable. – The word of man is the most durable of all material. – The most insignificant presence has over the most significant past the advantage of reality. (Schopenhauer)

Phil: Schopenhauer (1788-1860) was the first Western philosopher to have access to translations of philosophical material from India, both Vedic and Buddhist, by which he was profoundly affected: *It has been the solace of my life, it will be the solace of my death!* With Jung's words:

- *Schopenhauer was the first to speak of the suffering of the world, which visibly and glaringly surrounds us, and of confusion, passion, evil – all those things which the other philosophers hardly seemed to notice and always tried to resolve into all- embracing harmony and comprehensibility. Here at last was a philosopher who had the courage to see that all was not for the best in the fundaments of the universe.*

Mat: The basic distinction in Schopenhauer's metaphysics is between representation and the *thing-in-itself* which is nothing but the *will*, as expressed in his masterpiece *The World as Will and Representation* published 1819. Schopenhauer did not understand the new physics of light and electricity that had been developed by Thomas Young (1773-1829) and Michael Faraday (1791-1867) which he described as *crude materialism, mechanical, Democritean, ponderous, and truly clumsy.* But Schopenhauer would have been happy to learn how his beloved qualitates occultae would return in force with quantum mechanics: Things like strangeness, charm, baryon number, lepton number, etc., are exactly the kinds of irreducible types he demanded.

Phil: The Upanishads posit an identity of the Subject, the Atman or Self, with Brahman, the transcendent Supreme Reality, Being itself. In other words, body with soul. Schopenhauer makes a distinction between the body and the other objects of representation in space and time. For Schopenhauer, the body is known immediately and the perception of other objects is spontaneously projected, in a remaining fragment of Kant's theory of synthesis and perception, from the sensations present in the sense organs of the body onto the external objects understood as the causes of those sensations. The body itself becomes the most immediate manifestation of the will, a direct embodiment of the will-to-live.

Mat: Schopenhauer did not like Hegel, and as lecturer at the University of Berlin in 1820 he scheduled his own lectures to coincide with Hegel's, in an attempt to demolish student support of Hegel's philosophy. However, only five students turned up to Schopenhauer's lectures, and he dropped out of academia, like Leibniz. His late essay *On University Philosophy* expressed his resentments.

Phil: Schopenhauer has influenced many writers including Beckett, Borges, Mann, Musil, Proust, Strindberg, Tolstoy, Zola, who were inspired by his sense of the world's absurdity, from a nihilistic or comic point of view. Bergson and Nietzsche adhered to his views on the meaning of life, and his theory of the non-rational will.

Mat: Schopenhauer's theory of music, along with his emphasis upon artistic genius and the world-as-suffering, was also influential among composers such as Brahms, Dvorak, Mahler, Prokofiev, Rimsky-Korsakoff, Schönberg, and Wagner.

Figure 50.1: Schopenhauer to Hegel: *Change alone is eternal, perpetual, immortal.*

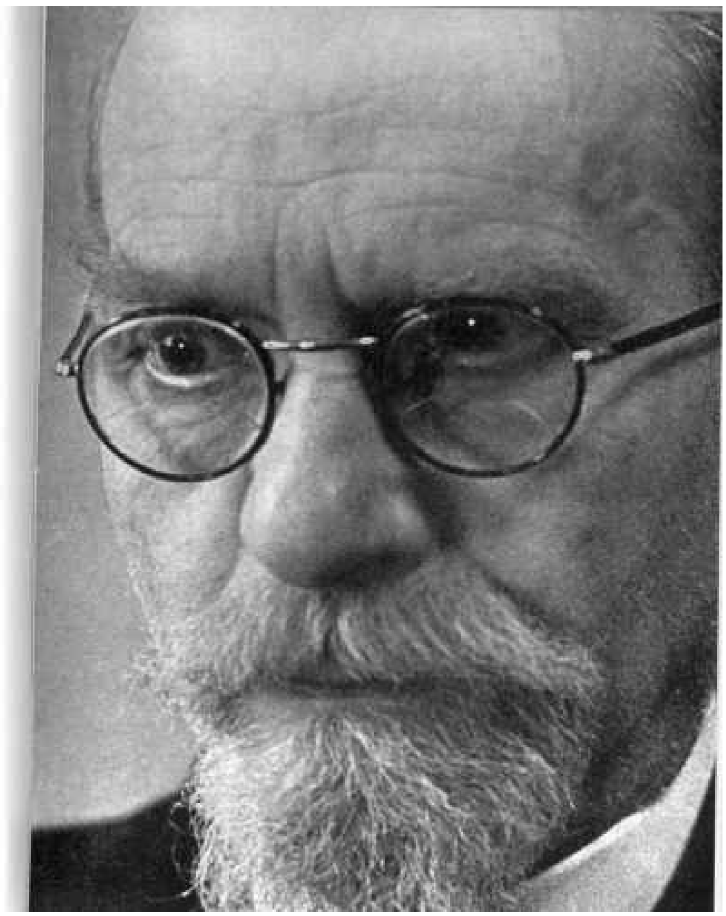


Figure 50.2: Husserl: *Pure phenomenology claims to be the science of pure phenomena. This concept of the phenomenon, which was developed under various names as early as the eighteenth century without being clarified, is what we shall have to deal with first of all.*

Chapter 51

Husserl

> Time-consciousness is the original seat of the constitution of the unity of identity in general. But it is consciousness producing only a general form. The result of temporal constitution is only a universal form of order of succession and a form of co-existence of all immanent data. But form is nothing without content. Thus the syntheses which produce the unity of a f ield of sense are already, so to speak, a higher level of constitutive activity (Husserl in *Experience and judgment; investigations in a genealogy of logic*)

Phil: Edmund Husserl (1859-1938) is the father of *phenomenology* emphasizing subjective experience as the source of knowledge of objective phenomena, and his work influenced Heidegger, Sartre, Carnap, Weyl and Derrida, among others. Husserl introduced the idea of *bracketing* any knowledge of the external world, including causal relations between the world and consciousness, in order to avoid importing considerations from outside consciousness into the investigation of consciousness as such, thus making a distinction between the act of consciousness and the phenomena at which it is directed (the object-in-itself, transcendent to consciousness).

Mat: Note that Husserl started his studies with mathematics under Weierstrass and Kronecker at Leipzig an Berlin, and was then attracted by Brentano's lectures on psychology and philosophy at the University of Vienna and decided to dedicate his life to philosophy. In his first works he tried to combine mathematics, psychology and philosophy with a main goal to provide a sound foundation for mathematics. In particular he analyzes the psychological process needed to obtain the concept of number and then tries to build up a systematical theory on this analysis.

Phil: In *Phänomenologie des inneren Zeitbewusstseins (1928)* Husserl studies our consciousness of temporality, The central pivot is his tripartite structure of temporal consciousness into *protention*, *retention* and and *primal impression*. When listening to a melody, for instance, at any given moment a specific note will be playing. This currently-given-as-new note is the primal impression. But this note is not heard as an isolated note, but as part of a temporally extended whole. The notes that have just been heard remain in consciousness, not as auditory images or echoes, but in what Husserl calls pretension. Retention is a process by which contents are held in consciousness and experienced-as-just-past, after having been given in primal impression when they were experienced-as-present. Part of the explanation for why the third note of the main theme of the final movement of Beethoven's 9th Symphony sounds the way it does is the context which is perceptually available in consciousness, a context provided by retention of the notes that immediately preceded it. Without retention of the preceding notes, the third note would in some sense be the same note in primal impression, but would nevertheless not sound the same. And as time passes, the third note will in turn sink into retention and provide part of the temporal context for the experience of the fourth note. The third element in the tripartite structure of temporality is protention, a process by which anticipations are formed concerning what will shortly be experienced (in primal impression). When I hear the third note, its phenomenal content is conditioned by the expectations I have concerning imminent notes. This is part of the reason that a composition can actually sound different after one hears it several times: protentions get more detailed and hence are able to make more meticulous contributions to the phenomenal content of each phase. Even without specific expectations of upcoming notes, however, protention accompanies the primal impression as a general openness towards imminent experience.

> The relation of experience to time has not been profoundly studied. Its objects are given as being of the present, but the part of time referred to by the datum is a very different thing from the conterminous of the past and future which philosophy denotes by the name Present. The present to which the datum refers is really a part of the past – a recent past – delusively given as being a time that intervenes between the past and the future. Let it be named the specious present, and let the

past, that is given as being the past, be known as the obvious past. All the notes of a bar of a song seem to the listener to be contained in the present. All the changes of place of a meteor seem to the beholder to be contained in the present. At the instant of the termination of such series, no part of the time measured by them seems to be a past. Time, then, considered relatively to human apprehension, consists of four parts, viz., the obvious past, the specious present, the real present, and the future. Omitting the specious present, it consists of three nonentities – the past, which does not exist, the future, which does not exist, and their conterminous, the present; the faculty from which it proceeds lies to us in the fiction of the specious present. (William James, Principles, 609; quoted from Kelly, The Alternative, 167-8)

Figure 51.1: Bergson: *I cannot escape the objection that there is no state of mind, however simple, that does not change every moment.*

Chapter 52

Henri Bergson

> I see plainly how external images influence the image that I call my body: they transmit movement to it. – In just the same way the thousands of successive positions of a runner are contracted into one sole symbolic attitude, which our eye perceives, which art reproduces, and which becomes for everyone the image of a man who runs. – In reality, the past is preserved by itself automatically. – In laughter we always find an unavoved intention to humiliate and consequently to correct our neighbor. – Intelligence is the faculty of making artificial objects, especially tools to make tools. – Sex appeal is the keynote of our civilization. – The present contains nothing more than the past, and what is found in the effect was already in the cause. – There is nothing in philosophy which could not be said in everyday language. – To exist is to change, to change is to mature, to mature is to go on creating oneself endlessly. – Wherever anything lives, there is, open somewhere, a register in which time is being inscribed. (Bergson)

Phil: For Henri Bergson (1859-1941), Nobel Prize in Literature 1927, the essence of life of becoming was the essence of time.

Mat: Don't you recall that we have already discussed this idea? But Bergson is interesting. In *Laughter: An Essay on the Meaning of the Comic* from 1901, he explains that *comedy* arises from the counterparts of the essential elements of life of irreversibility and individuality, that is, comedy results from *repetition* and *inversion*, which represent *mechanized life*. A dancing doll is comical because it mechanically mimics a real dancer. By mechanically putting on a new hat, a person changes character, and this is funny. If you meet a friend in the street accidentally whom you have not seen for an age; there is nothing comic in the situation. However, if you meet the person equally accidentally again the same day, you will find it funny and a third time will be absolutely hilarious. You laugh, because repeated life is surprising and the way to cope with surprise is to laugh. Repeated life is funny because it is a form of mechanized life. A situation is invariably comic when it belongs simultaneously to two altogether independent series of events and is capable of being interpreted in two entirely different meanings at the same time. An everyday situation interpreted equivocally becomes irresistibly funny. All forms of disguise is comical, because individuality is lost, and disguise is possible in mechanized life.

Phil: Bergson argued that the intuition is deeper than the intellect. His *Creative Evolution* (1907) and *Matter and Memory* (1896) attempted to integrate the findings of biological science with a theory of consciousness. Bergson's work was considered the main challenge to the mechanistic view of nature. He anticipated modern scientific theories of the mind in *Creative Evolution*:

- *In reality, the past is preserved by itself automatically. In its entirety, probably, it follows us at every instant; all that we have felt, thought and willed from our earliest infancy is there, leaning over the present which is about to join it, pressing against the portals of consciousness that would fain leave it outside.*

Mat: Bergson's philosophy attracted strong criticism, accused of intuitionism, indeterminism, psychologism and confused interpretation of the scientific impulse. Among those who explicitly criticized Bergson were Russell, Moore, Wittgenstein, Eliot, Gide, Adorno, Sartre, Woolf and Peirce, who wrote:

- *A man who seeks to further science can hardly commit a greater sin than to use the terms of his science without anxious care to use them with strict accuracy; it is not very gratifying to my feelings to be classed along with a Bergson who seems to be doing his prettiest to muddle all distinctions.*

Nevertheless, I believe Bergson was largely misunderstood and in fact was very much on the right track...

Chapter 53

Whitehead

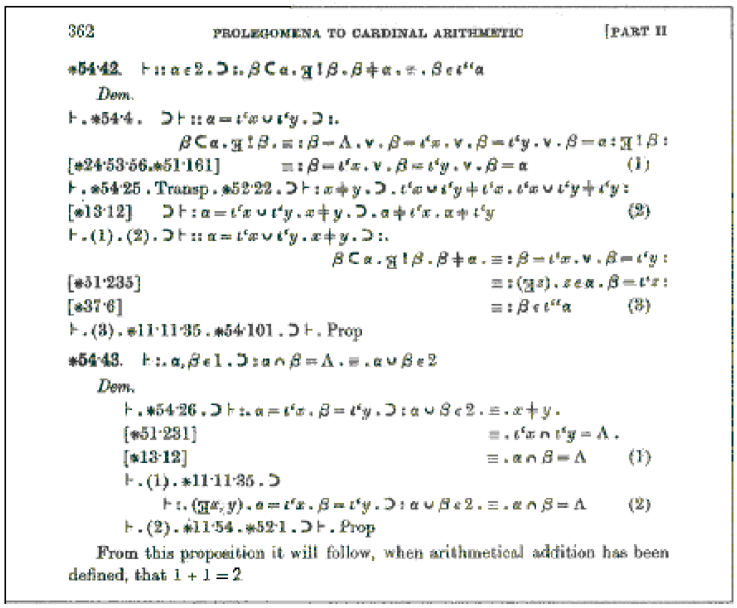
> Almost all new ideas have a certain aspect of foolishness when they are first produced. – Fools act on imagination without knowledge, pedants act on knowledge without imagination. – Not ignorance, but ignorance of ignorance, is the death of knowledge. – Philosophy begins in wonder. And, at the end, when philosophic thought has done its best, the wonder remains. – The art of progress is to preserve order amid change and to preserve change amid order. – Culture is activity of thought, and receptiveness to beauty and humane feeling. Scraps of information have nothing to do with it. – There are no whole truths; all truths are half-truths. It is trying to treat them as whole truths that plays the devil. (Whitehead)

Phil: Alfred North Whitehead (1861-1947) was a mathematician educated in Cambridge, who became a philosopher at Princeton. Together with Bertrand Russell, he coauthored *Principia Mathematica* in three volumes, in a (fruitless) monumental attempt to base mathematics on set theory. To prove that $1 + 1 = 2$ takes about 360 pages of Vol 1.

Mat: Very few have read Principia, even fewer have understood it, and I do not belong to the priviliged. Nobody was willing to print a first edition, but today every major academic library has a copy of this landmark publication.

Phil: Whitehead made a pioneering attempt to synthetize the philosophical underpinnings of physics, in a reaction to the shocking collapse of the Newtonian physics that he had witnessed. He also developed a rival doctrine to

Einstein's general relativity, but lost that battle. In *The Concept of Nature* and *Science and the Modern World* he studies the history of ideas, and the role of science and mathematics in the rise of Western civilization. In *Process and Reality* fom 1929 he founded *process philosophy*, which we have talked about, right? In *The Adventures of Ideas* from 1933 he provides definitions of beauty, truth, art, adventure, and peace, not bad.



362 PROLEGOMENA TO CARDINAL ARITHMETIC [PART II

***54·42.** $\vdash :: \alpha \in 2 . \supset :. \beta \subset \alpha . \exists ! \beta . \beta \neq \alpha . \equiv . \beta \in \iota``\alpha$

Dem.

$\vdash . *54·4 . \supset \vdash :: \alpha = \iota`x \cup \iota`y . \supset :.$

$\beta \subset \alpha . \exists ! \beta . \equiv : \beta = \Lambda . \vee . \beta = \iota`x . \vee . \beta = \iota`y . \vee . \beta = \alpha : \exists ! \beta :$

[*24·53·56.*51·161] $\equiv : \beta = \iota`x . \vee . \beta = \iota`y . \vee . \beta = \alpha$ (1)

$\vdash . *54·25 . \mathrm{Transp} . *52·22 . \supset \vdash : x \neq y . \supset . \iota`x \cup \iota`y \neq \iota`x . \iota`x \cup \iota`y \neq \iota`y :$

[*13·12] $\supset \vdash : \alpha = \iota`x \cup \iota`y . x \neq y . \supset . \alpha \neq \iota`x . \alpha \neq \iota`y$ (2)

$\vdash . (1) . (2) . \supset \vdash :: \alpha = \iota`x \cup \iota`y . x \neq y . \supset :.$

$\beta \subset \alpha . \exists ! \beta . \beta \neq \alpha . \equiv : \beta = \iota`x . \vee . \beta = \iota`y :$

[*51·235] $\equiv : (\exists z) . z \in \alpha . \beta = \iota`z :$

[*37·6] $\equiv : \beta \in \iota``\alpha$ (3)

$\vdash . (3) . *11·11·35 . *54·101 . \supset \vdash .$ Prop

***54·43.** $\vdash :. \alpha, \beta \in 1 . \supset : \alpha \cap \beta = \Lambda . \equiv . \alpha \cup \beta \in 2$

Dem.

$\vdash . *54·26 . \supset \vdash :. \alpha = \iota`x . \beta = \iota`y . \supset : \alpha \cup \beta \in 2 . \equiv . x \neq y .$

[*51·231] $\equiv . \iota`x \cap \iota`y = \Lambda .$

[*13·12] $\equiv . \alpha \cap \beta = \Lambda$ (1)

$\vdash . (1) . *11·11·35 . \supset$

$\vdash :. (\exists x, y) . \alpha = \iota`x . \beta = \iota`y . \supset : \alpha \cup \beta \in 2 . \equiv . \alpha \cap \beta = \Lambda$ (2)

$\vdash . (2) . *11·54 . *52·1 . \supset \vdash .$ Prop

From this proposition it will follow, when arithmetical addition has been defined, that $1 + 1 = 2$

Figure 53.1: Fraction of the proof that $1 + 1 = 2$ in Principia.

Phil: For Whitehead Nature is a process, which is directly exhibited in sense-awareness, but there is no explanation of this characteristic of nature. All that can be done is to use language which may speculatively demonstrate it, and also to express the relation of this factor in nature to other factors. It is an exhibition of the process of nature that each duration happens and passes. The process of nature can also be termed the *passage of nature*, which Bergson calls time. It is in virtue of its passage that nature is always moving on. There is time because there are happenings, and apart from happenings there is nothing.

Phil: Happenings, yes why not? For Whitehead memory is present as an immediate fact for the mind. Accordingly memory is a disengagement of the mind from the mere passage of nature; for what has passed for nature has not passed for mind.

Mat: Whitehead remarks that the materialistic theory has all the completeness of the thought of the middle ages, which had a complete answer to everything, be it in heaven or in hell or in nature. There is a trimness about it, with its instantaneous present, its vanished past, its non-existent future, and its inert matter. He states that this trimness is very medieval and ill accords with brute fact.

Phil: Yes, Whitehead realizes that the past and the future meet and mingle in the ill-defined present, and that it is impossible to meditate on time and the mystery of the creative passage of nature without an overwhelming emotion at the limitations of human intelligence. This is what we have to struggle against.

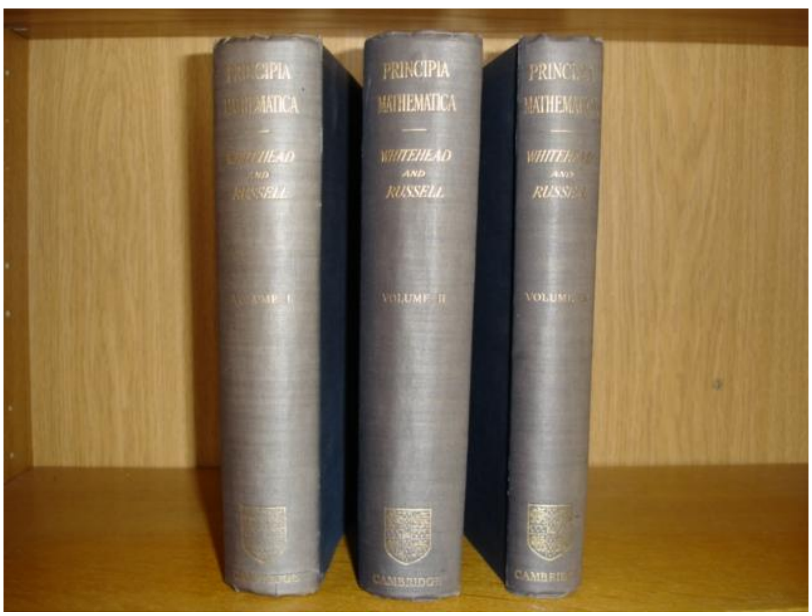


Figure 53.2: Whitehead: *Fundamental progress has to do with the reinterpretation of basic ideas.*

Chapter 54

Russell

> Against my will, in the course of my travels, the belief that everything worth knowing was known at Cambridge gradually wore off. In this respect my travels were very useful to me. – I like mathematics because it is not human and has nothing particular to do with this planet or with the whole accidental universe - because, like Spinoza's God, it won't love us in return. – If any philosopher had been asked for a definition of infinity, he might have produced some unintelligible rigmarole, but he would certainly not have been able to give a definition that had any meaning at all. – It has been said that man is a rational animal. All my life I have been searching for evidence which could support this. – Mathematics may be defined as the subject in which we never know what we are talking about, nor whether what we are saying is true. – Science is what you know, philosophy is what you don't know. – The point of philosophy is to start with something so simple as not to seem worth stating, and to end with something so paradoxical that no one will believe it. (Russell)

Mat: Bertrand Russell (1872-1970), was a British philosopher, historian, logician, mathematician, advocate for social reform, pacifist, rationalist, anti-war activist, championing free trade between nations and anti-imperialism, vigorous proponent of nuclear disarmament, antagonist to communist and nazi totalitarianism and an outspoken critic of the Vietnam War. In 1950, Russell was awarded the Nobel Prize in Literature, *in recognition of his varied and significant writings in which he champions humanitarian ideals and freedom of thought.*

Phil: He won a scholarship in 1890 to read for the famous *Mathematics Tripos* at Trinity College, Cambridge, and came under the influence of Whitehead.

Phil: In his *Our Knowledge of the External World* from 1914 Russell writes:

- *What is an instant? What are the properties we expect of instants? He continues: First, they must form a series; of any two, one must be before the other, and the other must be not before the one; if one is before another, and the other before a third, the first must be before the third. Secondly, every event must be at a certain number of instants; two events are simultaneous if they are at the same instant, and one is before the other if there is an instant, at which the one is, which is earlier than some instant at which the other is. Thirdly, if we assume that there is always some change going on somewhere during the time when any given event persists, the series of instants ought to be compact, i.e. given any two instants, there ought to be other instants between them. We shall say that an event is "at" an instant when it is a member of the group by which the instant is constituted; and we shall say that one instant is before another if the group which is the one instant contains an event which is earlier than, but not simultaneous with, some event in the group which is the other instant. When one event is earlier than, but not simultaneous with another, we shall say that it "wholly precedes" the other. Now we know that of two events which belong to one experience but are not simultaneous, there must be one which wholly precedes the other, and in that case the other cannot also wholly precede the on; we also know that, if one event wholly precedes another, and the other wholly precedes a third, then the first wholly pre- cedes the third. From these facts it is easy to deduce that the instants as we have defined them form a series. We have next to show that...*

Mat: Please stop, I cannot take more of this...

Mat: OK, let me try something different: The correlation of different private times is regulated by the desire to secure the simplest possible statement of the laws of physics, and thus raises rather complicated technical problems; these problems are dealt with by the theory of relativity, and show that it is impossible validly to construct one all-embracing time having any physical significance.

Phil: Aha, so also Russel jumped on to the relativity train with its denial of simultaneity and curved space-time?

Mat: Yes, everybody had to, in order not to appear to be stupid. But not without protest. Russell states:

- *The merging of physical space and time into space- time does not correspond to anything in psychology. Two events which are simultaneous in my experience may be spatially separate in psychical space, e.g. when I see two stars at once. But in physical space these two events are not separated, and indeed they occur in the same place in space-time. Thus in this respect relativity theory has complicated the relation between perception and physics...Physicists, ignorant and temptuous of philosophy, have been content to assume their particles, points, and instants in practice, while conceding, with ironical politeness, that their concepts laid no claim to metaphysical validity. Metaphysicians, obsessed by the idealistic opinion that only mind is real, and the Parmenidean belief that the real is unchanging, repeated one after another the supposed contradictions in the notions of matter, space, and time, and therefore naturally made no endeavor to invent a tenable theory of particles, points, and instants. Psychologists, who have done invaluable work in bringing to light the chaotic nature of the crude materials supplied by non-manipulated sensation, have been ignorant of mathematics and modern logic, and have therefore been content to say that matter, space, and time are "intellectual constructions," without making any attempt to show in detail either how the intellect can construct them, or what secures the practical validity which physics shows them to possess. Philosophers, it is to be hoped, will come to recognize that they cannot achieve any solid success in such problems without some slight knowledge of logic, mathematics, and physics; meanwhile, for want of students with the necessary equipment, this vital problem remains unattempted and unknown.*

Phil: This is not bad. It makes sense, to me at least.

Figure 54.1: Russell: *A truer image of the world, I think, is obtained by picturing things as entering into the stream of time from an eternal world outside, than from a view which regards time as the devouring tyrant of all that is.*

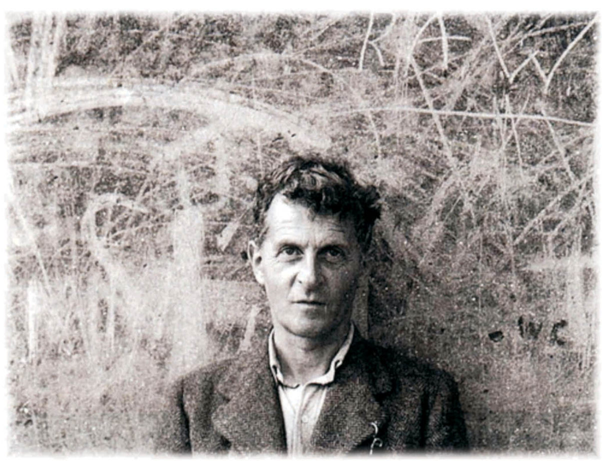


Figure 54.2: Wittgenstein: *If by eternity is understood not endless temporal duration but timelessness, then he lives eternally who lives in the present.*

Chapter 55

Wittgenstein

> Knowledge is in the end based on acknowledgment. – Like everything metaphysical the harmony between thought and reality is to be found in the grammar of the language. – Logic is not a body of doctrine, but a mirror-image of the world. Logic is transcendental. – Never stay up on the barren heights of cleverness, but come down into the green valleys of silliness. – One often makes a remark and only later sees how true it is. – Propositions show what they say: tautologies and contradictions show that they say nothing. – The limits of my language are the limits of my mind. All I know is what I have words for. – The world is the totality of facts, not of things. – Uttering a word is like striking a note on the keyboard of the imagination. (Wittgenstein)

Phil: What does Wittgenstein's famous *Whereof one cannot speak, thereof one must be silent*, say about time? What aspects can we not speak of?

Mat: Let's us see if we can find some hints in his *Tractatus-Logico-Philosophicus*:

- *Space, time and colour (colouredness) are forms of obejcts.*
- *The object is the fixed, the existent; the configuration is the changing, the variable.*
- *The picture is a model of reality.*
- *The totality of true thoughts is a picture of the world.*

- *Philosophy is not one of the natural sciences.*
- *The events of the future cannot be inferred from those of the present.*
- *The freedom of the will consists in the fact that future actions cannot be known now. We could only know them if causality were an inner necessity, like that of logical deduction. – The connexion of knowledge and what is known is that of logical necessity.*
- *Superstition is the belief in the causal nexus.*
- *The world and life are one.*
- *The I occurs in philosophy through the fact that the "world is my world".*
- *If a question can be put at all, then it can also be answered.*
- *Mechanics is an attempt to construct according to a single plan all true propositions which we need for the description of the world.*
- *We cannot compare any process with the "passage of time" – there is no such thing – but only with another process (say, with the movement of the chronometer).*
- *That the sun will rise to-morrow, is an hypothesis; and that means that we do not know whether it will rise.*
- *The temporal immortality of the human soul, that is to say, its eternal survival after death, is not only in no way guaranteed, but this assumption in the first place will not do for us what we always tried to make it do. Is a riddle solved by the fact that I survive for ever? Is this eternal life not as enigmatic as our present one? The solution of the riddle of life in space and time lies outside space and time.*
- *Not how the world is, is the mystical, but that it is.*

Phil: It seems that Wittgenstein has very little to say about time. Why? Because we cannot speak thereof?

Mat: Probably. And nothing really about the Arrow, for the same reason? Is there some other philosopher who says something?

Chapter 56

Baudrillard

> Information can tell us everything. It has all the answers. But they are answers to questions we have not asked, and which doubtless don't even arise. – There is nothing more mysterious than a TV set left on in an empty room. It is even stranger than a man talking to himself or a woman standing dreaming at her stove. It is as if another planet is communicating with you. – You are born modern, you do not become so. (Baudrillard)

Mat: Jean Baudrillard (1929-2007) was a French cultural theorist, philosopher, political commentator, and photographer. His work is frequently associated with postmodernism and post-structuralism. In *Symbolic Exchange and Death* he argued that in the modern information society, simulated virtual reality is replacing reality in a new form of *hyperreality*. This connects to the fable *On Exactitude in Science* by Borges where the map by the perfectionist Cartographers of the Empire eventually becomes so detailed that it covers the whole Empire, which is the beginning of the end:

- *In that Empire, the Art of Cartography attained such Perfection that the map of a single Province occupied the entirety of a City, and the map of the Empire, the entirety of a Province. In time, those Unconscionable Maps no longer satisfied, and the Cartographers Guilds struck a Map of the Empire whose size was that of the Empire, and which coincided point for point with it. The following Generations, who were not so fond of the Study of Cartography as their Forebears had been, saw that that vast Map was Useless, and not without some Pitilessness was it,*

> *that they delivered it up to the Inclemencies of Sun and Winters. In the Deserts of the West, still today, there are Tattered Ruins of that Map, inhabited by Animals and Beggars; in all the Land there is no other Relic of the Disciplines of Geography.*

Phil: Baudrillard followed up on Bergson's idea of the meaning and role of images. Rather than arguing, as did Susan Sontag in her book *On Photography*, that the notion of reality has been complicated by the profusion of images of it, Baudrillard asserted: "the real no longer exists". In so saying, he characterized his philosophical challenge as no longer being the Leibnizian question of:

- *Why is there something, rather than nothing?*

but, instead:

- *Why is there nothing, rather than something?*

Of course our question in this context is if the Arrow of Time is the same in hyperreality as in reality? Of course, you may answer yes, if hyperreality is more real than reality. On the other hand, hyperreality allows time travel in the sense that you can restart a simulation and relive a hyperreal experience as many times you wish. But doing so it will be difficult to deny that each recepetion will make the cells of your body a bit older, and eventually they will cease to function. The question is if this means the end also of your hyper-real self, or if it can continue to exist, like a hyper-real web page of a deceased person?

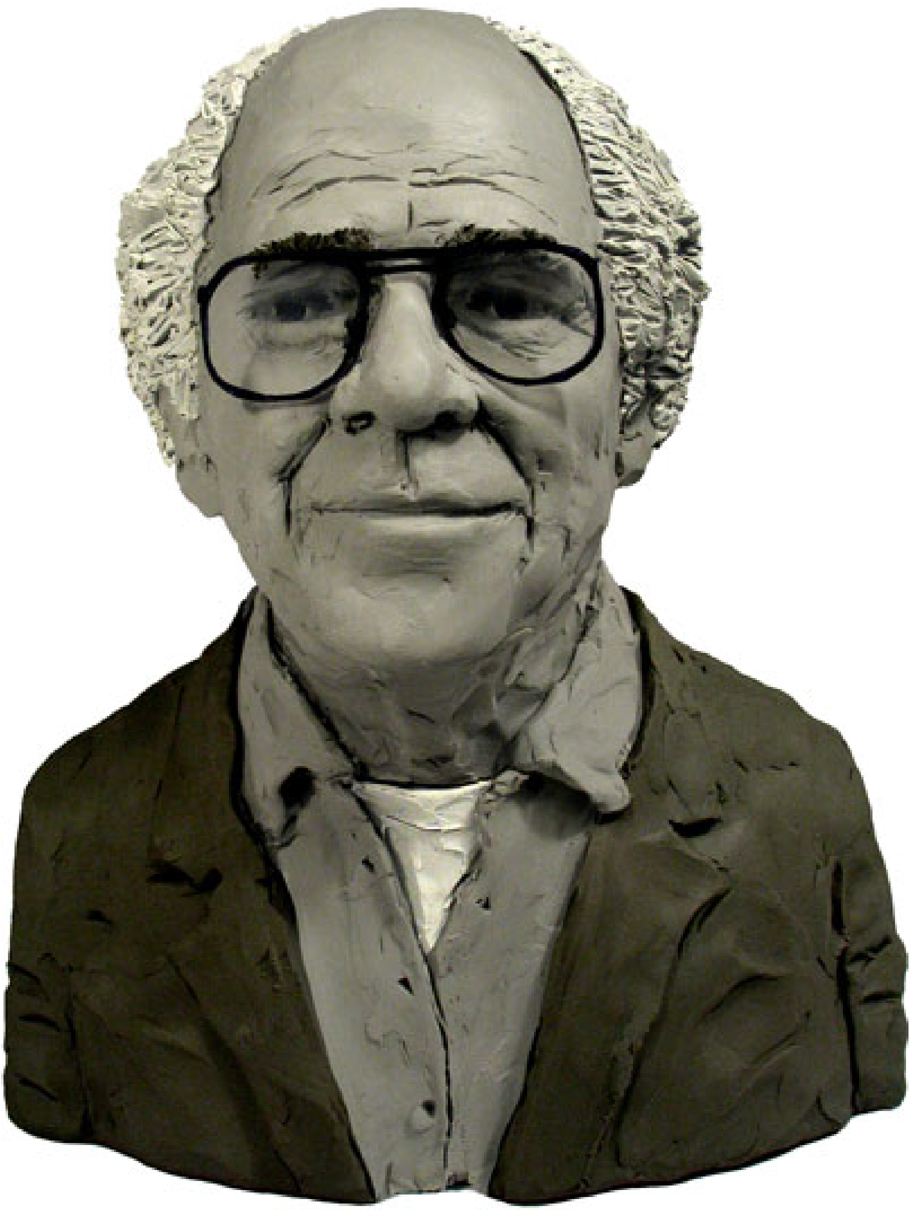


Figure 56.1: Baudrillard: *The great person is ahead of their time, the smart make something out of it, and the blockhead, sets themselves against it.*

Chapter 57

Deleuze

The philosopher creates, he doesn't reflect. (Deleuze)

Phil: The French philosopher Gilles Deleuze (1925-1995) states in his lecture *La Taverne* on Leibniz, connecting to Herakleitos:

- *What you call to die is completing the act of living, and what you call to be born is to start dying, just as what you call to live is to die while living. You don't wait for death to come; rather you are its perpetual companion.*

Deleuze's Ph D thesis *Difference and Repetition* from 1968, led Michel Foucault to declare that "one day, perhaps, this century will be called Deleuzian". Deleuze, for his part, said Foucault's comment was "a joke meant to make people who like us laugh, and make everyone else livid." Deleuze considers the concept of *repetition* in three models of time representing the present, the past and the future: The first is time as a circle. The subject then experiences the passing of moments cyclically (the sun will come up every morning), and contracts habits which make sense of time as a continually living present. Habit is thus the passive synthesis of moments that creates a subject. The second is time as a straight line of successive events. In this model habit has no role, since nothing ever returns, and instead Deleuze introduces memory as an active process of synthesis giving past instances a meaning. Unlike habit, memory does not relate to a present, but to a past which has never been present, since it synthesis from passing moments a form in-itself of things which never existed before the operation. The novels of Marcel Proust are for Deleuze the most profound development of memory as the pure past, or in Proust's terminology, as time regained. In this second model of time, repetition thus has an active sense in line with the synthesis, since it repeats something, in the memory, that did not exist before. The active constitution of a pure past of the second model, and the disparate experience of a present yet to be synthesized of the first model, produces for Deleuze a radical splitting of the subject into two elements, the I of memory, which is only a process of synthesis, and a self of experience, an ego which undergoes experience. In the third and final model, Deleuze proposes to make repetition itself the form of time. In order to do this, Deleuze relates the concepts of difference and repetition to each other. If difference is the essence of that which exists, constituting beings as disparates, then neither of the first two models of time does justice to them, insisting as they do on the possibility and even necessity of synthesizing differences into identities. It is only when beings are repeated as something other, that their disparateness is revealed. Consequently, repetition cannot be understood as a repetition of the same, and becomes liberated from subjugation under the demands of traditional philosophy.

Mat: To give body to the conception of repetition as the pure form of time, Deleuze turns to the Nietzschean concept of the *eternal return*, which is not is not the circle of habit allowing only the return of something already existing. While thus habit returned the same in each instance, and memory dealt with the creation of identity in order to allow experience to be remembered, the eternal return is the repetition of becoming being and thus represents the time of the future.

Figure 57.1: Reflections of Deleuze

Chapter 58

Reichenbach

> He was convinced that he had achieved a solution of the problem of the direction of time. (Maria Reichenbach in the Preface to *The Direction of Time* by her husband.)

Phil: Hans Reichenbach (1891-1953) was a leading philosopher of science, educator, proponent of logical empiricism and founder of the Berlin Circle: Society of Empirical Philosophy. He gained notice for his methods of teaching. Specifically, he was easily approached and his courses were open to discussion and debate, highly unusual in his time. In 1930 he and Rudolf Carnap began editing the journal Erkenntnis ("Knowledge"). In 1933, when Adolf Hitler became Chancellor of Germany, Reichenbach emigrated to Turkey, where he headed the Department of Philosophy at the University of Istanbul. He introduced interdisciplinary seminars and courses on scientific subjects, and in 1935 he published *The Theory of Probability.* In 1938, with the help of Charles Morris, he moved to the United States to take up a professorship at the University of California, Los Angeles. His work on the philosophical foundations of quantum mechanics was published in 1944, followed by *Elements of Symbolic Logic* and *The Rise of Scientific Philosophy.* He died on April 9, 1953 in Los Angeles while working on problems in the philosophy of time and on the nature of scientific laws published posthumously as *The Direction of Time.* Let me cite from this book:

- *The problem of time has always baffled the human mind.*
- *The study of time is a problem of physics.*

- *Einstein's and Minkowski's timeless universe is a four-dimensional Parmenidean Being, in which nothing happens, "complete, immovable, without end...; is is all at once, a continuous one". Time flow is an illusion, Becoming is an illusion; it is the way we human beings experience time, but there is nothing in nature which corresponds to this experience.*

- *It is a hopeless enterprise to search for the nature of time without studying physics. If there is a solution to the philosophical problem of time, it is written in the equations of mathematical physics.*

- *The direction of time is thus explained as a statistical trend; the act of Becoming is the transition from the improbable to probable configurations of molecules*

- *Transitions to lower entropy are as frequent as those to higher entropy; and this is the statement of the reversibility objection.*

What do you say about this?

Mat: Reichenbach correctly identifies the weakness of the position of the Eliatic school of Parmenides and Zeno that change is impossible, as well as Kant's subjective time, and he also raises the reversibility objection to Boltzmann's statistics.

Phil: The gist of *The Direction of Time* is to come to grips with the reversibility objection, and thus rationalize once and for all Boltzmann's statistical mechanics. However, the manuscript was left unfinished on his desk at the time of his sudden death in 1953, indicating that a life time was not enough to find a solution... It was published post-humously by his wife. by statistics.

Part IV

Arts and Literature

Chapter 59

Language

> Nostalgia is like a grammar lesson: You find the present tense and the past perfect.
>
> We should have a great fewer disputes in the world if words were taken for what they are, the signs of our ideas only, and not for things themselves. (Locke)
>
> It is a safe rule to apply that, when a mathematical or philosophical author writes with a misty profundity, he is talking nonsense. (Whitehead)

Mat: What does language tell us about time or rather about our concept of time? In school we learn that verbs can have three basics tenses: *preterite*, *presens* and *futurum* describing the past, present and future of the A-theory. Presumable reflecting the way our brains function in the spirit of Kant?

Phil: Could be. But in Chinese verbs do not have tenses; instead temporal adverbs are used when needed. English (like Swedish) has really only two tenses, the nonpast tense (present tense) and the past tense (indicated by ablaut or ending in -ed). Many languages including English have grammatical forms expressing the aspect of *prior*: past perfect/pluperfect (I had gone), present perfect (I have gone), future perfect (I will have gone); the aspect of *complete*: simple past/preterite (I went), simple present (I go), (simple) future (I will go); and the aspect of *incomplete*: past continuous (I was going), present continuous (I am going), future continuous (I will be going). You also have conditional (I would go) and imperfect (I used to go).

Mat: In French you have passé simple, passé composé, plus-que-parfait (indicatif / subjonctif), passé antérieur, futur antérieur, temps périphrastiques, temps surcomposés. It is quite complicated indeed. Is it because the concept of time is so multi-faceted and complex?

Phil: Probably. Tenses can be broadly classified as *absolute* indicating time in relationship to the time of the utterance and *relative* indicating another time than the time of utterance. Many languages define tense not just in terms of past/future/present, but also in terms of how far into the past or future they are. Thus they introduce concepts of closeness or remoteness, or tenses that are relevant to the measurement of time into days (hodiernal or hesternal tenses). Some languages also distinguish not just between past, present, and future, but also non-past, non-present, non-future. Each of these latter tenses incorporates two of the former, without specifying which.

Mat: How does language handle the Arrow?

Phil: Well, it allows you to express that certain processes can be reversed, in English by adding the prefix "un". You can sharpen and unsharpen a pen. You can do and undo something. But you cannot unsay, what you have once said. If you said something unpolite (or impolite) hurting somebody, you can try to repair it by excusing yourself and asking for pardon, but it is not sure that it will work. So language acknowledges that certain processes can be reversed and others not.

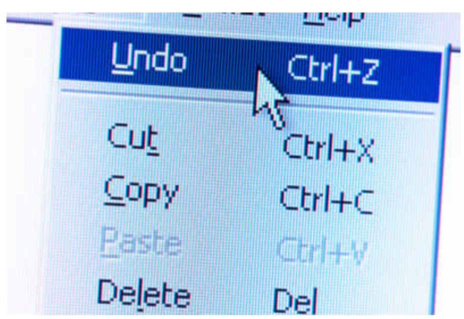


Figure 59.1: The undo command.

Chapter 60

Time Transfixed

Time is but the stream I go a-fishing in. (Henry David Thoreau)

Each morning when I awake, I experience again a supreme pleasure - that of being Salvador Dali. — The difference between false memories and true ones is the same as for jewels: it is always the false ones that look the most real, the most brilliant. (Dali)

If the dream is a translation of waking life, waking life is also a translation of the dream. — Everything we see hides another thing, we always want to see what is hidden by what we see. (Magritte)

Figure 60.1: Persistence of Memory and Disintegration of Persistence of Memory according to Dali

Phil: You can interprete Dali's melting clocks as expressing the vanishing present moment as well as the vanishing past moment or memory.

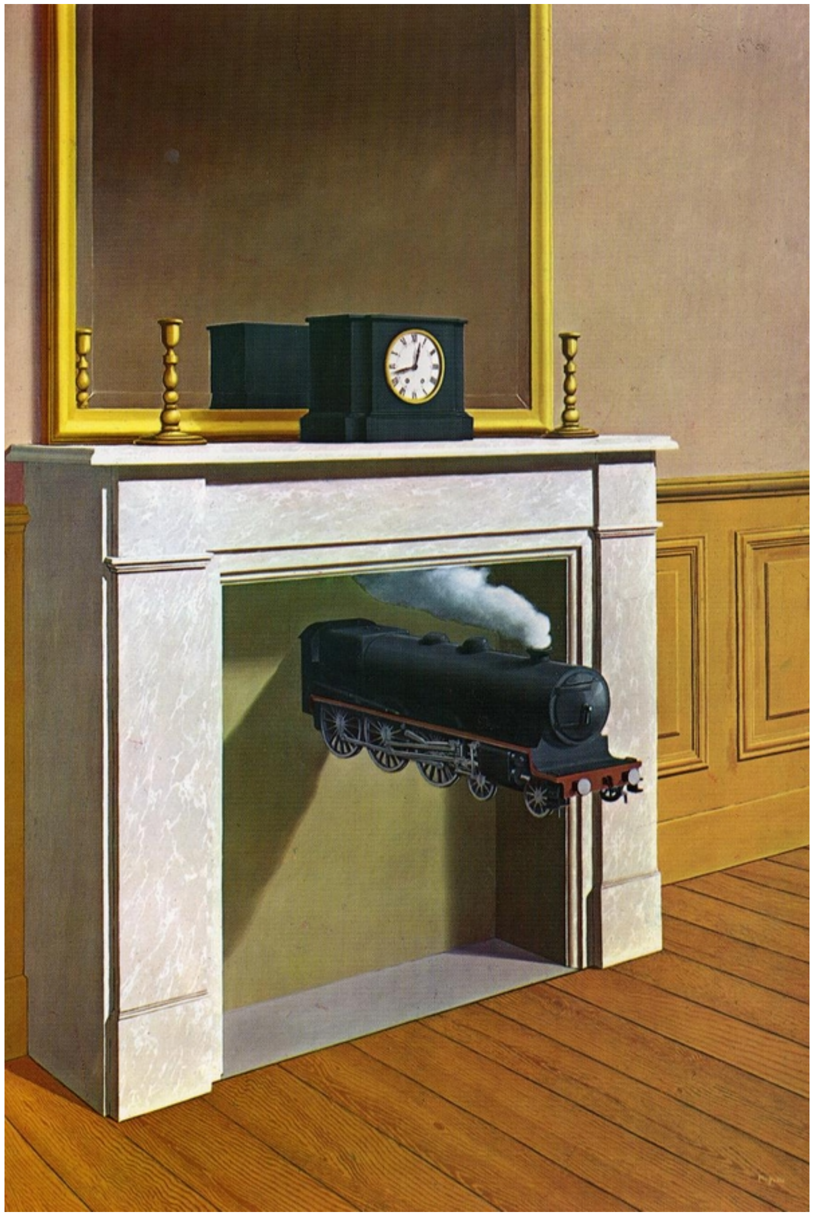


Figure 60.2: *Time Transfixed* by Magritte

Mat: Magritte combined the motion of a train with the fixed reading of clock thus juxtaposing the flow of time and fixed time in his remarkable *Time Transfixed* or *La Durée poignardée*, which literally means *Ongoing Time stabbed by a dagger*.

Phil: Time stabbed by a dagger? It reminds me about *nature morte*, or *stilleben*, or *still life*. Nature morte as a (dead) present would thus result from stabbing or freezing ongoing time. Rather interesting!

Mat: Yes, it suggests that the flow of time is alive, while the present is dead. I think this says something of interest.

Phil: You know, modern art and modern physics both emerged from the collapse of traditional values in the beginning of the 20th century leading into the First World War. In Einstein's theory of relativity, classical Newtonian mechanics of space and time is decomposed into isolated space-time "events", which in cubist paintings is represented by decomposition or fragmentation of impressions.

Mat: Isn't this like the modern way of looking at television where you swap between 100 channels sending 100 films, thus destroying the steady flow of time in a classical Newtonian world from beginning to end. You can swap between channels and movies, but you cannot really swap back and forth in real life. But the distinction between real and imaginary life is becoming increasingly unclear in the hyper-reality of post-modern society...

Chapter 61

Photography and Portraits

> Clocks slay time... time is dead as long as it is being clicked off by little wheels; only when the clock stops does time come to life. (William Faulkner)

Mat: What about the *snap shot* or *frozen moment* supposedly captured in a *photo*? Is it an infinitely thin *cut through time*? Does it tell us something about time? Did the the concept of *time cut* or time instant exist before the photo? The idea that time consists of a collection of infinitely short instants?

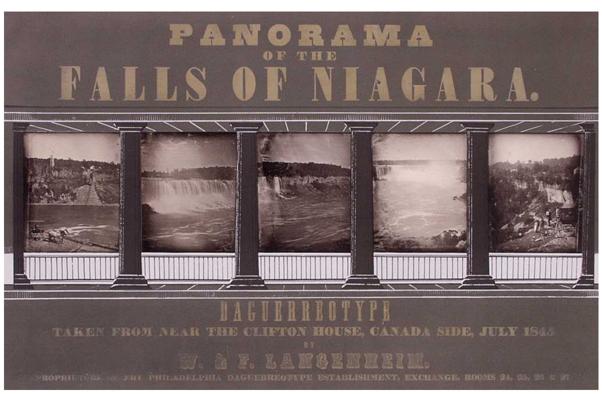


Figure 61.1: Daguerrotype of Niagra Falls

Phil: Good questions. Evidently photos exist, and probably so the idea of frozen moment or cut. We are now flooded with digital photos from digital cameras now on every mobile telephone, capturing the instant moment. It is surprising that photography was not invented earlier than the 1830s, because the *Camera Obscura* had been in existence for at least four hundred years, used by Leonardo da Vinci as an aid to drawing, and already in the sixteen hundreds Robert Boyle, a founder of the Royal Society, had reported that silver chloride turned dark under exposure. But maybe there was no demand of photos of instant moments. The first successful photo was produced in June/July 1827 by Niépce, using material that hardened on exposure to light. The time of exposure was eight hours, and thus hardly a snap shot or frozen moment.

Mat: You know, Louis Daguerre discovered a way of developing photographic plates, reducing the exposure time from eight hours down to half an hour, and that an image could be made permanent by immersing it in salt. The invention called *Daguerreotype requires no knowledge of drawing....anyone may succeed and perform as well as the author of the invention*, and was greeted with enormous interest, and *Daguerreomania* became a craze overnight.

Figure 61.2: Snap shot

Phil: Yes, but there was also a considerable scepticism like in Leipzig City Advertizer: *The wish to capture evanescent reflections is not only impossible... but the mere desire alone, the will to do so, is blasphemy. God created man in His own image, and no man- made machine may fix the image of God. Is it possible that God should have abandoned His eternal principles, and allowed a Frenchman... to give to the world an invention of the Devil*? Many artists saw in photography a threat to their livelihood (see Artists and

Photography), and some even prophesied that painting would cease to exist. Also recall that Islam forbids pictures of people in general and of Mohammad in particular including charicatures...

Mat: The development of mass-printed photos, from negatives, was then quick. On Regent Street in London there were in the 1850s more than 40 photographic establishments, and in New York 77 photographic galleries. The demand for photographs was such that Charles Baudelaire (1826-1867), a well known poet of the period and a critic of the medium, commented *our squalid society has rushed, Narcissus to a man, to gloat at its trivial image on a scrap of metal*.

Phil: The photo has transformed the way we perceive reality. It has given us the impression that time as a sequence of instants, but the question is if this is a good picture of reality and time. We know that today the digital camera can also record video sequences, and maybe the still image is only a parenthesis in the development of human civilization and concepts of reality. Maybe people will watch video sequences on Youtube, while still images will collect dust in forgotten photo albums and museums. Maybe we may return to a more realistic dynamic perception of time flow rather than illusionary frozen instants of absolute time? I will put my money on Youtube and throw away my old Instamatic!

Mat: I guess you are right. Time is dead, long live time flow!

Phil: The art of portrait painting probably tells us something about time. A portrait is supposed to capture the timeless character of the person. The smile of Mona-Lisa is timeless, but not without motion. Timeless motion. da Vinci uses a painting technique called *sfumato* (smoky) in Italian around the mouth and eyes, which overlays translucent layers of colour to create perceptions of depth, volume and form. Does the smile result from the shadows or the shadows from the smile?

Mat: Don't know. It may be interesting to analyze the role of time in portrait painting during different periods. During the baroque and rococo periods portraits were important as symbols of (timeless) power and wealth, but artists increasingly studied the facial expressions that accompanied different (timeless) emotions and human feelings Romantic artists during the first half of the 19th century brought in time flow in exciting portraits of inspired leaders and agitated subjects, using lively brush strokes and dramatic lighting. Cubist portraits often have a timeless character, while one

Figure 61.3: Portrait by Velazquez and of Churchill

form of expressionism is time flow. Francis Bacon's figures are tortured in timeless motion, while Lucian Freud's figures like Henry Moore's sculptures are resting.

Phil: Another example of timeless motion is the ballet jump or *Grand Jeté*, with the ballet dancer seemingly hanging in the air for an eternity.

Mat: It seems that a portrait is timeless, tenseless, in contrast to a tensed snapshot. A portrait is supposed to depict the timeless character of a person.

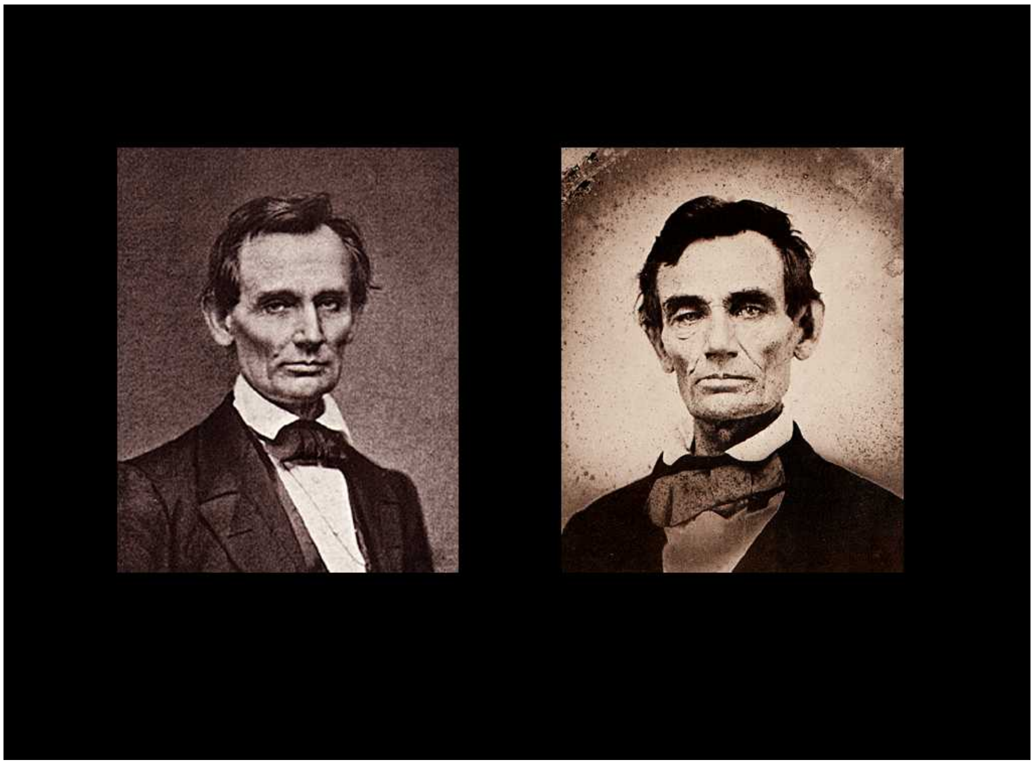


Figure 61.4: Portraits of Lincoln after and before retouche

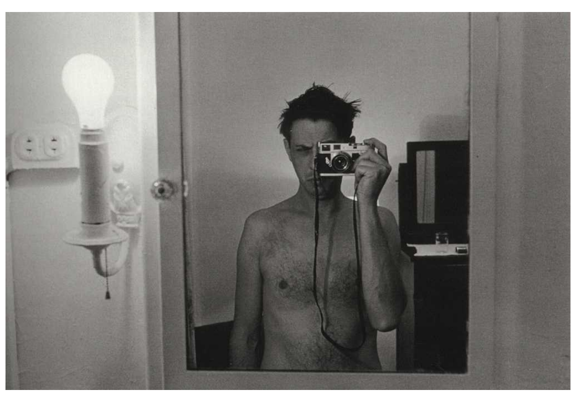


Figure 61.5: Self-referencing photo.

Figure 61.6: Wall paintings in the caves of Chauvet in France

Figure 61.7: Timeless Grand Jeté

Chapter 62

Joyce

> Then's now with now's then in tense continuant...at this auctual futule preteriting unstant...there is a future in every past that is present... Between me rassociations in the postleadeny past and mi disconnections with aplompervious futules...a time has a tense...will had been having... can could...willbe isnor was...a child that wouldbewas kidnapped at an age of recent probably, possibly remoter...there's a split in the infinitive from to have to have been to will be. (James Joyce in *Finnegans Wake*).

Phil: *Finnegans Wake* by James Joyce begins:

- *riverrun, past Eve and Adam's, from swerve of shore to bend of bay, brings us by a commodius vicus of recirculation back to Howth Castle and Environs. Sir Tristram, violer d'amores, fr'over the short sea, had passencore rearrived from North Armorica on this side the scraggy isthmus of Europe Minor to wielderfight his penisolate war: nor had topsawyer's rocks by the stream Oconee exaggerated themselse to Laurens County's gorgios while the went doublin their mumper all the time:*

and ends by returning to the start:

- *...Coming, far! End here. Us then. Finn, again! Take. Bussofthlee, mememormee! Till thousandsthee. Lps. The keys to. Given! A way a lone a last a loved a long the ...*

Mat: Oh, that is intriguing. What does it mean?

Phil: Finnegans Wake, crowning the work of seventeen years, is a wonderful mix of mythology, theology, mystery, philosophy, mathematics, physics, history, sociology, astrology, fiction, alchemy, music, color, nature, sexuality, humanity, you name it, written in a new intricately woven and obscure language. Impossible to read, but very funny! And very deep!

Mat: So you have read it?

Phil: Only parts, nobody has read all of it. It takes more than a lifetime. Joyce stated that he wanted to *encounter the reality of experience and to forge in the smithy of my soul the uncreated conscience of my race*. Quite ambitious! Here *Commodius vicus* refers to Giambattista Vico (1668-1744), who believed in a theory of cyclical history. In his work *La Scienza Nuova* Vico argued that the world was coming to the end of the last of three ages, these being the age of gods, the age of heroes, and the age of humans. Joyce argued: *I don't believe in any science, but my imagination grows when I read Vico as it doesn't when I read Freud or Jung.*

Mat: What is the story of the Wake?

Phil: There is one abiding story, that of the Fall, which is repeated over and over. The Fall, or crime, is sexual in nature and has to do with the exposure of the genitalia, male and female, to a voyeuristic gaze: The father gazes at the daughter and the daughter gazes at the father, each on him or her self, and both are gazed on by three soldiers, in the Phoenix Park in Dublin with its dominating monument, an obelisk to the triumph of the battle of Waterloo of the Irish Duke of Wellington.

Mat: What inspired Joyce?

Mat: Everything, including science. Joyce was born in Dublin in 1882 and after graduation in 1902 he went to Paris, then a mecca for artists, philosophers, and restless spirits. Relativity was the ideal scientific subject to the avantgarde meeting at Café de Flore on Boulevard Saint-Germain. The radical character and abstract nature of the new theory, the sense of crisis accompanying its creation, and the emphasis on the subjective element in the new definition of time, led several artists to embrace relativity as a dramatic scientific counterpart to their own artistic and philosophical endeavors. I wish I had been there!

Mat: I am glad I am here instead.

Phil: Evidently, Einstein legitimized Joyce and other writers of the new *time school* including Proust, Wolf, Mann and Faulkner, to present human temporal experience through the prism of the character's mind rather than by employing the spatial view of traditional novel. The time school novelists attempted to recreate the complexity of time consciousness by means of a *stream-of-consciousness* technique mixing the past and projected future into the present momentary perception, rather than any objective reality, which was the goal of the classical novel. Using this technique Joyce managed in *Ulysses* to create something more real than reality.

Mat: Oh, so what Joyce describes is hyper-reality?

Phil: Seems so. Although the action of Ulysses describes the course of a single day, the coexistence of the consciousness of the characters' past, present and projected future enables the reader to understand fully the characters in the context of the formative events of their lives. As *Molly Bloom* lies in bed, her past, present and future ceaselessly flow together. Her thoughts form a continuum in which there are no temporal divisions: it is an eternal present where differentiated time zones do not exist.

Mat: What is the connection to Homer's Odyssey?

Phil: There is a lot of parallelism following Joyce's idea of oneness of all ages. But in Finnegan's Wake Joyce creates a reality of his own, completely freed from the rational logic which dominates our waking state. Instead it resembles the logic of the dreaming mind, or the working of consciousness, where images are subject to constant movement and transformation. In place of realistic characters Joyce creates types: *Mister Typus, Mistress Tope and all the little typtopies* represented by *Humphrey Chimpden Earwicker* or *HCE* (*Here Comes Everybody*), his wife *Anna Livia Plurabelle* and their children: *Shem*, *Shaun* and *Issy* interacting in a relativistic fusion of time and space *with the help of the simulchronic flush in his pann*, without boundaries between the past, present and future.

Mat: For Joyce, the existence of Julius Caesar would be no problem?

Phil: Of course not. Everything is possible playing with the language: *Then's now with now's then in tense continuant – There is a future in every past that is present – Between me rassociations in the postleadeny past and mi disconnections with aplompervious futules – will had been having – can could – willbe isnor was – a child that wouldbewas kidnapped at an age of recent probably, possibly remoter* – and so on...

Mat: ... will had been having, isnor was, wouldbewas? I makes me dizzy.

Phil: The Fall is also the fall of Newtonian physics with relativity associated with the fall of the apple, both the fall of fruit as a symbol of nature's cycle of renewal, and the fall of the apple which effected Newton's insight into the similarity between earthly and heavenly bodies. Through the apple image, the fall of classical physics is linked with the biblical Fall and sometimes the two motifs are interrelated: Thus, for example, we hear: *For then it was the age . . . of a pomme full grave and a fammy of levity*, followed by *newt*, a typical Joycean clue. The apple in question is, of course, the forbidden fruit, with its grave consequences, and the woman of levity is Eve, but the applefall (any fall) is also the result of gravity, whose description brought Newton fame and made him an eponymous figure.

Mat: So there are many allusions to physics?

Phil: Certainly. In another reference to Newton, HCE is described as one who *thought he weighed a new ton when there felled his first lapapple – Let's hear what science has to say, pundit-the-next-best-king. Splanck! - Upfellbowm.* "Splanck!" is the sound of the falling fruit, as well as the physicist Max Planck, the father of the quantum theory; "Upfellbowm" is German Apfelbaum: appletree, distorted to bring out the idea of gravity and fall. A similar distortion appears earlier in *abfalltree.*

Mat: What about space and time?

Phil: Einstein's curved spacetime connected to the Viconian vision of time, curving back upon itself: *we come to newsky prospect from west the wave on schedule time (if I came any quicker I'll be right back before I left).* The idea of a re-entrant universe, in which the future somewhere has to meet the past, is also implied in *the only wise in a muck's world to look on itself from beforehand – Bloody certainly we've got to see to it . . . that down the gullies of the eras we may catch ourselves looking forward to what will in no time be staring you larrikins on the postface in that multimirror megaron of returningties, whirled without end to end.*

Mat: The brothers Shem and Shaun, do they represent time and space?

Phil: Yes, they represent the opposition between time and space, often represented as an opposition between an elm and a stone. Einstein's name suggested a way to enhance this motif since the physicist was born in Ulm. Joyce often blends these two motifs, as in *on the hike from Elmstree to Stene*, preceded by *it was mutualiter foretold of him by a timekiller to his spacemaker*. HCE is described as the *onestone parable – the cluekey to a worldroom beyond roomwhorld* A children's geometry lesson ends with a reference to *Eyeinsteye–will gift uns his Noblett's surprize*, referring to Einstein's Nobel Prize in physics.

Mat: What about unification of polarities?

Phil: Joyce also searched a unity of opposites. By placing temporal and spatial terms together he brings out the opposition between them, but at the same time he shows their unity by suggesting that a reference to either spatial or temporal coordinates requires the use of both in conjunction, time and space having been united by Einstein. A spatial context, for example, is augmented with a temporal reference in the following passage: *HCE came at this time-colored place where we live in our paroqial fermament one tide or another*. Conversely, a temporal context may be augmented by space. This happens, for example, when at the time is rendered as *for the space of the time being – just in time as if he fell out of space – having reprimed his repeater and resiteroomed his timespiece His Revenances, with still a life or two to spare for the space of his occupancy of a world at a time, rose to his feet*. Another way of suggesting the conjunction of time and space consists in replacing the spatial coordinates with the temporal ones, and vice versa in constructions as *thenabouts – anywhen – whenabouts*.

Mat: How was the reaction to Joyce?

Phil: Mixed. Many got angry. In *Time and Western Man* (1928), Wyndham Lewis launched a personal attack on Joyce. In the chapter entitled *An Analysis of the Mind of James Joyce*, Lewis blasted Ulysses, describing it as a disorganized quantity of *material, that was scraped together into a big, variegated heap*. He condemned Bergsonian philosophy and the relativistic concept of timespace for their reliance on the flux of reality instead of solid objects, and he assaulted Joyce, calling him *the poet of the shabby-genteel, impoverished intellectualism of Dublin.* Joyce, he said, *is steeped in the sadness and the shabbiness of the pathetic gentility of the upper shopkeeping class, slumbering at the bottom of a neglected province*. The conclusion Lewis reached in his analysis was that *there is not very much reflection going on at any time inside the head of Mr. James Joyce*.

Mat: How did Joyce react to this assault?

Phil: Joyce answers Lewis in the Wake in two passages: the lecture of Professor Jones followed by the fable of the Mookse and the Gripes; and in the fable of the Ondt and the Gracehoper. Professor Jones, who represents Wyndham Lewis (or space-oriented Shaun as opposed to temporal Shem), delivers a lecture on the *dime-cash problem* speaking *from the blinkpoint of so eminent a spatialist* he begins his lecture by dismissing both Bergsonian flux and Einsteinian physics, claiming that *the sophology of Bitchson . . . is in reality only a done by chance ridiculization of the whoo-whoo and where's hairs theorics of Winestein*. Professor Jones explains that the fallacy is the belief that *the inception, and the descent and the endswell of Man is temporarily wrapped in obscenity* whereas he, in his *own spacious immensity* prefers to be *reassured by ratio that the cube of [his] volumes is to the surfaces of their subjects as the sphericity of these globes . . . is to the feracity of Fairynelly's vacuum*. Pleased with his *augmentatively uncomparisoned* discourse, but doubting the capabilities of his audience, Professor Jones now *reverts to a more expletive method* and offers his version of Aesop's fable of the fox and the grapes.

Mat: Mookse and the Gripes?

Phil: Yes, carefully avoiding temporal terms, Professor begins his tale: *Eins within a space and a weary-wide space it wast ere whoned a Mookse. The onesomeness wast alltolonely, archunsitslike, broady oval, and a Mookse he would a walking go* However, his attempts to eradicate time are only partly successful since *onesome* and *Eins* evoke Einstein's name, and with it not only the notion of time but also that of spatiotemporal conjunction. Such problems of temporal interference in his purely spatial existence continue to plague the Mookse in his *roaming run through Room* and when he finds a place to sit down he is again joined with time, for the seat he has chosen is a stone, and a stone represents Einstein's name. Inevitably, as the story unfolds, the problem of time fallacy is brought up by the Mookse when he reacts violently to Gripes's innocent question: *By the watch, what is the time, pace?* To the Mookse, the question is insolent. Enraged, he informs the Gripes that clarifying the question of temporal fallacy is precisely the goal of his mission and then attempts to impose his spatial geometrical approach on the Gripes: *Quote awhore? This is quite about what I came on my missions with my intentions laudibiliter to settle with you, barbarousse. Let thor be orlog. Let Pauline be Irene. Let you be Beeton. And let me be Los Angeles. Now measure your length. Now estimate my capacity. Well, sour? Is this* *space of our couple of hours too dimensional for you, temporizer? Will you give you up?* But the other cannot give up his sense of time. The Mookse then is forced to revert to the formerly unsuccessful method of discourse. With the help of Greek, Latin and Rosicrucian literature he proves his point over and over, a hundred and thirty-three times in all, and then the same number again: *He gathered together the odds docence of his vellumes, gresk, letton and russicruxian, onto the lapse of his prolegs, . . . and set about his widerproof. He proved it well whoonearth dry and drysick times, . . . [proved it] by Neuclidius and Inexagoras and Munifsen and Thumpsem, by Orasmus and Amenius, . . . he reproved it ehrltogether when not in that order sundering in some different order, alter three thirty and a hundred times.* But the *promulgating of ipsofacts and sadcontras* has only as much effect on the Gripes as Professor Jones's lecture had on his *muddlecrass pupils.* The temporal Gripes remains as ethereal as he has always been: *Mee are relying entirely on the weightiness of mear's breath.*

Mat: What about the Ondt and the Gracehoper?

Phil: Be patient. Professor Jones takes the example of music to further clarify his views: *Of course the unskilled singer continues to pervert our wiser ears by subordinating the space-element, that is to sing, the aria , to the time-factor, which ought to be killed, ill tempor.* He advises any singer *to forget her temporal diaphragm at home . . . and attack the roulade with a swift colpo di glottide to the lug* and thus to eliminate the time-factor in music entirely. Professor Jones's attitude towards music expresses Lewis's own: *To the trance of music with its obsession of Time, with its inalienable emotional urgency and visceral agitation, we prefer what Bergson calls obsession of space.* In the fable of the ant and the grasshopper, Shaun is asked to sing a song, but he refuses to engage in this purely temporal form of art. He apologizes and offers instead to spin a yarn *from the grimm gests of Jacko and Essaup . . . and consider the casus . . . of the Ondt and the Gracehoper.* As in the story of the Mookse and the Gripes, the characters of this fable represent the Shem-Shaun polarity, but in another of their aspects they are Joyce's response to Wyndham Lewis. In the fable Lewis is the stern and prudent Ondt, *thothfolly making chilly spaces at hisphex affront of the icinglass of his windhame.* A clearly spatial character, he is a *raumybult* fellow, *chairmanlooking when not making spaces in his psyche* and smokes *a spatial brunt of Hosana cigals* The musicmaking Gracehoper is Joyce himself, *always jigging ajog, hoppy on akkant of his joyicity, . . . with a pair of findlestilts to supplant him.*

When they meet, the Ondt is *making the greatest spass a body could*, while the famished Gracehoper, like the ethereal Gripes at the close of the earlier fable, is a *featherweighed animule, actually and presumptuably sinctyfying chronic's despair*. But, unlike the Mookse and the Gripes tale, this time Joyce does not leave the space-time question unresolved. The Ondt may have the upper hand in the story but in the Gracehoper's song which closes the fable the opposition of space and time is dissolved into a unity:

- *A locus to loue, a term it t'embarass*
  These twain are the twins that tick Homo Vulgaris
  We are Wastenot with Want, precondamned, two and true
  Till Nolans go volants and Bruneyes come blue.

Space and time are thus pronounced to be one: each can only develop its essence by opposition to the other. It is this interdependence that ultimately unifies them. And as for the last word in the argument, it belongs of course to Joyce. It is a personal question addressed directly to Wyndham Lewis - both as a writer of prose and as a champion of space: *Your genus is worldwide, your spacest sublime. But, Holy Saltmartin, why can't you beat time?*

Mat: Can I borrow your copy of the Wake?

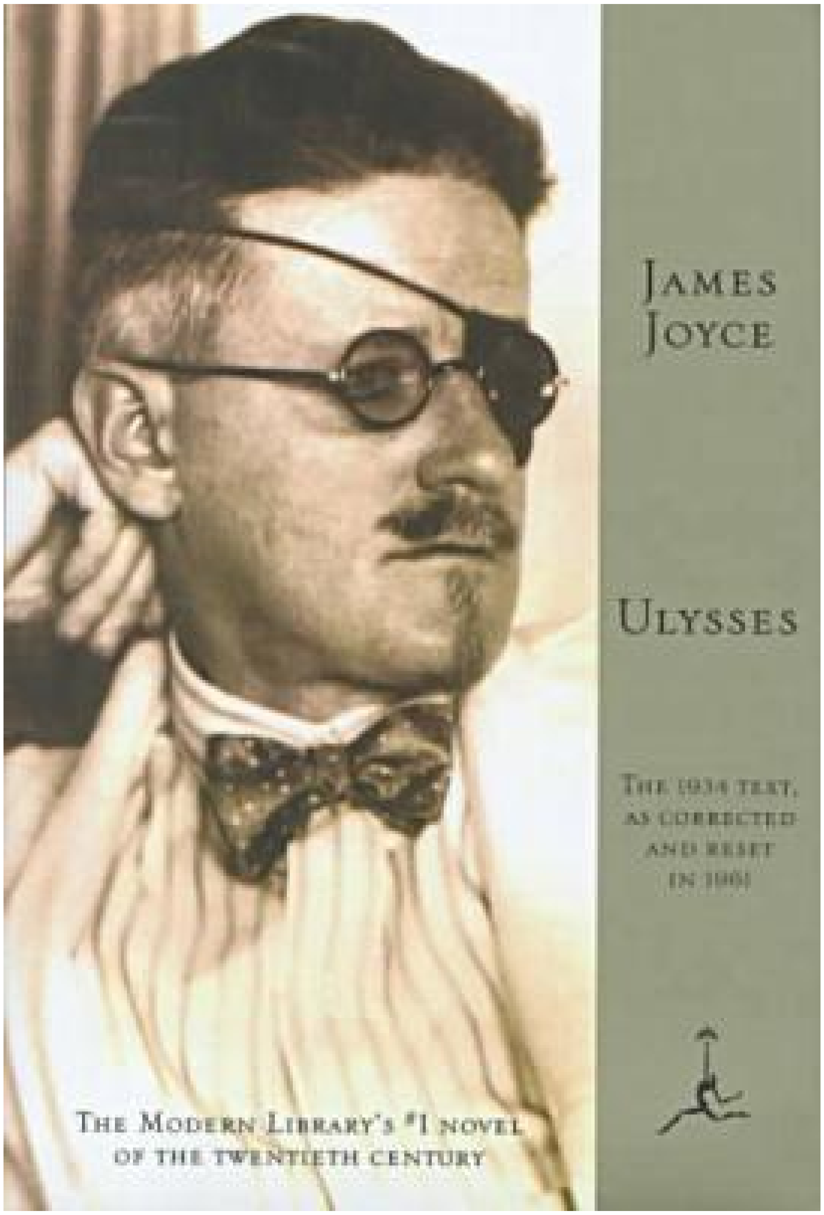


Figure 62.1: Stream of self-consciouness of Joyce: *Thanks eversore much. Pointcarried! I can't say if it's the weight you strike me to the quick or that red mass I was looking at but at the present momentum, potential as I am, I'm seeing raying-bogeys rings around me.*

Chapter 63

Beckett

> All I know is what the words know, and dead things, and that makes a handsome little sum, with a beginning and a middle and an end, as in the well-built phrase and the long sonata of the dead. – Birth was the death of him. – Ever tried. Ever failed. No matter. Try Again. Fail again. Fail better. – I write about myself with the same pencil and in the same exercise book as about him. It is no longer I, but another whose life is just beginning. – It is right that he too should have his little chronicle, his memories, his reason, and be able to recognize the good in the bad, the bad in the worst, and so grow gently old down all the unchanging days, and die one day like any other day, only shorter. – The tears of the world are a constant quality. For each one who begins to weep, somewhere else another stops. The same is true of the laugh. – They give birth astride of a grave, the light gleams an instant, then it's night once more. – Where I am, I don't know, I'll never know, in the silence you don't know, you must go on, I can't go on, I'll go on. – Words are all we have. (Beckett)

Phil: Beckett studied for his Bachelor's degree in French and Italian at Trinity College, Dublin, 1923-27 and became an intimate of Joyce's creative circle. In 1930 he published an arcane poem on Descartes, *Whoroscope.* Beckett settled in Paris in 1937, and French became his written language. His trilogy of novels, *Molloy* (1951), *Malone Dies* (1951), and *The Unnamable* (1953), later translated into English by Beckett himself, is considered among the greatest prose writings of the century. They mark out a very grim but ridiculously circuitous and laboured path of human life. Beckett got the

Nobel Prize in 1969 for *his writing, which — in new forms for the novel and drama – in the destitution of modern man acquires its elevation.* Having remarked that Joyce ought to have won it, Beckett gave much of the Nobel money away to charities and needy writers. Beckett wrote less and less in the 1970s and 1980s, whittling down even more rigorously his work to the barest essentials of expression. and died in 1989 in Paris. *Malone Dies* opens as follows:

> *Present state. This room seems to be mine. I can find no other explanation to my being left in it. All this time....But what is the last thing I remember, I could start from there, before I came to my sense again here? That too is lost. I was walking certainly, all my life I have been walking, except the first few months and since I have been here. But at the end of the day I did not know where I had been or what my thoughts had been. What then could I be expected to remember, and with what? I remember a mood...But perhaps I was stunned with a blow, on the head, yes, now that I speak of a forest I vaguely remember a forest. All that belongs to the past. Now it is the present I must establish, before I am avenged....Had it been foretold to me that one day I should feel myself living as I do today, I should have smiled.... I remember them well, these last few days, they have left me more memories than the thirty thousand odd that went by. When I have completed my inventory, if my death is not ready for me then, I shall write my memoirs, That's funny, I have made a joke. No matter...*

Mat: The past is evasive and there is no future. Is Beckett a presentist?

Phil: Let's see: His play *Happy Days* opens with a barren outdoor with a woman around fifty, Winnie, embedded to her waist in a mound of earth. Beckett depicts man in a state of being nothing and doing nothing; bare existence, with the mound representing time, I believe.

Mat: It seems that absence rather than presence characterizes Beckett's world. Is he then an absentist?

Phil: Could be. Winnie's memory is all fragments which do not make up a coherent story: *The sunshade you gave me...that day... (pause)...that day...the lake...the reeds. (Pause.) What day? (Pause.) What reeds?*

Mat: Evidently, Beckett does not describe linear time, but rather deconstructed time.

Phil: Winnie rests in an infinite moment when things pass so slow that no change can be seen, saying: *It's not hotter today than yesterday, it will be no hotter tomorrow than today, how could it, and so on back into the far past, forward into the far future. ...* Winnie tries to look at the present from the point of view of the past: *When the present becomes the past only nice things can be remembered, if one chooses to do so, while now the suffering of being cannot be avoided*. Thus, she treats the present if it would be her past, as it helps her bear her suffering : *Oh, this is going to be another happy day!* Since time does not pass in linear fluency, it does not mean any step closer to a goal. Winnie is deeper in the ground - time, and is completely confused as to how the time has slowed down. She is not able to use the past tense without anchoring it in her presence, as if her past were fused in it: *I used to think...(pause)...I say I used to think there was no difference between one fraction of a second and the next. (Pause.) I used to say...(pause)...I say I used to say, Winnie you are changeless, there is never any difference between one fraction and the next. Why bring that up again?*

Mat: This must be Zeno's paradox.

Phil: Believe so. The experience of time is expressed in its purest form in *Waiting for Godot*: The two tramps *Vladimir* and *Estragon*, seized in Zenoean time, which has almost stopped but not quite, are waiting for Godot in a waste land, having nothing to do but to be and to expect. The main subject of the play is not *Godot*, whatever that may be, a person, thing, event, death or God...etc., but the waiting itself, which is the most evident experience of time:

> ESTRAGON: *You're sure it was this evening?*
> VLADIMIR: *What?*
> ESTRAGON: *That we were to wait.*
> VLADIMIR: *He said Saturday.* (Pause.) *I think.*
> ESTRAGON: *You think.*
> VLADIMIR: *I must have made a note of it.* (He fumbles in his pockets, bursting with miscellaneous rubbish.)
> ESTRAGON: (very insidious). *But what Saturday? And is it Saturday? Is it not rather Sunday? (Pause.) Or Monday?* (Pause.) *Or Friday?*
> ...
> VLADIMIR: *Time has stopped.*

VLADIMIR: *And it's not over.*
ESTARGON: *Apparently not.*
VLADIMIR: *It's only beginning.*
ESTRAGON: *It's awful.*

Mat: When time has stopped, there is no longer any Arrow. It is like a compass at the North Pole. Is this McTaggart's time which does not exist?

Phil: Probably. In *Endgame* the main characters *Hamm*, blind in a wheelchair, and his son *Clov* also play a game about waiting. Already in the beginning of the play, time has stopped:

HAMM: *...What time is it?*
CLOV: *The same as usual.*
HAMM: (Gesture towards window right.) *Have you looked?*
CLOV: *Yes.*
HAMM: *Well?*
CLOV: *Zero.*

Hamm, Clov, and Hamm's parents *Nell* and *Negg* represent three generations and also three time periods. There is a horizontal linear time fluency from youth to old age, and a vertical representing Zeno's unchanging now, represented by the central position in the middle of the stage:

HAMM: *Back to my place!* (Clov pushes chair back to centre.) *Is that my place?*
CLOV: *Yes, that's your place.*
HAMM: *Am I right in the centre?*
CLOV: *I'll measure it.*
HAMM: *More or less! More or less!*
CLOV: (Moving chair slightly.) *There!*
HAMM: *I'm more or less in the centre?*
CLOV: *I'd say so.*
HAMM: *You'd say so! Put me right in the centre.*

Hamm hates his parents for giving him birth, Nagg and Nell wish to die, but the will to life keeps them breathing and going on:

> HAMM: *I'll give you nothing more to eat.*
> CLOV: *Then we'll die.*
> HAMM: *I'll give you just enough to keep you from dying. You'll be hungry all the time.*

Mat: The clock gets just the right momentum to take another tick.

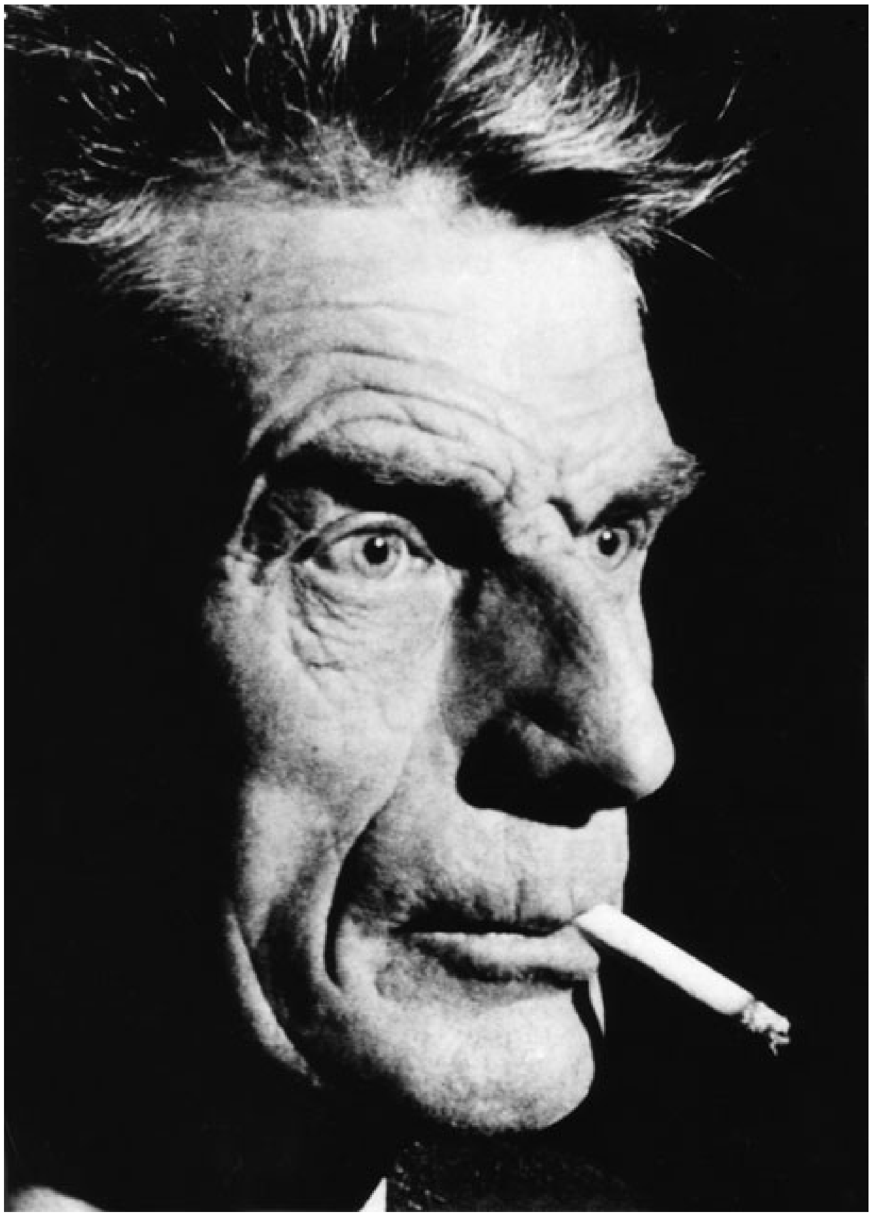


Figure 63.1: Beckett: *James Joyce was a synthesizer, trying to bring in as much as he could. I am an analyzer, trying to leave out as much as I can.*

Chapter 64

Borges

> Any life is made up of a single moment, the moment in which a man finds out, once and for all, who he is. – Every writer "creates" his own precursors. His work modifies our conception of the past, as it will modify the future. – Life and death have been lacking in my life. – The central problem of novel-writing is causality. – Writing is nothing more than a guided dream. (Borges)

Phil: Borges writes in *The Garden of Forking Paths*:

- *In all fictions, each time a man meets diverse alternatives, he chooses one and eliminates the others; in the work of the virtually impossible-to-disentangle Ts'ui Pen, the character chooses–simultaneously– all of them. He creates, thereby, 'several futures', several times, which themselves proliferate and fork.*

- *This web of time – the strands of which approach one another, bifurcate, intersect or ignore each other through the centuries – embrace every possibility.*

Mat: This is like Everett's *many-world* version of quantum mechanics. All possible worlds sort of exist in parallel, as possibilities, or realities, it is not clear, and we happen to live in one of them. *Schrödinger's cat* is both dead and alive in parallel in the box where it is kept, until someone opens the box, causing one of the two possibilities to 'condense' into reality. Our World is such a condensation out an ocean of possible worlds. Some, like Leibniz, consider it to be *best possible*, some believe it is not.

Phil: In *Tlön, Uqbar, Orbis Tertius* Borges writes:

- *One of the schools of philosophy on Tlön goes so far as to deny the existence of time; it argues that the present is undefined and indefinite, that the future has no other reality than as present hope, that past is no more than present memory. Another school posits that all time has already passed, so that our life is but a crepuscular memory, or crepuscular reflection, doubtlessly distorted and mutilated, of an irrecoverable process. Another maintains that the universe is comparable to those code systems in which not all the symbols have meaning, and in which only that which happens every three hundredth night is true. Yet another that while we sleep here, we are awake somewhere else, so that every man is in fact two men.*

- *The people of Tlön are taught that the act of counting modifies the amount counted, turning indefinites into definitites.... It has been decided that all books are the work of a single author who is timeless and anonymous...Their books are also different from our own. Their fiction has but a single plot, with every imaginable permutation. Their works of a philosophical nature invariably contain both the thesis and the antithesis, the rigorous pro and contra of every argument. A book that does not contain its counterbook is considered incomplete.*

Mat: Is this a future vision?

Figure 64.1: Collective writing in Uqbar.

Chapter 65

Writing and Painting

> The art of doing mathematics consists in finding that special case which contains all the germs of generality. (Hilbert)
>
> Every act of creation is first of all an act of destruction. (Pablo Picasso)

Phil: Writing something, fiction or poetry or science, is a creative process, where you differentiate or select a sequence of words from a set of possible sequences, until you are satisfied or exhausted. Along the way you produce waste in the form of discarded possibilities accumulating in your waste basket on its way to destruction. A writer must have a will or drive to write, a drive to differentiate, but also needs to destroy (some of) what has been written. The *ideal writer* would never throw anything he has written, because everything he/she writes is perfect. But that writer does not exist: if the writer never throws anything away, then his/her books cannot be perfect. Evidently, writing defines an Arrow by the process of creation-destruction. What has been burned cannot be retrieved.

Mat: Differentiation enhances difference and thus creates *information*. An painter starts with a sketch and adds details upon details until satisfaction. The smallest details have a finite size and the painting is of finite precision. A painter seeking infinite precision cannot finish any painting and thus sucombs. The painter has to *destroy information* in the sense that there are details in the motif which he decides to leave out. Information can be destroyed by a process of dissipation where sharp contrasts are smoothed out decreasing the amount of detail. This process defines an Arrow: A detail which has been smoothed out cannot fully be recovered.

Phil: We have already discussed this aspect, at length. It is important, but let us now proceed to something else. What about music?

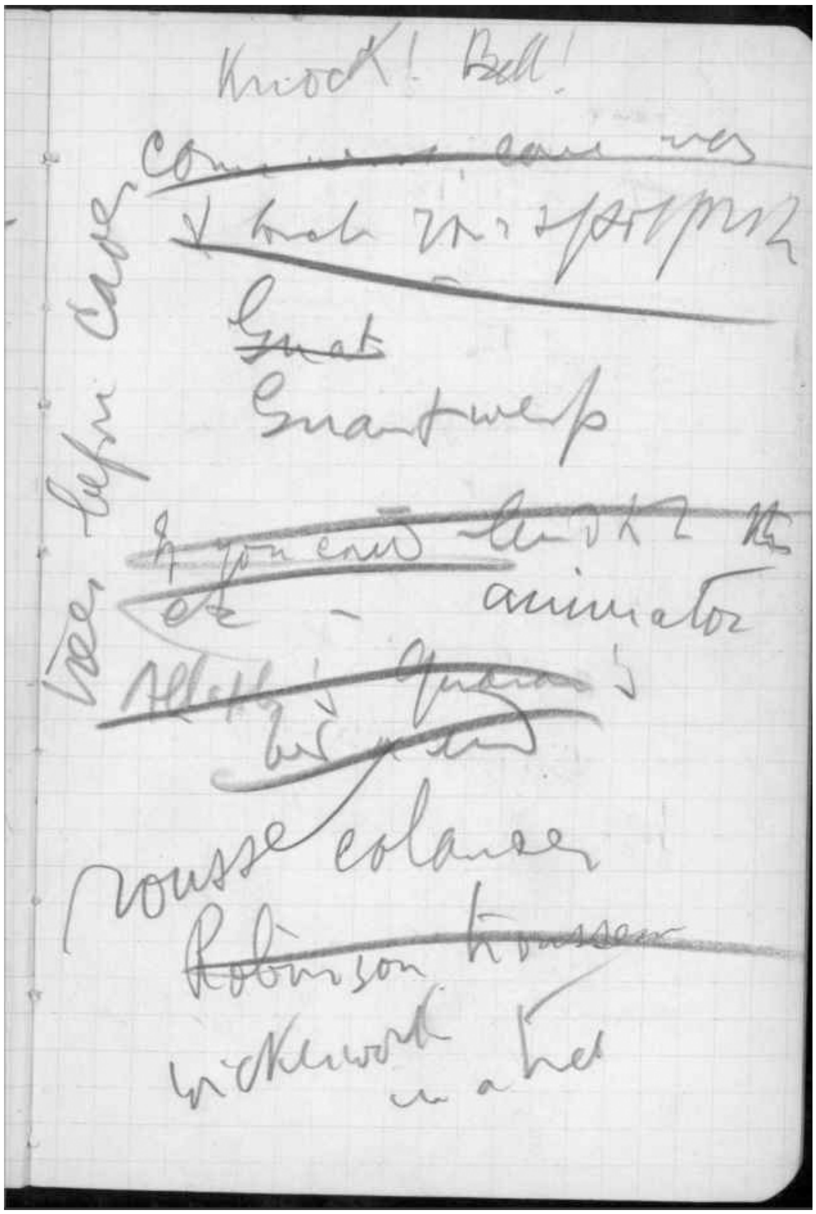


Figure 65.1: Creation and destruction of information during the writing of Finnegans Wake.

Chapter 66

Music vs Time

> Music is the process of counting without knowing it. (Leibniz)
>
> Music is your own experience, your own thoughts, your wisdom. If you don't live it, it won't come out of your horn. They teach you there's a boundary line to music. But, man, there's no boundary line to art. (Charlie Parker)

Phil: Music is a representation of time flow. The rythm sets the pace with one bar or beat following after the other by successive replacement.

Mat: There is an important difference between *notated music*, where each note is played according to a preset score, and *improvised music* such as *jazz*, where the only the basic structure is preset, and the players are inventing or creating the music in the moment in a many-minds interactive manner, each player listening to the other players and then playing something.

Phil: This is like a good constructive conversation around some common theme, where each person listens to the others and then says something, which is not decided upon beforehand. Sometimes our conversations are constructive like that, sometimes they collapse into (preset repetitive) monologues without listener. This is quite normal, I guess.

Mat: Improvised music, in contrast to notated music, illustrates the open-ended nature of time flow, where the future is not determined beforehand, and thus does not exist, but is created in each moment of change.

Phil: You may compare with *Commedia dell'arte*, the unscripted improvisational theatre popular in Italy in the 15th-18th century, also known as

Italian Comedy. Performances were held outside, free to watch and funded by donations. A troupe consisted of 10 people: 7 men and 3 women including characters such as Harlekin, Colombine and Pajazzo.

Mat: That is a good example. The performances were around a repertory of stock, conventional situations: adultery, jealousy, old age, love, some of which can be traced in the Roman comedies of Plautus and Terence, which are themselves translations of lost Greek comedies of the fourth century BC. These characters included the ancestors of the modern clown. The dialogue and action could easily be made topical and adjusted to satirize local scandals, current events, or regional tastes, mixed with ancient jokes and punchlines. Characters were identified by costume, masks, and even props, such as the slapstick.

Phil: The open-ended nature of our discussions illustrates that the future is not pre-determined. Or is it? Are we free to say whatever we want to, or are we simply following a (hidden) preset score?

Mat: Hard to say. Certainly we have the impression that some inspiration is needed to get forward, but from where the inspiration actually comes is a bit unclear. Chaotic quantum mechanics? Intelligent design? For now I have no answer. Maybe some idea will come up from somewhere sometime somehow. Let's hope for the best.

Figure 66.1: Creating music in flow of inspiration.

Chapter 67

Rythm and Beat

> Music and rhythm find their way into the secret places of the soul. (Plato)
>
> Rhythm is something you either have or don't have, but when you have it, you have it all over. (Elvis Presley)
>
> Music is a safe type of high. It's more the way it was supposed to be. That's where highness came, I guess, from anyway. It's nothing but rhythm and motion. (Jimi Hendrix)
>
> Music creates order out of chaos: for rhythm imposes unanimity upon the divergent, melody imposes continuity upon the disjointed, and harmony imposes compatibility upon the incongruous. (Yehudi Menuhin)

Phil: The sequential character of *music* is shown by a conductor marking the *beat* or *rythm*, while following the *bars* of the *score*, each bar being divided into a number of beats: 2 in *two-step*, 3 in *waltz*, 4 in *foxtrot*, and 5 and 7 in e.g. Greek folk music. A steady 4/4 beat does not have an Arrow, and sounds the same if played in reverse. More complex pattern have an Arrow and sound strange in reverse.

Mat: A *metronome* is a *pendulum* for which the *effective length* can be regulated by shifting a weight to make the pendulum swing back and forth at different rates from *largo* at 40-60 periods to *prestissimo* at 200-208 periods per second. The length of a pendulum scales like the inverse of the frequency squared so that a shorter pendulum swings quicker, as can be seen in Fig. (67.1).

Phil: In *jazz music* the beat is supposed to be very steady, but on top of the steady beat there is a lot of off-beat *syncopes.* The precise *timing* of these syncopes is what gives the *swing.* Jazz is a combination of African and European music, with the rythmic complexity coming from Arica and the harmonic complexity from European classical music. The rythmic complexity is expressed in *polyrythm* with both 2 beats and 3 beats in a bar at the same time. This is called “triol-feeling”.

Mat: I classical music, the beat is either steady or more flowing, with less of syncopation. A composer wanting to add a flavor of jazz adds syncopes, e.g. like Ravel did in his two piano concerts with inspiration from his friend George Gershwin.

Phil: I have heard that humans are the only living creatures with a good sense for rythm. Does that tell us something about our concept of time?

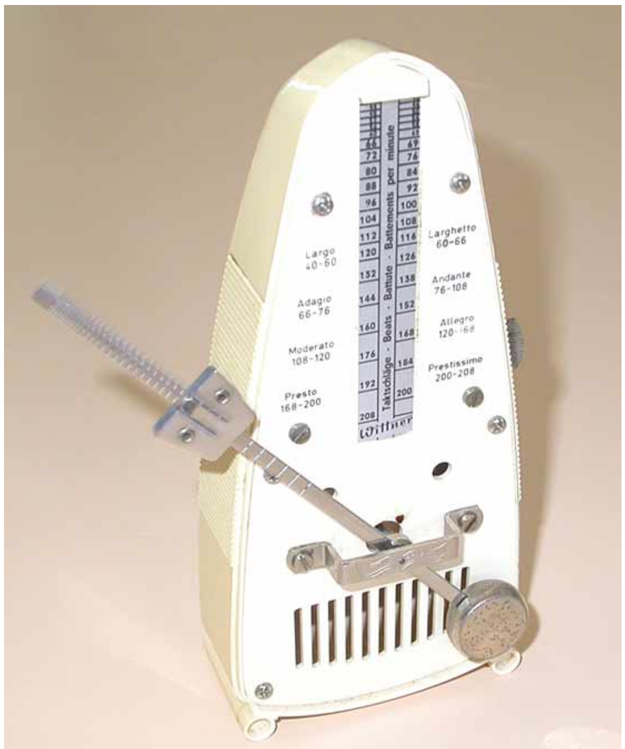


Figure 67.1: A metronome. Notice the scaling: the effective length of the pendulum scales like the inverse square of the frequency making the scale look sparser for higher frequencies.

Chapter 68

Cadenza Dynamics

> In almost all Mozart'ss major cadenzas one can make out a clear division into three; an *opening* (I), which begins either with one of the themes of the concerto or with virtuoso passage-work......a middle section (II), which is almost always a sequential development of some important theme or motive from the concerto movement.......This is the starting point for a number of virtuoso runs, arpeggios, etc., which lead to a closing section (III) of the cadenza, usually ending on a trill. (Paul Badura-Skoda)

Phil: A steady 4/4 beat will sound the same in reverse, but if you add melody and harmony, it will in general sooound strange in reverse. A melody may up and then down, and such a movement will be the same in reverse, but of course many musical phrases will sound very different in reverse. How about harmony? Is there an Arrow in a the most common harmonic progression?

Mat: You mean if there is sawtooth dynamics? Let's see: The most common sequence formed by three chords in the key of C that every guitar player knows is: C, F, G7 and then back to C. This is a *cadenza* or sequence of chords which starts "at home" with a C major chord consisting of CEG, then builds a tension by going away from home from the C major chord to a F major chord consisting of FAC with the the new note F a half tone above E as the most important alteration, and then increases the tension further to a G7 chord consisting of GHDF with the new important note H a half step below C. The G7 chord has the two notes F and H, which are a half step away from the C and E in the C major chord. Therefore G7 has *maximal* *tension* and seeks to be resolved into a C major chord by F moving down to E and H moving up to C in half-steps. The diminished fifth HF is resolved into the third CE. HF is felt more dissonant and wants to be resolved into the harmonious third CE. In frequencies, the two notes of the third CE has (close to) the ratio 5/4, while the diminished fifth is (in the temperate scale) nothing less than the weird $\sqrt{2} \approx 1.41$. Thus the third is much more "at home" than FH which is "out".

Phil: So in the chord change C to F to G7 to C, there is like an gradually increased tension (C to F to G7) followed by a more abrupt resolution of tension G7 to C. This is the sawtooth pattern.

Mat: Evidently, music is about creating tension and releasing tension, in that order, in melody, harmony and also rythm. To create tension is to increase difference, to release tension is to decrease tension. You may say that to release tension is to create order and reach equilibrium, and to create tension is to create disorder and leave equilibrium. This is completely opposite to the classical 2nd Law of thermodynamics of increasing entropy/disorder and decreasing difference.

Figure 68.1: Irreversible Cadenza by Haydn in C major with C, F and G7 chords.

Part V

Ficciones

Chapter 69

Time Dilation

> What reason could not avoid, has often been cured by delay. (Seneca)
>
> Every delay that postpones our joys, is long. (Ovidius)

Mat: When you make long distance calls on the mobile telephon, you notice a time delay in the communication.

Phil: Yes, this doesn't matter in monologs but is very irritating for quick conversation and exchange of ideas. You say something and then you have to wait some time for a response. Both you and the one you are talking with have the impression that the other is subject to a time delay or time dilation.

Mat: What is funny is that I have recently noticed the same phenomenon in the direct oral communication with my wife, who has the same funny feeling. She claims that when she says something to me, it takes some time before I get the message and respond. And I have the same impression. It started with just a few seconds delay some time ago, but now the delay is about 10 minutes. I wonder if this can be a saturation effect from a long marriage, or if is some form of relativistic time dilation?

Phil: Sorry to hear that. It must be very disturbing. How do you handle this difficulty?

Mat: Well, you get used it. But you cannot simply wait 10 minutes for a response to say something again. The trick is to remember what you said 10 minutes ago and understand that what you hear from your wife is a response to that, so that at the same time you keep two conversations going with a delay of 10 minutes. Me and my wife have got used to that and it works quite fine. But it can be confusing if you use the same technique when talking to other people.

Phil: I hope you don't have other syndromes of time dilation.
Mat: I have to admit that I have also noticed when playing the piano that the rate of time of the left and the right hand no longer is the same, with the effect that the right hand gets to the last bar well before the left hand. Again I have learned to compensate for that by separating the input from the two hands when listening and correcting for the delay. But to an audience it is very disturbing.

Phil: What will happen if this form of time dilation will spread? What if all people and even different parts of the body of individuals will follow different clocks? This seems like a serious threat to humanity, of the same dimension as global warming. Is the syndrome you seem to suffer from contagious? What is the cause and a possible cure?

Mat: Discipline, I think. Time discipline. With relevant and effective training in school, ideally in conjunction with mathematics education, it should be possible to keep this problem under control. The motto should be: Zero tolerance for time dilation.

Chapter 70

The Marriage of Space and Time

> In the Space and Time marriage we have the greatest Boy meets Girl story of the age. To our great grandchildern this will be as poetical a union as the ancient marriage of Cupid and Psyche seems to us. (Lawrence Durrell in *Balthazar* 1958)

> The views of space and time which I wish to lay before you have sprung from the soil of experimental physics, and therein lies their strength. They are radical. Henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality. (Hermann Minkowski in *Space and Time*, address at the 80th Assembly of German Natural Scientists and Physicians, 1908)

> My intellectual development was retarded, as a result of which I began to wonder about space and time only when I had already grown up. (Einstein)

> The modern artist is working with space and time, and expressing his feelings rather than illustrating. (Jackson Pollock)

> And how the One of Time, of Space the Three,
> Might, in the Chain of Symbols, girdled be. (Tait)

Mat: Did you read in the newspaper today that the marriage between *Space* and *Time* has ended?

Phil: Oh no, that is shocking! I thought this was a happy marriage. I still remember the wedding ceremony with Einstein and Minkowski as officiants: "We hereby declare you united into *Space-Time*, more precisely into *Curved Space-Time*". So beautiful, and sensual! And revolutionary! A marriage like this was unthinkable in Newtonian times, when *Space* was *absolute space* and *Time* was *absolute time*, and any form of intimate relation between the two seemed absolutely impossible, or at least strictly forbidden.

Mat: Yes, it was a beautiful young couple, but already on the honey-moon the troubles started, although very few got to know about it. Evidently *Time* wanted to go on a time-travel trip to some exotic times, while *Space* was happy just to sit on the beach in the Sun, and not travel at all, at least not in time. As we all know time-travel is expensive due to the very high speeds required and the associated space-contraction can also be very strenuous. When you travel in space you suffer from *time-lag*, but when you travel in time you suffer from *space-lag*, and that is much worse. You may have to get used to get contracted by a factor of 100. Very tiring. So *Space* didn't like time-travel at all, while *Time* insisted. That was how the trouble started. Then it was all that dirty talking with people claiming that that kind of relation was against Nature and so on...

Phil: Yes, I had my doubts from the beginning, but I kept it for myself. After all it was not very natural.

Mat: So what will happen now? Are we back to Newtonian absolute space and absolute time?

Phil: Don't think so. That time is gone. We somehow have to find forms of co-existence and cooperation other than Curved Space-Time. We must let *Time* be time and *Space* be space and not force any unification. You can view it as a part of our multi-cultural society, with different religions and political opinions peacefully co-exising. I think this is what the book we are writing is about, or what do you think?

Figure 70.1: Hermann Minkowski (1864-1909)

Chapter 71

The Timeless Society of Pol Pot

> I want you to know that everything I did, I did for my country. (Pol Pot, leader of the Red Khmers)

Phil: Did you read in the newspaper that the trial of the former leaders of the Red Khmers as started?

Mat: Yes, it was really time to get process that started, before all leaders has passed away. I recall that on April 17th 1975 the Red Khmers led by Pol Pot, educated in Paris in the 1950s, made their way into Phnom Penh, the Cambodian capital, and declared the start of *Year Zero*. A new society based on utopian communism or maoism had been born.

Phil: The makers of the French Revolution also restarted time choosing 1793 as Year One and declared the week to consist of 10 days, each day being 10 hours long with an hour being 100 minutes and a minute 100 seconds. So Pol Pot learned something in Paris.

Mat: Yes, restarting time with each new Emperor was also the standard in China. Now, Pol Pots society was a classless society without ownership of money and property, with everyone dressed the same with the same haircut, without machinery and electronics, and any sort of music or scripts that was not political propaganda. Wearing glasses or speaking a foreign language was subject to death penalty. Cities were abandoned and the whole population was relocated to farming communes in a "cultural revolution" of massive reeducation. The old Cambodian society was completely destroyed and a new society was shaped, a new society approved by UN and praised in Sweden.

Phil: Yes, that I remember those happy days.

Mat: What was so remarkable was that the new society was not only classless, it was also timeless; all clocks were forbidden, as well as calendars and any form of note books recording past events. Possession of any of these items was punished with death. Even counting was forbidden. Only Pol Pot was to have a number, *Number One.* There were no hours of the day, days of the week, weeks of the month, months of the year, and no years. It would be Year Zero for ever. Why? Because, like money and property, time was not equally distributed in society. Some people lived longer than others, some people had to work longer hours than others, some people aged quicker than others, and even more fundamentally unequal: some people were older than other, some were younger than other. All this inequality was eliminated in the timeless society, the society without clocks.

Phil: How it worked out? Fine, you may say, just fine. Since there were no cities and complicated machinery, there was no need for time-keeping. People went into the fields when the Sun rose in the morning and went to bed with the Sun in the evening, day after day. No one counted anything and there was no inequality anymore....

Figure 71.1: The timeless society of Pol Pot

Chapter 72

Problems Problems

Mat: Here are a couple of easy math quiz problems relating to time:

- A father was twice as old when he died as when his second son was born, How old was then his first son?
- Two trains part from Stockholm in the North and South direction. Determine which train will first meet the other if the Earth is a sphere of radius 1000 km.
- To build a 100 meter high pyramid takes 10 years for 10000 slaves. How long time does it take to build 10000 pyramids for one mathematician?
- Two twins parted from Stockholm the 1st of January 1900, and rejoined there for the 50th birthday of the first twin. How old was then the other twin assuming that the velocity of light is 300.000 km per second?
- How quickly is an electron aging, if the age of the Universe is 13.4 billion years?
- The Word record on 100 m sprint run was 11.0 seconds in 1900 and 10.0 seconds in 2000. What will the record be in year 2100?

Phil: Trivial problems. Too easy. Here are some difficult ones:

- How much longer would a second be if Planck's constant was doubled?
- Are dreams reversible in time?

- Suppose it took 4 billion years for life to develop into homo sapiens. How long time will it take to destroy human civilization?
- What will be the life time of a human being be in year 3000?
- What is the total length of pauses in a Beethoven sonata?

Part VI

Mathematics and Physics

Chapter 73

The Death of Boltzmann

> To go straight to the deepest depth, I went for Hegel; what unclear thoughtless flow of words I was to find there! My unlucky star led me from Hegel to Schopenhauer . . . Even in Kant there were many things that I could grasp so little that given his general acuity of mind I almost suspected that he was pulling the reader's leg or was even an imposter. – The most ordinary things are to philosophy a source of insoluble puzzles. With infinite ingenuity it constructs a concept of space or time and then finds it absolutely impossible that there be objects in this space or that processes occur during this time . . . the source of this kind of logic lies in excessive confidence in the so-called laws of thought. (Boltzmann)

> Ad hoc assumptions abound in modern mathematical physics....They create the false impression of excellence...In most cases modern science is more opaque, and more deceptive, than its 16th- and 17th-century ancestors have ever been. (Feyerabend in *Against Method*)

> Boltzmann has proved that the entropy of a given state is connected by a simple relationship to the probability of the state....only those spontaneous transformations occur which take the system to states of higher probability. (Enrico Fermi, Nobel Prize in Physics, in *Thermodynamics* 1936)

Phil: So far we have expressed Principe Perfeito and discussed aspects of the Arrow using ordinary language, but I would now like to see a translation into the language of mathematics.

Mat: Yes, it is a matter of translation: The essence remains the same but the mathematical dress is reduced to a minimum, like a bikini covering only the essentials. This is the beauty of mathematics!

Phil: First I would like to know what the trouble is with the standard answer to the riddle of the Arrow in the form of the mathematics of statistical mechanics?

Mat: The trouble is to give a mathematical definition of *entropy*. Boltzmann, the inventor of statistical mechanics, struggled with this definition throughout his scientific career until he finally gave up and ended his life. On his grave stone is imprinted the formula

$$S = k \log(W), \tag{73.1}$$

which defines the entropy S of a certain *macrostate* to be proportional to the logarithm of the number W of *microstates* corresponding to the macrostate, and k is *Boltzmann's constant*. Boltzmann's 2nd Law states that S (with high probability) can only increase.

Phil: How do you motivate that S can only (with high probability) increase, or what is the same, why W can only increase? How to you count the number W of micro-states underlying a macrostate?

Mat: Boltzmann tried to answer these questions in a mathematical model of a very dilute sparse gas consisting of very many molecules colliding elastically according to Newton's laws. His basic idea was to prove that such a gas will have a tendency (high probability) to move from an ordered state to an more disordered state under increasing S and W, with the number of microstates W representing the probability of the corresponding macrostate. The macrostate with the largest number of corresponding micro-states would be the equilibrium state with maximal entropy/disorder. Boltzmann thus claimed that there would be a general tendency (in a dilute gas) towards equilibrium states with maximal entropy/disorder, which would be characteristic of natural processes and which would explain the Arrow. Forward time was in the direction of increasing entropy/disorder bringing a system closer to equilibrium.

Phil Is that the catastrophe scenario of the *heat death* as the final state of the Universe?

Mat: This was first suggested in 1862 by William Thomson (Lord Kelvin) in the article *On the age of the Sun's heat*:

- *The result would inevitably be a state of universal rest and death, if the universe were finite and left to obey existing laws. But it is impossible to conceive a limit to the extent of matter in the universe; and therefore science points rather to an endless progress, through an endless space, of action involving the transformation of potential energy into palpable motion and hence into heat, than to a single finite mechanism, running down like a clock, and stopping for ever.*

Phil: Yes, the inevitability of a heat death according to existing laws is clear, but Kelvin hesitates and opens to a possibiltiy of endless progress. Is the heat death the same as the catastroph scenario of global warming we are now facing?

Mat: Not really, because the temperature of the dead rest state of the Universe would be close to absolute zero, while with global warming there would be tropical climate also in the North of Sweden, far from a dead state.

Phil: Back now to Boltzmann: So a disordered state would be more probable than an ordered state. Increasing entropy would thus reflect a tendency towards increasing disorder with time, because disorder would be more probable than order. But isn't this a circular definition? That a more probable state is more probable? How can a gas know what is ordered and disordered? When me and my wife have very different opinions on such matters. And again: Since Newtonian mechanics is time reversible, any motion from ordered to disordered can be reversed into a motion from disordered to ordered with decreasing entropy contradicting the 2nd Law of non-decreasing entropy, right?

Mat: Yes, Boltzmann was criticized by many, and he had to go into longer and longer explanations with more and more statistics. He started out with deterministic reversible Newtonian mechanics, and derived an irreversible differential equation referred to as *Boltzmann's equation*, which has an Arrow.

Phil: Irreversibility in reversible mechanics? What was the trick?

Mat: His antagonist *Loschmidt* directly pointed out that Boltzmann had sneeked in an extra assumption of statistical nature into the reversible Newtonian mechanics, later referred to as *molecular chaos*, or *Stossansatz*, stating independence of molecular velocities just *before* collision, but not after, thus defining an Arrow by assumption.

Phil: How did Boltzmann react to this blow?

Mat: By changing the argument to concern instead *initial states* with certain intial states being more probable than others. If the Universe started in a highly improbable state (like Big Bang) it would then have to evolve into something less improbable, and Voila! there was the Arrow! In our time Hawking has taken up this Big Bang idea: It is highly probable that the Universe started out in a highly improbable initial state.

Phil: You are kidding! Try to be serious instead! We are talking about serious matters. But I cannot understand how life and the organized structures we see all around can develop if everything is only falling apart into disorder? This was what Prigogine used to ask and which gave him the Nobel Prize in Chemistry in 197?.

Mat: It is likely that it was questions like that which drove Boltzmann to take his own life in 190?, maybe in an ultimate last attempt to prove that he was right, that death is the ultimate answer?

Phil: A tragedy. Maybe life after all is a tragedy? But isn't there any hope of a better more ordered World?

Mat: Yes, there is some hope: Principe Perfeito: Edge stability and finite precision.

Phil: So what is then the mathematical basis of Principe Perfeito?

Mat: Do you really want to know? If so, we will first have to talk a bit about the mathematics of Newtonian mechanics, in particular the concept of *time derivative* and *differential equation*. We can then write down the differential equation for a pendulum, which can be viewed as a clock. A clock without an Arrow, since the pendulum swings back and forth marking rate of time but not any direction of time. We shall then write down the equations of thermodynamics, and see that they have a form similar to the pendulum equations, with one important difference: There is an additional term representing turbulence reflecting edge stablity and finite precision, which defines an Arrow. Thermodynamics thus contains a clock with a direction.

Phil: But I never understood thermodynamics. Is it really possible to understand?

Figure 73.1: Ludwig Boltzmann updating his web page on statistical mechanics.

Chapter 74

The Birth of the Dot Age

> This is something we're very committed to, it's something that I think people are underestimating right now as they've seen some of the dot-com promises not come through. I think they're missing the fact that the basic technology is moving forward, the new platforms are here and this vision of the digital decade will be a reality. (Bill Gates)

> Es braucht kaum hervorgeben zu werden, dass diese neue Affassung des Zeitbegriffs an die Abstraktionsfähigkeit und an die Einbildungskraft des Physikers die allerhöchsten Anforderungen stellt. Sie übertrifft an Kühnheit wohl alles, was bisher in der spekulativen Naturforschung, ja in der philosophischen Erkenntnistheorie geleistet wurde; die nicheuklidische Geometrie ist Kinderspiel dagegen. (Planck [22])

> Those who have talked of chance are the inheritors of antique superstition and ignorance...whose minds have never been illuminated by a ray of scientific thought. (T. H. Huxley)

Mat: Yes, I think so. Let us start recalling that time is change (and change is life) and the mathematics of change is Calculus. Change is measured mathematically by *derivatives*. The time derivative of some quantity measures how much the quantity changes per unit time step. The derivative of the *distance* you travel on a highway is your *velocity*, and the derivative of your velocity is your *acceleration*. Newton denoted time derivative by a dot. If $u(t)$ is your distance traveled at time t, then $\dot{u}(t)$ is your velocity and $\ddot{u}(t)$ is your acceleration, at time t. Newton's time is often referred to as the *dot-age*.

Newton's dots should not be confused with dots used in e.g. German and Swedish spelling making $\ddot{a}$ and $\ddot{o}$ sound different from plain a and o, but in English spelling you don't have this problem.

Phil: Fine, a dot indicates differentiation with respect to time. I hope we do not end up with anything circular here, requiring time to be defined in order to define time? And are we not know entering the "dot-com-age" instead of the "dot-age"?

Mat: Don't worry. We will not fall into any circular reasoning. Let's recall that Leibniz did not use dots to denote derivative, and wrote $\frac{du}{dt}$ instead of $\dot{u}$, which is much better since it precisely expresses change per unit time step with du the change in u over the time step dt. It is believed that this was the reason that mathematics in Germany flourished after Leibniz but mushroomed in England after Newton. We use here anyway the dot to denote time derivative, which is ok if we remember that it means $\frac{du}{dt}$.

Phil: I agree that Leibniz notation is much more suggestive. A dot can mean anything. But for the moment we know what it means.

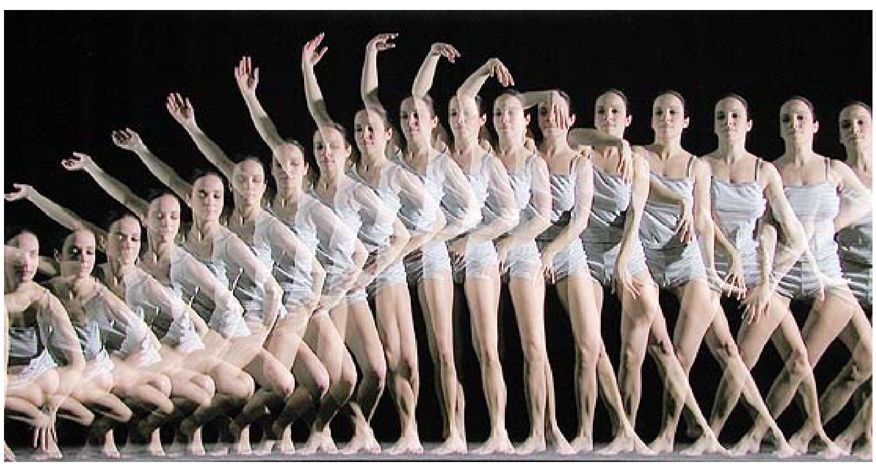


Figure 74.1: Time sequence of motion.

Mat: Now, we are ready to go: *Newton's law* for the motion of a body B of mass m subject to a force f, reads

$$ma = f,$$

where a is the acceleration of B, which can be formulated

$$m\ddot{u}(t) = f(t) \tag{74.1}$$

where $u(t)$ is the position of B, $\dot{u}$ the velocity, $\ddot{u}(t)$ the acceleration, and $f(t)$ is the force acting on B, at time t. If you know the initial position $u(0)$ and initial velocity $\dot{u}(0)$ at the initial time $t = 0$ together with force $f(t)$, then the position $u(t)$ for $t > 0$ is determined as a solution to the *differential equation* (74.1).

Phil: Is the equation reversible?

Mat: Yes: If you change t to $-t$ putting in a minus sign, thus changing the direction of time, each derivative changes sign, and thus two dots corresponds to changing sign twice, which is no change, and thus the equation takes the same form in reverse time. Newtonian mechanics is reversible. You cannot determine any direction of time from the *form* of the differential equation. If there is an Arrow, it seems to be invisible.

Phil: Can you solve the differential equation (74.1) analytically, that is, can you find a *formula* for the solution?

Mat: In simple cases, yes, in general not. For example, if if $f(t) = 0$, then the solution is $u(t) = u(0)+t\dot{u}(0)$ stating that B moves with constant velocity along a straight line, in forward or backward time.

Phil: This is Newton's 1st Law, right?

Mat: Yes. If B is the Earth and $f(t)$ is the gravitational force of the Sun, then $u(t)$ traces an elliptical orbit around the Sun. Kepler's three laws all follow from (74.1).

Phil: Impressive!

Mat: Yes, this was completely overwhelming to the scientific community of the late 17th century: Newtons differential equation (74.1) as a model of the World: Knowing the initial state at $t = 0$ and the force $f(t)$, by solving the differential equation for $t > 0$, you can *predict the future* state of the World. This is Laplace's deterministic model of the World as a clock with infinite precision. A reversible world without Arrow. And there is another big question mark: You cannot solve the differential equation analytically in general not even for system of three bodies, which you obtain if you add the Moon to the Sun-Erath system. What is the value of the differential equation if you cannot solve it? Isn't it like a riddle without answer?

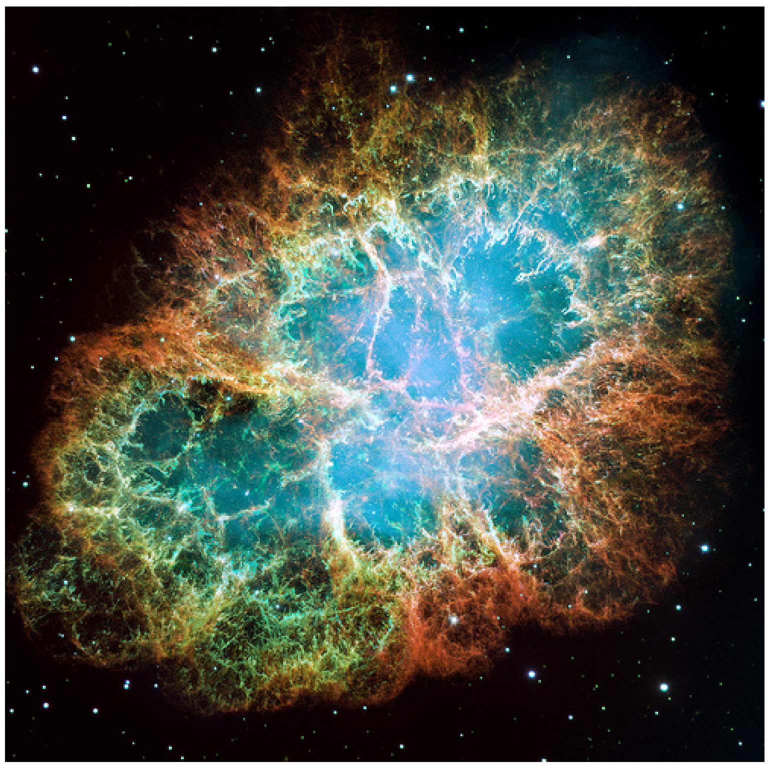


Figure 74.2: The Crab Nebula resulting from a super-nova explosion: Is it a result of solving $\ddot{u} = f(u)$?. Yes, what else? The picture was taken by the Hubble telescope in 2000. The nebula was first observed by naked in 1054 by Chinese astronomers.

Chapter 75

Time Stepping

> Einstein: Neither Herr Boltzmann nor Herr Planck has given a definition of W. – Usually W is put equal to the number of complexions. In order to calculate W, one needs a *complete* (molecular-mechanical) theory of the system under consideration. Therefore it is dubious whether the Boltzmann principle has any meaning without a *complete* molecular-mechanical theory or some other theory which describes the elementary processes (and such a theory is missing). (Einstein)

> Mechanically, the task seems impossible, and we will just have to get used to it (quanta) (Planck 1909).

Mat: It is not hopeless: For given initial data you can *compute* the solution by *time-stepping*: First you rewrite the equations as a *first order system*:

$$m\dot{v} = f, \quad \dot{u} = v, \tag{75.1}$$

or formally,

$$mdv = fdt, \quad du = vdt. \tag{75.2}$$

Now, given $u(t)$ and $v(t)$ at a time t, you can compute the changes du and dv over a short time interval dt, and compute $u(t + dt) \approx u(t) + du$ and $v(t + dt) \approx v(t) + dv$. This way you can *time-step* the solution from $t = 0$ to dt to $2dt$ and so on to any time you like, just as the real system will "tick" forward in time. Simple, if you have a computer, because you need to take small time-steps and thus to take many time-steps to get anywhere.

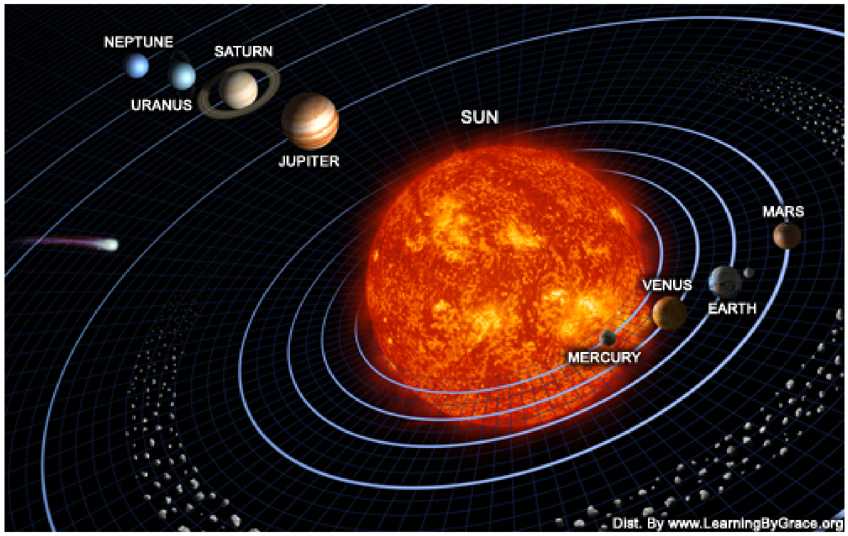


Figure 75.1: A reversible Solar system, computed from $m\ddot{u} = f$.

With a standard laptop you can this way compute the dynamics of system of thousands or millions of interacting particles.

Phil: This is also impressing. But a *mole* gas consists of more than 10^{23} molecules, which seems way beyond the capability of any thinkable computer.

Mat: You are right, you cannot use such *particle methods* following the individual trajectories in space and time of 10^{23} particles. But there are more economical so called *continuum models*, typically partial differential equations involving derivatives also in space. The basic continuum model for fluid/gas dynamics was formulated by Euler in 1755 in the form of the *Euler equations*. Until recently these equations were of little use, since they have no physically meaningful analytical solutions. Solutions are *turbulent* and there are no formulas for turbulent solutions. *However*, today you can solve these equations on a laptop and predict the motion of an airplane through air, a boat through water, or the blood through your heart. 250 years after invention, Euler's equations have become useful!

Phil: What a revolution! But what about reversibility. Are the Euler equations reversible?

Mat: You now touch the heart of matter. The Euler equations are *formally reversible*, but computed turbulent solutions are not! Irreversibility is an emergent phenomenon resulting from the complexity of turbulent solutions.

Phil: Is that the Arrow? Formally reversible equations having complex turbulent solutions which are irreversible?

Mat: You are right. That is the answer to Princess Turandot's first question: Why is there an Arrow of time?

Chapter 76

The Unsatisfied Pendulum

I can't get no satisfaction
I can't get no satisfaction
'Cause I try and I try and I try and I try
I can't get no, I can't get no
When I'm drivin' in my car
And a man comes on the radio
He's telling me more and more
About some useless information
Supposed to fire my imagination
I can't get no, oh no no no
Hey hey hey, that's what I say
(The Rolling Stones)

Mat: The basic dynamical system of Newtonian mechanics is the *harmonic oscillator*

$$\ddot{u} = -u, \tag{76.1}$$

corresponding to choosing $f(u) = -u$ and $m = 1$ in Newton's law $m\ddot{u} = f$, which in first order system form reads

$$\begin{aligned} \dot{u} &= v, \\ \dot{v} &= -u. \end{aligned} \tag{76.2}$$

The equation $\ddot{u} = -u$ models according to Fig. 76.1 a body fixed to springs with $u(t)$ the deflection of the body at time t from its equilibrium position at O and $-u(t)$ the corresponding spring force Of course the springs pull/push the mass to the left if the mass is to the right of O (with $u > 0$), and pull/push the mass to the right when the mass is to the left of O. This makes the mass oscillate back and forth with a certain period.

Phil: OK, I can imagine the mass oscillating back and forth because of the action springs. What is the period?

Mat: The total energy of the system is the sum of the kinetic energy $K = \frac{\dot{u}^2}{2}$ of the mass and the elastic energy $E = \frac{u^2}{2}$ stored in the springs. The total energy $K + E$ stays constant while the contribution from K and E varies: At the extreme points the velocity and thus kinetic energy K is zero and E maximal, and at the midpoint with $u = 0$ the elastic energy E is zero and K maximal.

Phil: OK, so the oscillation comes from a repeated shift of energy between kinetic and elastic energy. But what is the period?

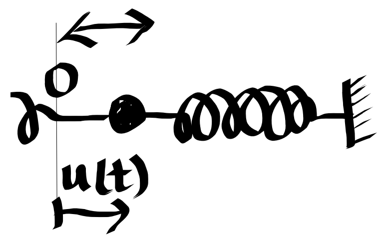


Figure 76.1: Harmonic Oscillator

Mat: The equation $\ddot{u} = -u$ also models the motion of a pendulum of unit length and mass with u the angle of the pendulum from the vertical position, if we assume that u stays small, see Fig. (76.2). We know that a pendulum swings back and forth, shifting energy between kinetic and potential energy. To find the *period*, let us formulate the corresponding initial value problem: Find the function $u(t)$ satisfying

$$\begin{aligned} &\ddot{u}(t) = -u(t), \quad \text{for } t > 0, \\ &u(0) = 1, \dot{u}(0) = 0, \end{aligned} \tag{76.3}$$

where we made a specific choice of initial data. The solution is given by the formula

$$u(t) = \cos(t), \tag{76.4}$$

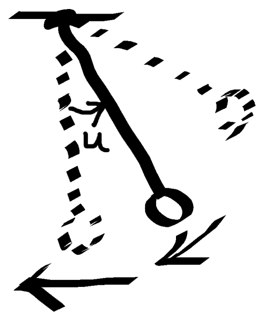


Figure 76.2: Pendulum.

which shows that the period is 2π since the cosine function $\cos(t)$ is periodic with period 2π. If you do not know what the cosine-function $\cos(t)$, you you can simply define it to be the (unique) solution to the initial value problem (76.3.

Phil: What harmonic oscillator corresponds to a cesium clock?

Mat: It is described by the function $\cos(2\pi\omega t)$, corresponding to the equation $\ddot{u}(t) = -(2\pi\omega)^2 u(t)$, which is analogous to the equation $\ddot{u} = -u$ with a different scaling, where $\omega = 9192631770$ is the number of cycles per second. Recall that we have agreed to define (the rate of) time by a cesium clock, and thus we can say that we define time by the solution $u(t)$ of a differential equation of the form $\ddot{u}(t) = -u(t)$, and we then agree to identify time with the variable t.

Phil: But isn't this circular: Don't you need to define time t to formulate the differential equation $\ddot{u}(t) = -u(t)$?

Mat: No, and that is the beauty of mathematics: The t in the differential equation $\ddot{u}(t) = -u(t)$, with $\dot{u} = \frac{du}{dt}$ represents a *real variable*, and the solution $u(t) = \cos(t)$ is a function of that variable. What you do is to assign the meaning of time to that variable, and doing so you can measure time by counting the number of cycles of a harmonic oscillator such as a cesium clock. That is an *operational definition* of time referring to a physical harmonic oscillator, like a pendulum, and a mathematical definition of time referring to the mathematical solution a certain differential equation.

Phil: I see that this is an operational definition of time. But what about the Arrow?

Mat: A harmonic oscillator does not have a direction. You can see this from the differential equation $\ddot{u} = -u$: Changing the direction of time replacing t by $-t$, you will change $\dot{u}$ to $-\dot{u}$ thus multiplying by (-1), but $\ddot{u}$ will remain unchanged since $(-1)(-1) = 1$, and so the differential equation $\ddot{u} - u$ is invariant under change of direction of time t. Thus, a harmonic oscillator does not have an Arrow. Its time can go either way.

Phil: It seems to me that the oscillation between potential and kinetic energy of a pendulum expresses an inability of the pendulum to be satisfied: When the pendulum has a lot of potential energy (in the top position), it seeks to get rid of it (by moving down), and in doing so it picks up kinetic energy, which it then seeks to get rid of by moving up on the other side picking up potential energy, which it seeks to get rid of.... and so on, in an endless cycle driven by a constant dissatisfaction.

Mat: You are perfectly right. This is like seeking to give up smoking by starting to eat chocolate, and then trying to stop eating chocolate by starting to smoke, in a endless cycle, with all the time the sum of the addictions being constant and the addict never reaching satisfaction. I know this too well.

Phil: This must be the essence of Newtonian mechanics: Satisfaction means equilibrium in a stationary immobile state. Dissatisfaction means endless motion in an unsuccessful search for equilibrium. The Sun always seeks to swallow the planets by attracting them by the gravitational force directed towards the Sun, but the planets always (miraculously) manage to escape by always moving at an angle to the line of attraction (perpendicular if the orbit is a circle). In endless dissatisfaction without ever reaching equilibrium...

Mat: Yes, that must the essence. Recall that *Foucault's pendulum*, named after the French physicist Léon Foucault (1819-1868), was conceived as an experiment to demonstrate the rotation of the Earth. It is a tall pendulum free to oscillate in any vertical plane. The direction along which the pendulum swings rotates with time because of Earth's daily rotation. The direction of a pendulum at the North Pole will rotate once in 24 hours, at the equator it will not change. Foucault motivated more precisely that at a latitude of θ the period will be $24/\sin(\theta)$ hours, which at the latitude of Paris of $\theta \approx 50$ degrees give a period of about 32 hours. Thus you may need to wait for an hour or so to see a distinct change in direction, if you are in Paris. The first public exhibition of a Foucault pendulum took place in February 1851 in the Meridian Room of the Paris Observatory. A few weeks later, Foucault made his most famous pendulum experiment, when he suspended a 28-kg bob with a 67-metre wire from the dome of the Panthéon in Paris: And yes, the Earth did indeed rotate, to the astonishment of the assembled expertize!

Phil: But wasn't it known long before 1851, by all the followers of Galileo including Newton, that the Earth is rotating around its axis?

Mat: Yes, of course, but the motion of a pendulum on a rotating Earth had not received a correct mathematical analysis. On the contrary, the famous mathematician Laplace had erroneously predicted a negligible influence on the direction of a pendulum from the rotation of the Earth. Foucault was not a mathematician and thus his discovery was first met with skepticism, and then with envy when it showed that his formula indeed was correct. After much ado he was elected in the French Academy of Sciences in 1865 three years before his death at the age of 48, although Napoleon III liked him and made him an Officer Légion d'Honneur in 1862.

Figure 76.3: Focault's pendulum experiment in Pantheon in Paris, 1851

Chapter 77

The Laws of Thermodynamics

> There are great physicists who have not understood it. (Einstein about statistical mechanics)
>
> Every mathematician knows it is impossible to understand an elementary course in thermodynamics. (V. Arnold)
>
> No one knows what entropy is, so if you in a debate usethis concept, you will always have an advantage. (von Neumann to Shannon)
>
> As anyone who has taken a course in thermodynamics is well aware, the mathematics used in proving the 2nd Law is of a very special kind, having only the most tenuous relation to that known to mathematicians. (S. Brush, The Kind of Motion we call Heat)
>
> Thermodynamics is a funny subject. The first time you go through it, y ou don't understand it at all. The second time you go through it, you think you understand it, except for one or two small points. The third time you go through it, you know you don't understand it, but by that time you are so used to it, it doesn't bother you any more. (Sommerfeld)

Mat: We have said that thermodynamics is the study of transformations between kinetic and heat energy in a gas/fluid. If we view heat energy as kind of potential energy, then we can say that thermodynamics concerns transformations between kinetic and potential energy. As a simple model of thermodynamics, we can thus choose a pendulum or a harmonic oscillator.

Phil: Get to the point, please.

Mat: OK, let us rewrite the equation for a pendulum or harmonic oscillator so that it connects to both the 1st and 2nd Laws of thermodynamics, as we will meet them below. Multiplying the first equation in (76.2) by u and the second by v, and noting that $\dot{E} = \dot{u}u$ and $\dot{K} = \dot{v}v$, we get the system

$$\begin{aligned} \dot{E} &= -W, \\ \dot{K} &= W, \end{aligned} \tag{77.1}$$

where $K = \frac{v^2}{2}$ is the kinetic energy, $E = \frac{u^2}{2}$ is the potential energy and $W = -uv$ represents the transfer of energy from potential to kinetic energy in the form of *work* performed by the system. If $W < 0$ with the velocity v and the position u having different signs, then the pendulum is moving down from its top position and performs work by increasing its speed and thus its kinetic energy. If $W < 0$, then the pendulum is moving up from the bottom position and stores energy in the form of potential energy.

Phil: Fine, I buy that. The equations (77.1) describe the interplay between potential energy E and the kinetic energy K mediated by the work W: Whatever goes out from E goes into K and vice versa. This is clear!

Mat: Adding the two equations gives for the *total energy* $K + E$,

$$\frac{d}{dt}(K + E) = \dot{K} + \dot{E} = 0, \tag{77.2}$$

that is, the total energy stays constant. We saw this above. Now, the system (**??**) expresses the 1st Law. This equation is time reversible: Changing the direction of time and the direction of the velocity v, leaves the system invariant. In other words, the transfer of energy from kinetic energy to heat enargy is reversible. Whatever you invest in potential energy by supplying kinetic energy, you can get back, and vice versa. And there is no transaction cost.

Phil: Yes, the 1st Law is a kids game. What about the 2nd Law?

Mat: The 2nd Law is the following variant of (76.2)

$$\begin{aligned} \dot{E} &= -W + D, \\ \dot{K} &= W - D, \end{aligned} \tag{77.3}$$

where $D > 0$. The novelty of the 2nd Law is evidently the positive D-term. The sign of the D term means that kinetic energy is transformed into heat/potential energy, but not the other way around. This gives time a direction in (77.3): The 2nd Law defines the forward direction of time to be the direction in which kinetic energy is transformed into heat/potential energy as defined by the D-term. As before, the work W can freely be transformed back and forth from kinetic to potential energy, but the D-term only allows transfer from kinetic to heat energy.

Phil: What about the sign of the work term W?

Mat: In the thermodynamics of a gas, $W > 0$ means that the gas performs work under expansion increasing its speed and thus its kinetic energy. If $W < 0$, then the gas stores energy under compression in the form of heat energy.

Phil: How do you see that (77.3) is not reversible?

Mat: Changing the direction of time and the sign of the velocity v, gives the system

$$\begin{aligned} \dot{E} &= -W - D, \\ \dot{K} &= W + D, \end{aligned} \tag{77.4}$$

with different signs of the D terms, corresponding to transfer from heat energy to kinetic energy, which is unphysical.

Phil: How do you motivate the 2nd Law (77.3)?

Mat: It is a consequence of the 1st Law combined with Prinicple Perfeito of edge stabliity and finite precision. The formally reversed law (77.4) is thus incorrect and does not correspond to a physical law. Again: Principe Perfeito combined with the 1st Law imply the 2nd Law. This is thermodynamics in a nut shell: Principe Perfeito + 1st Law is enough. The 2nd Law is just a corollary and not an in dependent basic law. The net result is that we do not have to worry about satifying the 2nd Law: It is automatic, which makes life (in particular for a thermodynamicist) much easier. This is like automatic payment of your bills from your Internet bank. You don't have to worry any more about paying your bills in time (and about the currencies), as long as you have money on your bank account.

Phil: What do we have to do to get a 2nd Law with a positive D-term for a pendulum?

Mat: The standard answer is just to add a little bit of friction or viscosity, and the pendulum will eventually come to rest with all of its kinetic energy transformed into heat energy. That is correct! In a sense, but the scientific question is from where does that little friction or viscosity come? This question is answered by Prinicipe Perfeito and the answer is: Turbulence. If the pendulum is swinging in air, then it will generate turbulence in the air which will transform kinetic energy into heat energy through a process of *turbulent dissipation*, and eventually bring the pendulum to rest in the bottom position (with a bit higher temperature).

Phil: But why is turbulent dissipation consuming kinetic energy inevitable?

Mat: This is the price Nature has to pay because gradients, differences, tension, have sharpened to such a degree that they further sharpened is impossible and a release of tension, a breaking of the wave, is necessary. Let's look at analogy: Parking in Stockholm. Since there are many more cars than parking places, every evening there is a fierce fight for finding a legal over-night parking place, which is free but difficult to find. There is a steady sharpening of the tension until 12 pm, when desperate drivers simply give up and park illegally anywhere to get a few hours sleep, and prepare for paying a fine.

Phil: OK, so the non-existence of an exact legal solution is thus handeled by approximate solution combined with a penalty, and the penalty corresponds to turbulent dissipation?

Mat: Exactly! A life process shares the same impossibility of finding an exact solution and therefore pays a penalty which makes the process irreversible. You can thus say that

- *irreversibility is the price we have to pay to live.*

Chapter 78

Joule's Experiment

> I know that most men, including those at ease with problems of the highest complexity, can seldom accept even the simplest and most obvious truth if it be such as would oblige them to admit the falsity of conclusions which they have delighted in explaining to colleagues, which they have proudly taught to others, and which they have woven, thread by thread, into the fabric of their lives. (Tolstoy)
>
> The simulacrum is never that which conceals the truth–it is the truth which conceals that there is none. (Baudrillard)

Mat: In 1845 the British physicist Joule made an experiment, which illustrates a most basic aspect of thermodynamics. Joule filled a container or chamber with a gas to high pressure, let the gas come to rest at temperature, say $T = 2.5$ in some units. Then he immersed the chamber into a bucket of water also of temperature $T = 2.5$, together with an empty container, opened a valve between to two containers and allowed the gas to expand (all by itself) into the double volume and then come to rest, see Fig. (78.6) displaying the set-up of the original experiment. Joule measured the temperature in the water during and after the expansion.

Phil: What was Joule expecting to see? A temperature drop during the expansion?

Mat: Yes, that is right! Because a gas cools off when it expands. This is why a spray can cools off when you let the spray out. This is the same phenomenon, in reverse, what makes the bicycle pump warm up as you compress air into the inner tube of the tire.

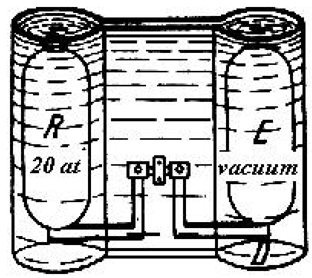


Fig. 358 Concerning overflowing experiment of Joule (Scientific Papers). R contains at first air compressed to 20 atm, E is initially a vacuum, D the tube

Figure 78.1: The Joule-Thomson experiment

Phil: I guess this is the principle of a refrigerator: A *refrigerant* (freon) in liquid form passes an expansion valve and evaporates to a gas while cooling off, absorbs heat from the interior of the fridge, is compressed to a liquid delivering heat to the exterior and then repeats the cycle. The net effect is that heat is moved from the interior of the fridge at low temperature to the exterior at higher temperature, thus making heat flow from cold to warm, by spending the energy to run the compressor. A heat pump works the same way. But now back to the experiment. What did Joule find?

Mat: To his surprise, Joule could not detect any temperature drop! The entire scientific community was stunned. What was going on?

Phil: That seems really strange. But I know that my fridge works, so there must be a temperature drop! But how can we find out what is going here?

Mat: Well, we have device at hand which Joule did not have, namely a computer. We can make a *computational simulation* of the experiment on a computer. We can then follow what happens and come to understand the process. Computational simulation gives us a very precise and flexible laboratory for scientific experiments. This is hyper-reality in the sense of Baudrillard. Let's use it.

Phil: Great! What do we see? How is the simulation done?

Mat: What the computer does is to solve the mathematical equations expressing *conservation* of *mass*, *momentum* and *energy*, which is the 1st Law, by the same time-stepping procedure we used above to find the distance from knowing the velocity.

Phil: What about the 2nd Law? Don't we have to satisfy that as well?

Mat: Don't worry, it will come for free. To avoid the vacuum, which is a bit extreme, we changed the data so that initially the pressure and density in the right chamber is one tenth of that in the left, not zero as in the original experiment, while the temperature $T = 2.5$ in both the right and left chambers. The essence of the experiments remains the same. Take a look a the snap-shots of computed density and temperature and how density, kinetic energy and temperature varies in time. What do you see looking at the figures?

Phil: Well, I see as expected that the gas expands into the right chamber with the lower pressure and density, and I see that there a complex turbulent flow develops, but eventually the gas comes to rest in the full volume of the two containers with the temperature dropping to about 2.0 in the left chamber and increasing to about 3.0 in the right, thus roughly of mean-value 2.5 as the common temperature at start, while the density in the left chamber settles to about 0.6 and in the right to about 0.4 with a remaining gap of about 0.2, and the pressure equilibrates to about 0.55 equal in both chambers.

Mat: You are right. The total energy, the sum of the *kinetic energy* and the *heat energy*, is constant, and so the energy required to put the gas into motion (expansion) must be taken from the heat energy, resulting a temperature drop in the left chamber. However by turbulence the kinetic energy is eventually transformed back to heat energy in the right chamber where thus the temperature increases. But the mean-value at the end of the process is 2.5, the same as the common value at start.

Phil: OK, so initially the temperature drops in the left chamber, when heat energy is converted to kinetic energy and the gas expands into the right chamber, where eventually by turbulence the kinetic energy is converted back to heat energy. But the mean-value remains the same as the initial temperature and if only the mean-value is measured as in the Joule bucket, one could get the impression that there was no temperature drop.

Mat: You've got it!

Phil: But is this process irreversible? Is it possible that the gas by itself contracts back to the left chamber? Intuitively, this seems impossible. The

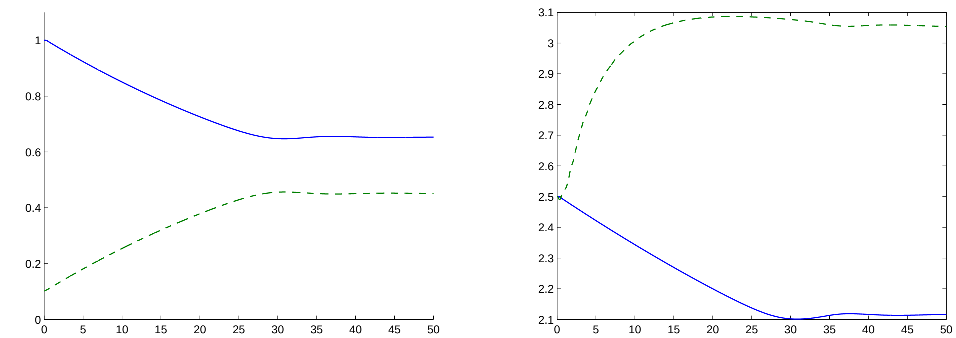


Figure 78.2: Density and temperature in left and right chambers

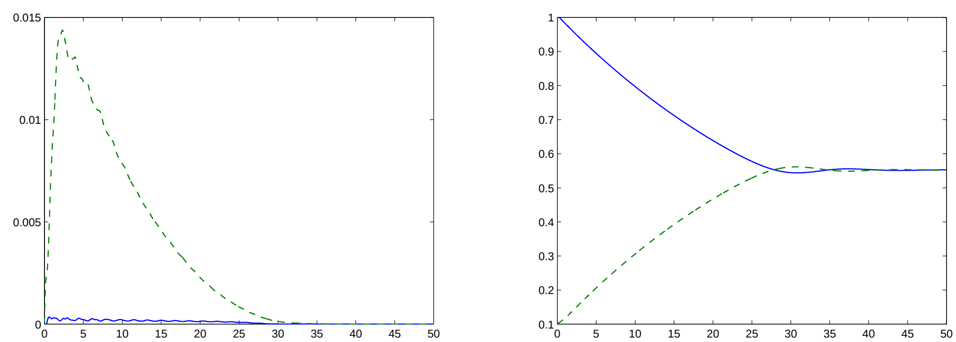


Figure 78.3: Kinetic energy and pressure in left and right chambers

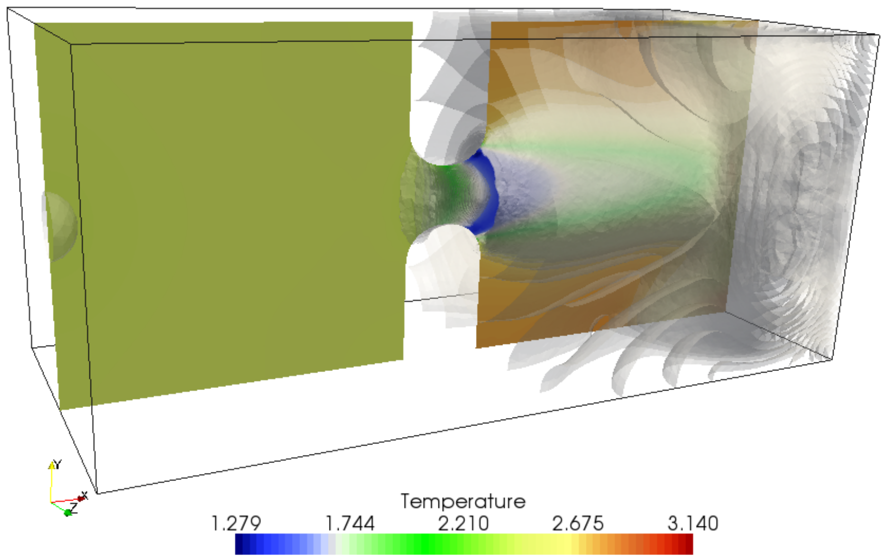


Figure 78.4: Distribution of gas temperature at $T = 3$

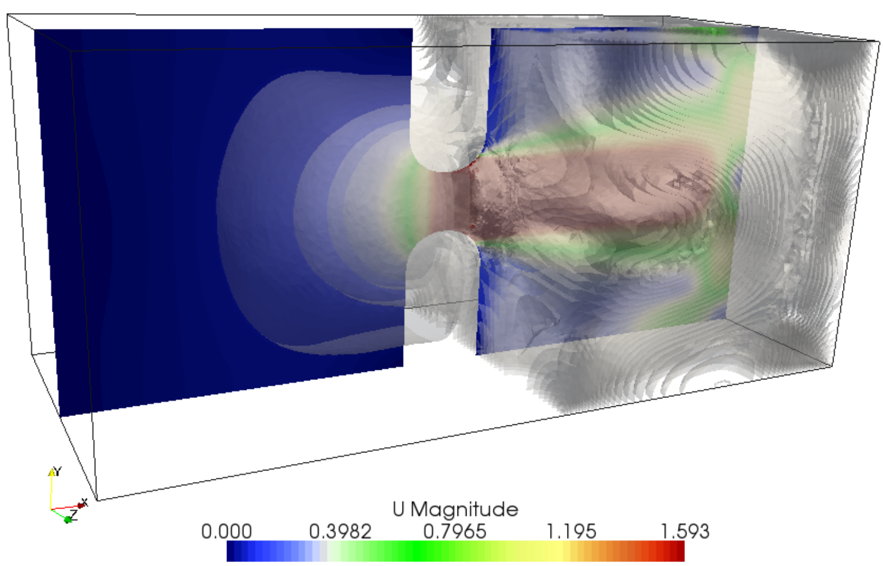


Figure 78.5: Distribution of gas speed at $T = 3$

gas can expand by itself but it seems to me that it cannot contract by itself. Can the 2nd Law help out?

Mat: Yes, it can. Recall that it takes the form

$$\dot{K} = W - D,$$
$$\dot{E} = D - W,$$

and that the work W is positive under expansion and negative under compression. Thus the gas can by itself get into motion from rest by expansion, but not by contraction/compression. Thus once the gas has come to rest in the two chambers, it cannot by itself contract to the left chamber. You can only compress it back by applying a compressive force. Since D is positive, there is always a transfer of large scale kinetic energy into small kinetic energy in the form of heat energy. This acts is like a tax on (high quality) kinetic energy , which is transferred to (low quality) heat energy, like a Robin Hood transfer from rich to poor. This transfer only goes one way.

Phil: I have seen the phenomenon of expansion in herds of sheep which are capable of escaping through a hole in a fence, but will not go back by itself unless forced by a sheep dog, see Fig. (**??**). I think I have for the first time in my life understood something about the thermodynamics of heat engines converting heat energy to kinetic energy.

Mat: Great! Life is a form of heat engine: You eat and burn calories to get your body and mental processes moving. That is an irreversible thermodynamic process. Having understood the Joule's experiment, we have understood a good deal of thermodynamics, without thinking of entropy, and a good deal about all the processes around us and inside us which are based on thermodynamics, and thus also some of the mystery of the Arrow.

Phil: What does classical thermodynamics say about a gas expanding to its double volume? What about entropy?

Mat: Well, it says that a gas in a bigger volume has more entropy and is less ordered, because it is more spread out. Maybe this catches something essential, but it also raises a lot of questions concerning the physical meaning of entropy and order/disorder which have no good answers. You can stay away from this without missing anything if you instead use the 2nd Law of Principe Perfeito, which does not involve the concept of entropy.

Figure 78.6: A sheep dog compressing a sheep herd.

Phil: This connects to *Ockham's principle* that a simple scientific explanation is better than a complicated explanation! Why? Because, what is simple can be understood better than what is complicated, and thus can be more useful to more people.

Mat: You can replace Joule's experiment with an experiment you can do yourself if you just have a U-glass or something similar, or you can simply make a thought-experiment: Start with a volume of fluid at rest in the left half of the glass, and open a valve at the bottom to let the fluid free. It will then swing to the right just like a pendulum and then back again. But not quite, because inevitable turbulence will develop and in each swing some kinetic energy will irreversibly be transformed into heat energy, so that eventually the fluid comes to rest in a symmetric equilibrium configuration with all kinetic energy transformed to heat energy. We understand that the dynamics is similar to that in Joule's gas experiment, with the difference that the initial energy appears in the form of compression in the gas and as potential energy in the fluid.

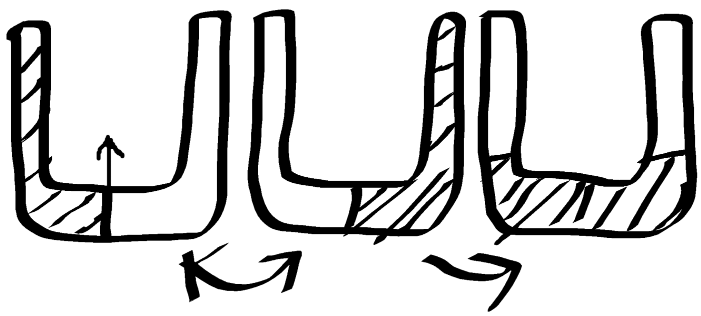


Figure 78.7: Water in a U-glass oscillating back and forth until it eventually comes to rest in equilibrium.

Chapter 79

Physics of Principe Perfeito

> Equilibrium is the very opposite of disorder. (Rudolph Arnheim)

> A life is like a wave forming and breaking on the shore. (Unknown Neanderthaler)

> Born believes in the God who plays dice, and I in complete law and order in a world which objectively exists, and which I, in a wild speculative way, am trying to capture. I hope that someone will discover a more realistic way, or rather a more tangible basis than it has been my lot to find. Even the great initial success of Quantum Theory does not make me believe in the fundamental dice-game, although I am well aware that younger collegues interprete this as a consequence of senility. No doubt the day will come when we will see those instinctive attitude was the correct one. — Einstein: Some physicists. among them myself, cannot believe that we must abandon, actually and forever, the idea of direct representation of physical reality in space and time; or that we must accept then the view that events in nature are analogous to a game of chance. —In any case I am convinced that *He* does not throw dice. (Einstein)

Mat: Recall that *Principe Perfeito* combines

- *finite precision and edge stability*,

A basic aspect of edge stability is reflected in the fish trap model by the fact that it is easy to get in but difficult to get out of the trap. And of course a real fish has finite precision (while an ideal fish with infinite precision would be able to escape). We met the aspect of precision also in connection with the process of separation, which may require both care and time.

Phil: What about edge stability then?

Mat: Take a look at the figure below of a wave breaking on a shore. The dynamics follows Newtonian mechanics and thus is formally reversible. We see a slow build-up with the wave successively becoming sharper and sharper until the eventual quick break-down. The build-up and successive sharpening of the wave reflects edge stability. Reversing the process would require quick precise build-up, which is impossible with finite precision, while quick imprecise break-down is possible.

Phil: I see that the wave breaks down quickly and brutally, but do you really see a slow build-up of the wave?

Mat: Yes, if the slope of the shore is small, then the wave can slowly build up over a long time (and distance). Further, waves in very viscous fluids, like heavy syrup, will quickly be damped and thus cannot build up, but in a slightly viscous fluid like water it can. The most interesting case a wave forming and almost breaking for long time until it eventually breaks. That is the essence of edge stability, which you can see in life process like a wave slowly forming and eventually breaking on the shore.

Phil: But why has the wave to break? Why do we all have to die?

Mat: The tendency to break comes from the fact that the bottom of the wave is slowed down by the shore while the upper part is not, which means that the steepness of the wave increases, until the wave tips over and breaks. We are familiar with this scenario: some parts move faster than the others and the tension builds up, until something breaks.

Phil: I see that the wave before breaking down completely, breaks just a little bit on the top, seemingly in an attempt to slow down the top and keep going for a while. But it does not seem to help in the long run since eventually it breaks down completely. So maybe we can slow down the process of aging by paying insurance or tax, by eventually we have to give in.

Mat: We can summarize the dynamics of Principe Perfeito as

- create difference-destroy difference,
- create tension-release tension,

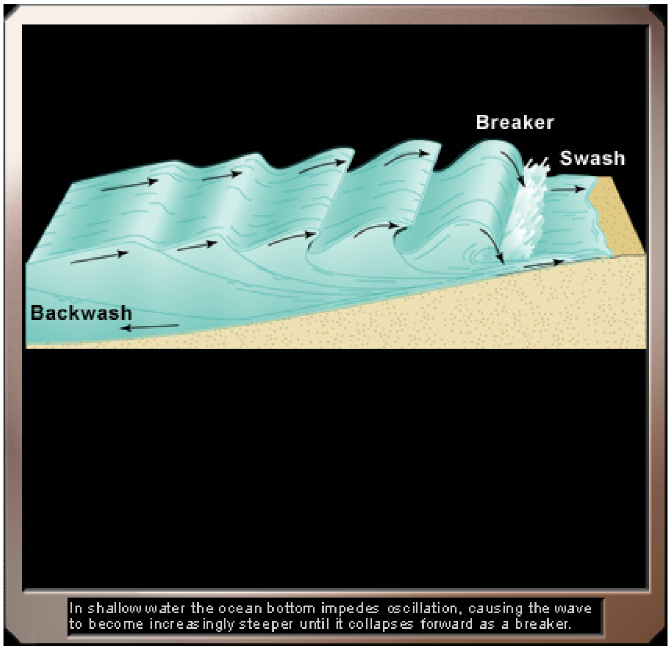


Figure 79.1: Life as a breaking wave.

- build up-break down,
- form-deform,
- paint-erase,

The irreversible nature of such processes comes from the different requirements of precision and tine: Creation requires precision and takes time, destruction does not. Creation always takes time, destruction not always. Principe Perfeito also explains *why* destruction is necessary, *why* death cannot be avoided, *why* continued creation inevitable leads to final destruction in an edge stable system.

Phil: This reminds me about *Chanson Sans Paroles* by Jacques Brel about the (too long) time required to write a love letter:

J'aurais aimé ma belle
T'écrire une chanson
Sur cette mélodie
Rencontrée une nuit

J'aurais aimé ma belle
Rien qu'au point d'Alencon
T'écrire un long poéme
T'écrire un long "je t'aime"

Je t'aurais dit "amour"
Je t'aurais dit "toujours"
Mais de mille facons
Mais par mille détours
Je t'aurais dit "partons"
Je t'aurais dit "brulons"
Brulons de jour en jour
De saisons en saisons

Mais le temps que s'allume
L'idée sur le papier
Le temps de prendre une plume
Le temps de la tailler
Mais le temps de me dire
Comment vais-je l'écrire
Et le temps est venu
Ou tu ne m'aimais plus

Mat: Yes, it takes time to build a house, because you have to put brick to brick in the correct order, and there are many bricks. Yet you can blow up a house in a second and rip the bricks apart. Glueing together takes time, ripping apart does not. When you rub your hands to warm them by friction, you rip molecules apart, which creates heat, but you cannot reverse the process and rub your hands by heating them, because you cannot reverse the ripping. You can rip a piece of paper apart in a second, but you cannot unrip it exactly even if you have a life time, letting each pair of atoms ripped apart meet again. Ripping families apart to different camps, can never be fully reversed.

Phil: What about finite precision? Can you make it more precise?

Mat: Precision is connected to the space scale of a certain process. The *macroscopic* scale of a volume of many atoms, which could be a *meter*, is different from the *microscopic* scale of individual atoms, which could be a *nano-meter* $= 10^{-9}$ meters. This means that a precision of 10^{-9} meters may seem like low precision for an atom, that is microscopically a low precision,

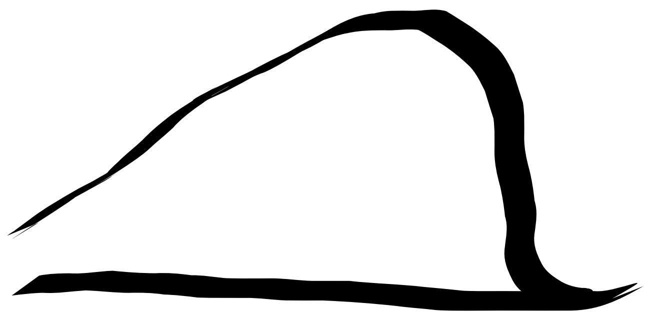


Figure 79.2: Irreversible life-death dynamics: slow build up followed by quick decay.

but of course on a macroscopic scale of meters, it may seem like a very high precision. The effect of this that natural laws may be of very high precisison macroscopically, but of low precision microscopically. This of course makes a connection to the microscopic games of roulette of statistical mechanics, but it does not throw determinism over-board, only takes the precision relative to the scale into account. This way it is possible to achieve, what statistical mechanics seeks to achieve, and more so, without paying the very high price of introducing microscopic games of roulette.

Phil: OK: *formally reversible* system like Newtonian mechanics or quantum mechanics, can be *practically irreversible*, because on microscopic scales the natural laws *can only be satisfied to a very low precision*, and the fine for violation acts like a dissipative effect. Moreover, the dissipative effect is not small and cannot be diminish by introducing finer scales. The impossibility of time reversal will remain even if you improve the precision of the Clock. When you make the Clock more delicate and precise in order to reverse it, you will find the increased precision is canceled by the delicacy of the machinery with more little things can get tangled under reversal. But *how* can individual molecules "know" that they cannot satisfy e.g. Newton's law exactly?

Mat: They will try their best but will not succeed, but why can't they succeed? Because of tension, because of difference: Fluid particles in a whirling turbulent flow live with very strong velocity gradients with nearby particles moving with vastly different velocities. That is the nature of turbulence. Fluid particle have to interact with nearby particles to satisfy Newton's law, but will find it increasingly difficult to do so with increasing tension. Even-

Figure 79.3: Lenin creating increased tension in 1920. (Trotsky to the right of the podium was later removed from the photo by reversing his presence.)

tually they will have to release the tension by violating Newton's laws. They do that not because they are criminal, but because they cannot any longer obey the lawful.

Phil: What you are describing is optimistic version criminology: Make it possible to be lawful and there will be no criminals. But that requires more parking places or fewer cars in Stockholm.

Mat: An individual in a society undergoing a revolution: may not understand anything of what's going on, but surely will note an increased tension everywhere and a resulting difficulty of getting things right. And a child in a marriage breaking down will note the increased tension without understanding the issues, and will not perform well at school...There are many examples of this phenomenon. The net result that irreversibility may arise in a formally reversible system, because by the complexity of the flow, the natural laws cannot be satisfied exactly (i.e. there is no exact solution), and the fine is irreversible dissipation. The price for not being able to satisfy the laws is that you have to go forward in time and leave your shortcomings behind. In other words, you have to "loose time", because you are not perfect.

Phil: So, a capitalistic economy can be viewed to be edge stable. In general terms, a process is said to *stable* if it does not change much under perturbations, while it is *unstable* if it changes a lot under very small perturbations. Stability thus concerns the *growth of perturbations*: if perturbations don't grow or even shrink, then the process is stable, and if small perturbations can grow large, then the process is unstable. An edge stable process is on the border between stable and unstable, neither very stable nor very unstable, somewhere between *order* and *chaos*. Since edge stable processes are almost unstable, they need to be controlled, and the control amounts to a price to pay or a cost to take like paying interest or tax.

Chapter 80

Mathematics of Thermodynamics

> However sublime are the researches on fluids which we owe to Messrs Bernoulli, Clairaut and d'Alembert, they flow so naturally from my two general formulae that one cannot sufficiently admire this accord of their profound meditations with the simplicity of the principles from which I have drawn my equations ...(Euler 1752)

> The 2nd Law cannot be derived from purely mechanical laws. It carries the stamp of the essentially statitical nature of heat. (Bergman in Basic Theories of Physics 1951)

> The total energy of the universe is constant; the total entropy is continually increasing. (Rudolf Clausius)

> Shut up and calculate. (Dirac)

Phil: Thermodynamics has an Arrow of Time, the 2nd Law, and if we can understand the mathematics of thermodynamics, then we can understand the mathematics of the Arrow. Is it difficult?

Mat: Let's see: The mathematical equations describing thermodynamics consists of Newton's equation $ma = f$ expressing *conservation of momentum*, plus equations expressing *conservation of mass* and *conservation of energy*, plus a *state equation* describing how the pressure depends on density and temperature. These equations are the *Euler equations* formulated by Euler in 1755 and can be summarized as the 1st Law: Conservation of mass, momentum and energy.

Phil: What do the Euler equations look like?

Mat: Consider an *ideal* gas or fluid enclosed in a fixed volume Ω in three-dimensional space $\mathbb{R}^3$ over a time interval $[0, T]$ with intial time zero and final time T. An ideal gas is a model of a gas (or fluid) with very small viscosity and heat conductivity, like air (or water). The Euler equations expressing conservation of mass. momentum and energy take the following form in terms of the *density* ρ, *momentum* $m = \rho u$ with u the *velocity*, and *total energy* ϵ:

$$\begin{aligned} \dot{\rho} + \nabla \cdot (\rho u) &= 0 \qquad \text{in } \Omega \times I, \\ \dot{m}_i + \nabla \cdot (m_i u) + p_{,i} &= 0 \qquad \text{in } \Omega \times I, \quad i = 1, 2, 3, \\ \dot{\epsilon} + \nabla \cdot (\epsilon u + pu) &= 0 \qquad \text{in } \Omega \times I, \end{aligned} \tag{80.1}$$

together with an initial condition and suitable boundary conditions, where $p = p(x, t)$ is the *pressure* of the gas, $v_{,i} = \frac{\partial v}{\partial x_i}$ is the partial derivative with respect to x_i, $\dot{v} = \frac{\partial v}{\partial t}$ is the partial derivative with respect to time t, and the total energy $\epsilon = k + e$, where

$$k = \frac{\rho |u|^2}{2}$$

is the *kinetic energy*, and

$$e = \rho \tau$$

is the *internal energy* with τ the *temperature*, assuming the heat capacity is equal to one. Here $\nabla \cdot v = \sum_i v_{i,i}$ denotes the divergence of $v = (v_1, v_2, v_3)$ and $\nabla w = (w_{,1}, w_{,2}, w_{,3})$ the gradient. There are five equations in the Euler system (80.1), while the number of unknowns including the pressure is six, and so we need one more equation, which is the *state equation* and which for a *perfect gas* takes the form of *Boyle's law*:

$$p = (\gamma - 1) \rho T \tag{80.2}$$

with $\gamma > 1$ the *gas constant*.

Phil: So if you know the initial and boundary values, and the gas constant, then you can compute the state of the gas a later time by solving the Euler equations. How do you then solve them?

Mat: By transforming the equations using the *finite element method*, dividing the volume Ω into a large collection of little fluid packets, so that the equations can be fed into a computer. Then the computer solves the equations to finite precision by time stepping. This way you can simulate a world of thermodynamics. The Joule experiment is just one example.

Phil: What does solutions of the Euler equations tell us about the Arrow?

Mat: Well, you prove that Euler solutions satisfy a 2nd Law of the form we already met:

$$\begin{aligned} \dot{K} &= W - D, \\ \dot{E} &= -W + D, \end{aligned} \tag{80.3}$$

where K is the total kinetic energy, E is the total heat energy, W is the rate of total work by expansion/compression, and $D > 0$ is the rate of total turbulent dissipation.

Phil: OK, I see that Euler solutions are irreversible in case they are turbulent with $D > 0$. Are Euler solutions turbulent?

Mat: Yes, they all are turbulent, and thus irreversible. This makes thermodynamics irreversible, and thus thermodynamics has an Arrow. This is the Arrow of our lives.

Phil: Why are they all turbulent?

Mat: Because the Euler equations are edge stable with a tendency to sharpen gradients or increase difference, which ultimaltely has to be penalized by turbulent dissipation. Like the wave breaking on the shore. In turbulent dissipation large scale kinetic energy is transformed into small scale kinetic energy in the form of heat, and this transfer is irreversible because of finite precision.

Phil: OK. The Euler equations don't look that frightening, and apparently they can uncover the secret of the Arrow. That is neat!

Chapter 81

Photoshop Irreversiblity

> Look, I'm not an intellectual - I just take pictures. (Helmut Newton)
>
> To me, photography is the simultaneous recognition, in a fraction of a second, of the significance of an event. (Henri Cartier-Bresson)
>
> What wanted to say was just this: In the present circumstances the only profession I would choose would be one where earning a living had nothing to do with the search for knowledge. (Einstein's last letter to Born Jan 17 1955 shortly before his death on the 18th of April, referring to Born's statistical interpretation of quantum mechanics).
>
> It seems to me that the concept of probability is terribly mishandled these days. A probabilistic assertion presupposes the full reality of its subject. No reasonable person would express a conjecture as to whether Caesar rolled a five with his dice at the Rubicon. But the quantum mechanics people sometimes act as if probabilistic statements were to be applied *just* to events whose reality is vague. (Schrödinger in a letter to Einstein 1950)
>
> Therefore I feel that the Heisenberg-Bohr (Copenhagen) interpretation of quantum mechanics is dead". (H.D. Zeh [28])

Mat: I see you have a digital camera. How many pixels?

Phil: It is a cheap one, only 7 million pixels, but the pictures are pretty sharp and detailed. But of course the precision is finite, and I am dreaming about a new one with 60 million pixels, which should give incredibly sharp pictures also in large format.

Mat: To you play with Photoshop to improve your pictures? **Phil:** Yes I do. Why do you ask? Is there an Arrow or irreversibility in Photoshop?

Mat: Yes, there is. You can subject a given image to *smoothing* making it softer more blurred, and in the other direction you can sharpen a blurred picture. But there is a limit to how much you can sharpen a blurred picture.

Phil: OK, let me test that on my computer. I start with an image of Leibniz teaching philosophy of time to Queen Sophie Charlotte von Brandenburg, smooth it and the sharpen the smooth image. This is what I get:

Figure 81.1: Original, blurred and sharpened blurred image.

Mat: So you don't get back the original image. The smoothing operation is irreversible.

Phil: This is natural: Smoothing involves mixing pixels, and unsmoothing is like unmixing. Photoshop can't do that, apparently. Can you explain it in mathematical terms?

Mat: Yes, smoothing is like solving the *heat equation* $\dot{u} - \Delta u = 0$ forward in time starting with an initial condition at $t = 0$ and finding the solution $u(x, t)$ for $t > 0$, where $u(x, t)$ represents the gray-shading of the image at the pixel at position x, with say $u = 1$ for black and $u = 0$ for white. Here Δ is the *Laplace operator*. You can solve the heat equation by time stepping involving taking repeated averages of gray-shades around each pixel, which acts like smoothing.

Phil: So what Photoshop does to do the smoothing is to solve a heat equation over the domain of the picture. Amazing!

Mat: If we change the direction of time we get the *backward heat equation* $-\dot{u}-\Delta u = 0$ or equivalently $\dot{u}+\Delta u = 0$ with a change of sign of the Laplace operator.

Phil: OK, so we have the forward heat equation $\dot{u}-\Delta u = 0$ and the backward heat equation $\dot{u} + \Delta u = 0$. Do they have different properties?

Mat: You bet! In the forward heat equation little perturbations quickly get damped by the smoothing process of taking mean values, while in the backward heat equation perturbations get amplified. Damping of perturbations in forward time and amplification of perturbations in backward time. This means that Photoshop can solve the forward heat equation with finite precision, but not the backward heat equation, where the effects of finite precision become visible.

Phil: Yes, if you blur a sharp picture into an almost uniformly grey image, it will impossible to recover the original sharp picture. There is a limit to the precision of the recovery. Of course, this is the old story of mixing and unmixing milk into your coffee. And turbulence is a form mixing or smoothing which thus is irreversible. It all fits together!

Chapter 82

Equilibrium

> Now equilibrium is the very opposite of disorder. — A system is in equilibrium when the forces constituting it are arranged in such a way as to compensate each other, like the two weights pulling at the arms of a pair of scales. (Arnheim)

> But maybe that is our mistake: maybe there are no particle positions and velocities, but only waves. It is just that we try to fit the waves to our preconceived ideas of positions and velocities. The resulting mismatch is the cause of the apparent unpredictability. (Stepen Hawking)

> It seems to me that the concept of probability is terribly mishandled these days. A probabilistic assertion presupposes the full reality of its subject. No reasonable person would express a conjecture as to whether Caesar rolled a five with his dice at the Rubicon. But the quantum mechanics people sometimes act as if probabilistic statements were to be applied *just* to events whose reality is vague. (Schrödinger in a letter to Einstein 1950)

Phil: We said that change is time, but why do things change? What makes the World go round?

Mat: You may say that it comes from a search or drive to equilibrium: Everything, everybody, ultimately is searching for equilibrium. Is it a deep thought? Not really, it just says that if a body B is not in equilibrium, then there must be some forces acting on B which do not balance, and then B is moving so as to decrease the imbalance, and that is towards equilibrium with full balance. The idea is to decrease tension to reach equilibrium with no tension. Simple.

Phil: But why is then not everything stand-still in equilibrium since long? A static World without change and thus without time.

Mat: Well, that happens sometimes, that a system comes to stop, and find an equilibrium, but not always evidently, since in fact the World goes around. We have already met the basic example of an unsuccessful seasch for equilibrium: A pendulum or a clock. Why does not the clock stop? Why does not the pendulum come to a halt? Well, it tries, but does not succeed. Just as in our lives we all strive for happiness (to be in equilibrium), but rarely really succeed.

Phil: Adam Smith's *The Wealth of Nations* marks the birth of the economical theory of the industrial revolution. The central idea is that an *Invisible Hand* will lead a *free economy* of *economical men* to equilibrium with supply and demand in balance. We know that economies follow cycles like a (slowly swinging) pendulum, which shows that equilibrium is never attained, but the drive to equilibrium is there. Economies in fruitless search for equilibrium and in need of stabilization to minimize oscillations, by Keynesian control of government spending or Friedman's monetary control.

Mat: A waving flag is an example of a system seeking equilibrium but never succeeding: The static equilibrium is a flat flag in the direction of the wind, but that is unstable and instead the flag waves from one side to the other, always searching equilibrium but never succeeding. In a *Perfect Sweden*, flags would not wave but stay flat and still, but that country does not exist (fortunately). The flag is also a model for turbulent flow: a flow searching equilibrium but never succeeding, and therefore oscillating. In fact the wavy motion of a flag is caused by turbulent motion of the air around the flag. Without turbulence the flag would be flat.

Figure 82.1: Dynamics of the Swedish society. In a perfect society the flag would be flat.

Chapter 83

Order and Disorder

> We abandon the past, but the past does not abandon us. (Erwin Strittmatter in *Doré's Bible* by Torgy Lindgren)

> The distinction between past, future and present is only an illusion; even if a stubborn one. (Einstein)

Mat: The classical 2nd Law as interpreted by Boltzmann states that Nature has a tendency to move from order towards disorder. This is supported by the observation that if you leave your car in the street for a longer time, it will fall apart, by itself. True, but what about the other things that do not fall apart just because you do not attend to them. What about your children who can take care of themselves, without much of your good advice, or the flowers in the fields and the birds in the sky? They do not disintegrate just because you are not looking after them. And the crystals forming on your window in the winter, and the waves forming on the sea? Is that disorder? Does everything fall apart?

Phil: Of course not: There are two forces in Nature, Brahma for creating order and Shiva for destroying order. There is not only Shiva as in Boltzmann's utterly pessimistic world steadily approaching "heat death", but also the possibility of order from chaos. Principe Perfeito expresses the balance (or battle) between Brahma and Shiva, between creation and destruction, what gives the World such an interesting dynamics.

Mat: The terminology chosen by Boltzmann is very unfortunate, because order and disorder are so ill-defined concepts, with the negative connotation of disorder making you believe that everything that can go wrong will go wrong. The advantage of ill-defined concepts is that they can be used to fool people, but doing so you may also fool yourself. You could say that creating difference is like creating order, and destroying difference is like destroying order. Thus creating difference would correspond to t decreasing entropy and destroying difference would correspond to increasing entropy. The classical 2nd Law states that only the former can occur (in a closed system), and thus would prevent creation of difference or creation of order.

Phil: But you see creation of difference or order in many processes, and thus Boltzmann has a problem with his entropy as disorder: How about oder? How can order be created?

Mat: If you look into the literature on this subject, you find no answer, or an answer suggesting the state of the Universe created at Big Bang was very ordered and after that there has only been erosion to more disorder. This is no more than "believing in ghosts". Or what do you say? Why was there so much order initially? By chance? What was the probability for so much order initially?

Phil: I have no clue. But Principe Perfeito does not speak about order/disorder and entropy, only about turbulent dissipation.

Chapter 84

Cause-Effect

> He who never made a mistake never made a discovery. (Samuel Smiles)

Phil: What makes the the cause the cause and not the effect in a cause-effect relation?

Mat: Well, of course you say that the cause comes *before* the effect, so if we know the Arrow, then we know if the cause can be a cause. What comes later cannot be the cause of something occurring earlier. So we have to consider an irreversible process of cause-effect, because in a reversible process, we can change the order and let the effect preceed the cause. An example, where we cannot say what is cause and what is effect, without changing view all the time, is the reversible motion of a pendulum, where potential energy is transformed to kinetic energy and back again. We cannot say that the potential energy always is the cause of the kinetic energy, as little as saying that the kinetic energy always is the cause of the potential energy. In a reversible process the directionality in cause-effect ceases to be meaningful, since it can be reversed. We recall some examples of irreversible cause-effect processes:

- bake a cake - eat and digest that cake,
- write a poem - erase that poem,
- rub your hands - feel the heat,
- put milk in your coffee and stir - get café crème,

- say something nice to somebody - see the the warmth in the eyes,
- decide to lift your arm - do it,
- stretch a piece of paper - rip it into pieces.

In all these cases the irreversibility comes from the fact that the reverse process would require a precision that you cannot reach. For example to un-digest and un-eat a cake requires a new unseen reverse metabolism of incredible precision, as well as un-baking and un-mixing the ingredients would require a reverse bakery of extremely high precision.

Phil: How about deciding and then lifting your arm? The reverse process would be to see your arm lowering itself (seemingly without cause), whereupon you would say that you have no intention to lift it. Weird? Is precision involved here?

Mat: Probably so, because to decide to lift your arm takes precision; there are so many things you could do, so to come up with the idea to lift your arm requires high precision. To actually do it is not so difficult unless you are a dancer and want to do it in a specific way (which takes even more precision to initiate...).

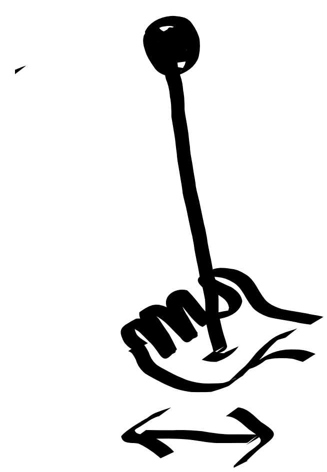


Figure 84.1: The motion of a normal pendulum is reversible, but that of a balanced inverted pendulum is not.

Chapter 85

The Principle of Least Action

> Let us search for him [God] in the fundamental laws of the cosmos ... rather than in the complicated results of those laws. – The laws of movement thus deduced [from the Principle of Least Action], being found to be precisely the same as those observed in nature, we can admire the application of it to all phenomena, in the movement of animals, in the vegetation of plants, in the revolution of the heavenly bodies: and the spectacle of the universe becomes so much the grander, so much the more beautiful, so much more worthy of its Author ..(Maupertuis)

> It is my hope to remodel the whole of dynamics, in the most extensive sense of the word, by the idea of my characteristic function. (Hamilton)

> We live in a Best of Worlds, which is a world with maximal complexity governed by simplest possible laws. (Leibniz)

Phil: I have heard that the refraction of light can be understood the solution of a minimization problem: A light ray through a medium with variable light speed, such as partly water and partly air for example, follows a broken line such that the total travel time is as small as possible. This means that since the light speed in air is larger than that in water, light can afford a longer distance in air. A pole sticking into water appears to be broken at the water surface. But what drives a light ray to minimize travel time? Is there a *final cause*, minimum travel time, which the ray seeks to reach? How could that be? Is a light a sort of a (intelligent) minimalist?

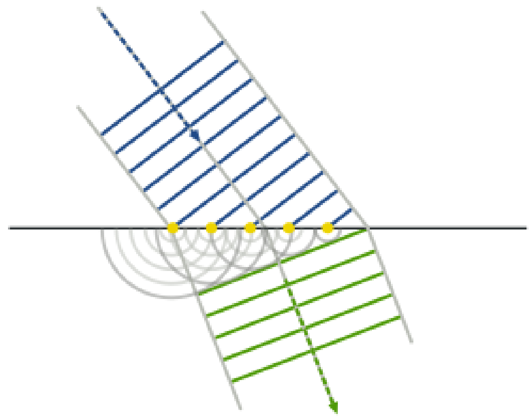


Figure 85.1: Wave refraction.

Mat: This connects to the *Dream of Calculus* of formulating and solving equations of motion by analytical mathematics. It started as a controversy between Descartes concerning the refraction of light. In his *Optics* Descartes derives a *sine law* of refraction stating the sine the angle of the incoming ray with the vertical, divided by the angle of the outgoing ray with the vertical, is equal to the quotient of the light speed in water with that in air. This is an incorrect form of the sine law since the quotients of the sines should be equal to the refractive index which is the quotient of the speed in air and that in water (and not the other way around). The correct law was discovered by Fermat based on a minimal travel time, which he enthusiastically describes:

- *The price for my work turned out to be most extraordinary, the least expected, and the happiest there ever was. Indeed after running through all the equations, multiplications, antithesis, and the other operations which my method requires, and having finally solved the problem, as you will see in the enclosed sheet, I have found that the my principle yielded the very same proportion that Mr. Descartes had discovered for refractions. I was so taken away by such an unexpected result that I almost could not overcome my surprise. I have done my calculations over and over again, and the outcome has always been the same, even though my proof assumes that light travels faster through rarer medium (air) that denser do (water), which I believe to be very true and necessary, although Mr. Descartes assumes the opposite.*

Phil: So Fermat was correct and Descartes wrong. Did that mean that the principle of minimal travel time was accepted?

Mat: Not really. Nobody could not explain how Nature could think ahead and take decisions. But Fermat's idea was taken up by Maupertuis, rocketing to fame overnight in 1736 by experimentally confirming Newton's prediction that the Earth is slightly flattened at the poles, in an expedtion to Lapland in 1736. Maupertuis generalized Fermat's minimal time principle to a new *principle of least action* expressed in his *The Laws of Motion and Rest Deduce from a Mathephysical Principle* from 1745 as:

- *The quantity of action necessary to cause any change in Nature, is always the smallest possible....How satisfying for the human spirit to contemplate these laws, so beautiful and simple, which may be the only ones that the Creator and Ordainer of things has established in matter to sustain all phenomena in the visible world.... Once it becomes known that the laws of motion are founded on the prinicple of the better, no one will doubt that they are due to an all-powerful and all-wise Being, who may have given bodies the power to act upon each other, or who may have used some other way which is even less known to us.*

This was nothing but grand unification!

Phil: A bit too grand: Maupertuis was ridiculed by Voltaire and died as broken main in 1759. In *Candide* Voltaire continued the deconstruction in the form Doctor Pangloss, the incurable optimist always able to see the optimal aspects of any catastrophe.

Mat: But the Dream of Calculus was not over: Euler and Lagrange could not resist the temptation of a principle of least action and reformulated the equations of motion in the form of an optimization problem stating that the actual trajectory of a mechanical system minimizes the action defined to be the integral of the difference of the kinetic and potential energy. Later is was understood that the action is not really minimized, but rather made *stationary*, that is staying unchanged under small perturbations. Hamilton extended the scope in the late 19th century and termed the action the *Hamiltonian*. Physicists still like the idea that Nature seeks to make a Hamiltonian stationary.

Phil: But the question remained right: Why should Nature care about making a Hamiltonian or action stationary? According to Leibniz there must be a *sufficient reason* for such a state of affairs, and what is the reason?

Mat: Well of course both Euler and Lagrange viewed the principle of stationary action as being just another way of writing the equations of motion in rate form, as the *Euler-Lagrange equations* of the optimization problem. Superficially, it seems that an integrated quantity, the action, is minimized (made stationary), but the very process of optimization kicks out same old equations of motion rate form. The Euler-Lagrange optimization approach is a neat way of obtaining the equations of motion, without having to explicitly define the forces: You just optimize the action as the integral of the difference of kinetic and potential equations, and you the equations of motion!

Phil: You find grand ideas of optimization also in politics and economy: Adam Smith in his *Wealth of Nations* claims that, in a free market, an individual pursuing his own self-interest tends to also promote the good of his community as a whole through a principle that he called "the invisible hand". He argued that each individual maximizing revenue for himself maximizes the total revenue of society as a whole, as this is identical with the sum total of individual revenues. Or the British economist Hutcherson who coined the formula "the greatest welfare for the greatest number" underlying the modern welfare state. Of course, this optimization problem is impossible to solve, which couples to the problems now facing the modern welfare state.

Mat: If you think of it, you see that the "invisible hand" is nothing but time-stepping following the laws of motion (or trade). The Dream of Calculus can come true today with the help of computers solving the equations of motion and thereby creating all sorts of virtual reality. I hope you get as excited as Fermat at these new possibilities. Grand unification is soon coming to a store near you...by computation. And you do not have to believe that Nature in some mysterious way is making a Hamiltonian stationary.

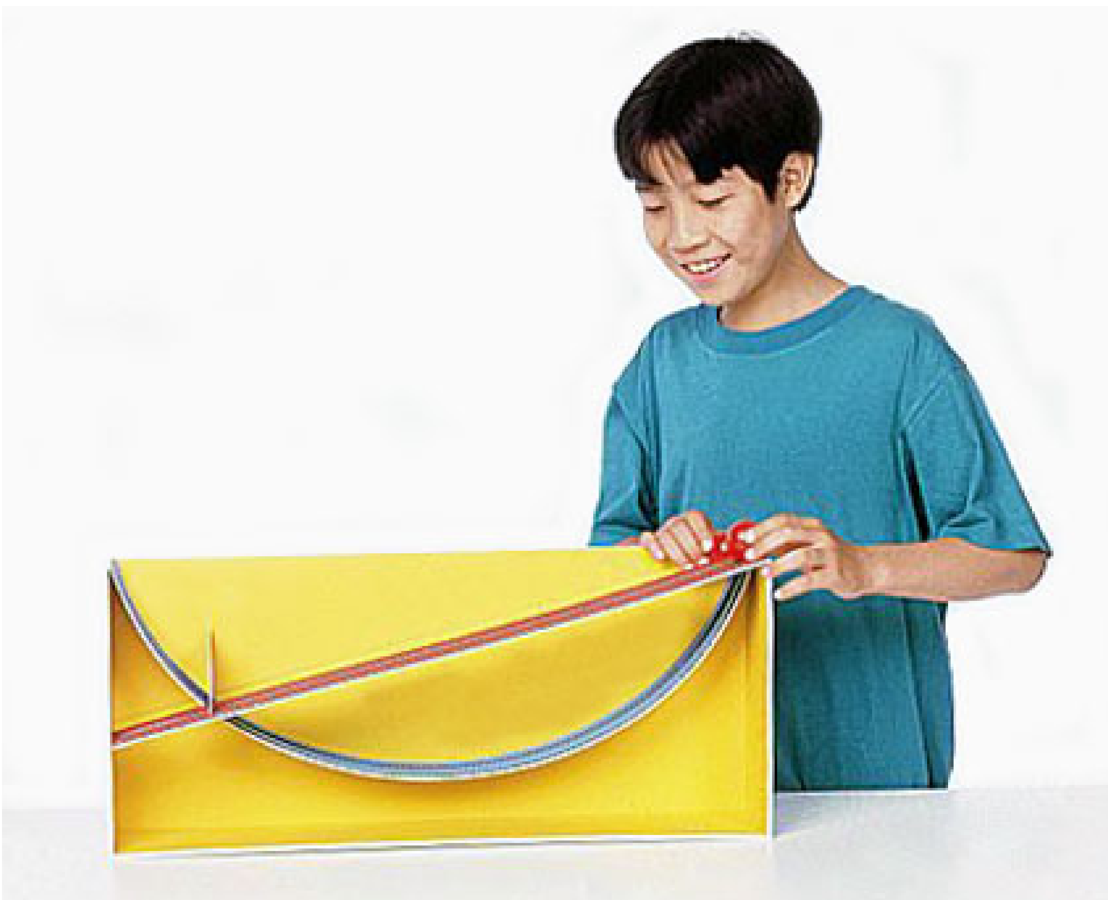


Figure 85.2: The *brachistochrone* curve gives the quickest descent under gravity and is not a straight line.

Chapter 86

Dark Age of Modern Physics

> The effort to understand the universe is one of the very few things that lifts human life a little above the level of farce, and gives it some of the grace of tragedy. (Stephen Weinberg)
>
> What exactly is the meaning of time and its directionality – the "arrow of time"? Has it something to do with quantum theory, or does it arise at some other level? (David Peat in *Superstrings and the Search for the Theory of Everything*, 1988)
>
> Fable should be taught as fable, myth as myth, and miracles as poetic fancies. To teach superstitions as truth is horrifying. The mind of a child accepts them and only through great pain, perhaps tragedy, can the child be relieved of them. Men will fight for superstition as quickly as for the living truth – even more so, since a superstition is intangible, you can't get at it to refute it, but truth is a point of view, and so is changeable. (Hypathia)

Mat: Modern physics is based on quantum mechanics of the world of elementary particles like electrons, neutrons and protons, and the general theory of relativity of gravitation on cosmological scales. The unsolved enigma since 100 years is a unification of the two theories into one *Grand Unified Theory* or *GUT*.

Phil: Yes, I know this from reading some of the very many popular science books explaining modern physics. I must say that what is presented is beyond any fiction that I could dream up myself: I have read with increasing astonishment (and excitement) about *Big Bang*, *black holes*, *dark* *energy*, *dark matter*, *collapse of the wave-function*, *Higgs ocean*, *probability waves*, *quantum entanglement*, *relativistic quantum field theory*, *string theory*, et cetera. I read that we all *have to give up* our intuitive conceptions of space, time and matter and accept that modern physics is full of strange and inexplicable phenomena. The more inexplicable the better, it seems. Yes, modern physics is a wonderful source for authors of science-fiction and popular science, much better than any other science.

Mat: Yes, you are right. It is very difficulty to understand what physicists are talking about today. Either the mathematics is extremely inaccessible or the physical notions are contradictory like *wave-particle duality*. The great Hilbert said :*(modern) physics is becoming too difficult for the physicists*. I see three concepts of modern physics which can be referred to as tragedies if you like: (i) space-time unification, (ii) superposition, and (ii) entropy.

Phil: Tragedies? How can you say that? Are you really in a position to judge? You must be joking. What you mention is the very basis of modern physics.

Mat: No I am not joking. But of course, I may be wrong. Maybe it is instead a farce. Anyway, we have already talked about the lack of reason for (i) space-time unification.

Phil: OK, I think you have made a good point here. Mixing space with time is not a good idea. But what about (ii) superposition?

Mat: It comes from the *formal linearity* of Schrödinger's equation allowing you to add two wave functions to get a third. This is represented by Schrödingers cat being alive and dead at the same time: One wave function is *live cat*, another is *dead cat*, and their sum is *live/dead cat* as if this could represent a reality. But this is an illusion based on the magical belief that since you can write down Schrödinger's equation, and see that they formally are linear, then there must be solutions to the equations (wave functions) which you can add. But this is like believing that by *saying* appetizer, entree and dessert and adding them up you would have a dinner. Superposition is superstition!

Phil: Is it? What a relief! I have always found it difficult to imagine a live/dead cat, in particular since it is supposed to have 9 lifes. But (iii) entropy is a wonderful scientific concept, isn't it? Which explains why time is moving forward, right?

Mat: Yes, this is what you read in many books, but it seems that nobody understands what entropy really is. The great mathematician von Neumann suggested to Shannon, the inventor of information theory, to use the concept of entropy because then he would be able to win any discussion, since nobody knows what it is. And so Shannon did, and became famous.

Phil: So you suggest not to use the concept of entropy at all, because nobody understands what it is. Radical, but does it work? Can you refuse to use entropy and still be a scientist?

Mat: Ys, you can. If you explain the Arrow by Principe Perfeito, then there is no need for entropy, since the role of entropy is to explain the Arrow.

Phil: Oh, really? Can it be that simple? I kind of believe I understand the essence of Principe Perfeito, but I never could understand what entropy is. What a relief!

Figure 86.1: Destruction of the Library of Alexandria by Christians during the reign of Christian Emperor Theodosius in 391 C.E.

Mat: Speaking about dark ages, let us recall massive destruction of the contents of the Library of Alexandria by Christians during the reign of Christian Emperor Theodosius in 391 C.E. The knowledge lost, the history destroyed and eliminated, was a devastating setback, and was a precursor to the dark ages, a time when only the church fathers retained knowledge.

Phil: In particular, *Hypatia* of Alexandria, the first notable woman in mathematics, was killed by a Christian mob as a *valiant defender of science against religion*, marking the end of the Hellenistic Age. Hypatia was legendary for her talent, intellect versed in science, math, philosophy, poetry, the arts, and religion. and beauty. Her lectures was sparkling with mathematical ingenuity. She invented the astrolabe and the planesphere, devices used for studying the stars and planets. She also invented a device to distill water, another to measure the level of water, and a third to determine specific gravity of liquids, called a hydroscope. Hypatia was the single most brilliant mind of her time and none other would ascend to her level until the works of Descartes, Newton, and Leibniz many centuries later. She affirmed that she had never married because she was wedded to the truth, but love affairs was apparently OK.

Mat: Yes, that makes sense.

Phil: At the height of her beauty, and the apex of her intellectual wisdom, having refused marriage in favor of educating her disciples, Hypatia was in 415 AD torn from her chariot by a hungry mob of screaming Christians. Stripping her naked, dragging her to their church, she was inhumanely butchered. Led by Peter the reader, the savage fanatics ripped her living flesh from her bones with pottery shards; the still quivering limbs then delivered to the flames. One can almost hear the bitter hateful words of the mob and their subsequent laughter, "Paul tells us women should be silent, now this one obeys."

Figure 86.2: Hypathia.

Chapter 87

The Game of Atoms

> My work is a game, a very serious game. (M. Escher)

Mat: What is the time conception of a cow, a bird, a flower or a stone? Or of an atom? We don't know. But to seek some clue, let us play the most basic game of all, let us play the *Game of Atoms*.

Phil: Sounds interesting. Is it a new computer game?

Mat: Yes, brand new, but also very old, about 15 billion years old. The play field is a box filled with $2 \cdot 10^{23}$ atoms of a helium gas. The atoms are distributed to the players and each player is supposed to monitor the motion of his/her atoms including collisions and free flight between collisions, all according to Newton's laws of motion. Each player can control the size and direction of a gravitational force acting on all the atoms and the objective of the game is to position as many of your atoms close to the center of the box. The first difficulty of this game you have to overcome, is the larger number of atoms to monitor.

Phil: How on Earth can you monitor 10^{23} atoms, supposing there are two players? I already find it difficult to juggle with 2 balls, not to speak of 3. But 10^{23} seems completely overwhelming.

Mat: Yes, that is what makes this game very interesting. It is becoming increasingly popular, now more than golf! The only way to play this game is to somehow allow the atoms to control themselves. The atoms thus are capable of a certain self-control, if you only tell them rules how to behave, which they can understand and follow. This is like controlling a class of kids by giving them understandable instructions to follow. If you succeed, then you can lean back and let the kids control themselves. The alternative of surveying each child individually is not viable. It is the same in society at large.

Phil: I get the idea. So you first have to set up instructions for the motion of your atoms. May I ask if the atoms are equipped with clocks?

Mat: Unfortunately not. They are not capable of reading clocks. An atom can check if it is colliding or not, and feel a gravitational force, and update its position and velocity accordingly. That is all.

Phil: Update position and velocity? That sounds like time stepping. Are all atoms using the same time step?

Mat: Not necessarily. Since they are all alike, you may suspect that, but you cannot know, because you cannot check all of them. So you don't know that they use the same time step. In fact, they probably don't have, since the size of the time step is up to each atom. In fact, the atoms don understand clocks so they don't really know how big a time step they are using. The only thing you can expect is that all of them use small time steps, but possibly different. This is like computing compound interest rate on a yearly, monthly or daily basis, which gives slightly different effective interest rates. Different banks may use different time steps, but they all compute interest rates.

Phil: OK, I understand. Then I instruct each atom to update its position with some (small) time step according to Newton's laws. This means updating the velocity from the acceleration according to Newton's 2nd Law $ma = F$, and updating the position from the updated velocity. Over and over again. That is my strategy.

Mat: Funny, this is precisely my strategy also. Let us then play the game.

Phil: Yes, this will be fun. But first let us contemplate what now have: A set of $2 \cdot 10^{23}$ atoms in a box, each one time-stepping its position and velocity according to Newton's law. This is a system which functions *without universal time* and *without a universal clock*. It is like a stack of ants, with each ant time-stepping its position and velocity according to some fixed laws of motion, without any *master clock* setting the rate of time. When two ants meet, or two atoms collide, they interact and then part, and for this interaction there is no need of clock synchronization. They meet when they meet. It is not so that one ant first meets another ant, and then later that other ant meets the first ant. They meet simultaneously without clock synchronization, because there are no clocks. You can say that time does not exist. And there is no universal time rate either. Only a subjective time rate setting the time step for each atom or ant.

Mat: You can as well say that the positions of the atoms or the ants, effectively acts like *acts like clocks.* This is like the arm of a clock, the position of which indicates the time. You can thus say that the atoms or ants have built-in-clocks counting time by position, at least between collisions when they travel with constant velocity. Each atom will update its position x and velocity v from the update formula

$$v = v + \Delta t\, a, \quad x = x + \Delta t\, v,$$

where Δt is the *time step* and $a = \frac{F}{m}$ the acceleration (according to Newton's law $ma = F$). We can assume that when particles interact by collision they use the same time step (and update frequency), because during interaction synchronization is naturally maintained, while between collisions they travel with constant velocity (like the arms of a clock) and thus accomodate time by position. collison **Mat:** Wonderful. A box a atoms or a stack of ants, what is the World but something like this? With a built-in clock somehow represented by the configuration. In this World there is no master clock setting the time step and update frequency, only a changing World acting like a form of clock. Can we then say that objective time does not exist, nor does objective time rate?

Phil: Yes, so it seems. You may expect that the clock rate for identical atoms is equal, but it may be different for different types of atoms. Objective time and time rate seems to be something man-made required to coordinate the many actions in our society, and since it is man-made it is not objective. Homo Sapiens lived hundred thousand years without other clocks than the Sun and the seasons, and the incentive to construct accurate clocks came from navigation over the oceans, where it is needed to determine longitude.

Mat: It is now time to stop all these tedious speculations and get going with the game instead! Since we are both here at the same time we can play together and interact, with the same time step and update frequency. When we part, we are free to use our own time, and we will meet again when we meet.

Figure 87.1: A dangerous game of atoms

Chapter 88

A Dynamical System with Memory

> Music is the art which is most nigh to tears and memory. (Oscar Wilde)
>
> I have always been amazed at the way an ordinary observer lends so much more credence and attaches so much more importance to waking events than to those occurring in dreams... Man... is above all the plaything of his memory. (Andre Breton)
>
> The light that radiates from the great novels time can never dim, for human existence is perpetually being forgotten by man and thus the novelists discoveries, however old they may be, will never cease to astonish. (Milan Kundera)
>
> Happiness is the longing for repetition. (Milan Kundera)
>
> The struggle of man against power is the struggle of memory against forgetting. (Milan Kundera)
>
> Without the meditative background that is criticism, works become isolated gestures, historical accidents, soon forgotten. (Milan Kundera)

Phil: What about the mathematics of memory?

Mat: OK, consider an dynamical system of the general form: Find $u(t)$ such that

$$\dot{u}(t) = f(u(t)) \quad \text{for } t > 0, \quad u(0) = u^0, \tag{88.1}$$

where $u(t)$ describes the state of the system at time t, $f(u)$ is a given function of u and u^0 is a given initial value. Such a system formally has *no memory*: The values of the state function $u(s)$ for $s < 0$ do not enter into the formulation (88.2), only the initial value $u(0) = u^0$.

Phil: So the present state $u(t)$ at some time t determines the state $u(s)$ for any later time $s > t$. The influence of the previous states $u(s)$ with $s < t$ is channeled to later states $u(s)$ with $s > t$ through the "window of the now": $u(t)$.

Mat: Exactly. Now, a dynamical system *with memory* can take the form

$$\dot{u}(t) = f(u(t) + \int_0^t g(t,s,u(s))\,ds \quad \text{for } t > 0, \quad u(0) = u^0, \tag{88.2}$$

where $g(t,s,u)$ is a given function, and the integral

$$\int_0^t g(t,s,u(s))\,ds \tag{88.3}$$

represents the accumulated influence on the current rate $\dot{u}(t)$ of all the previous states $u(s)$ with $s < t$. In this case $u(t)$ does not serve as the only channel to later states, but also previous states $u(s)$ with $s < t$ influence the future as memories remembered at the current time t. Depending on the function $g(t,s,u)$ the memory can be short, long, fading or have some other quality. What is important is that in order to take a time step from t to $t + dt$, it is necessary to have access to all the values of the state $u(s)$ for $s < t$ which enter into the integral (88.3), which thus need to be stored or memorized. Each value $u(s)$ then represents a "frozen moment" from time s which is stored in memory until "evaluation" at time $t > s$. A stored memory $u(s)$ is then "reused" for all $t > s$ for which the integral $\int_0^t g(t,s,u(s))\,ds$ contains the value $u(s)$.

Phil: Yes, this is the way a photo album functions. Or the memories you have stored somewhere in your brain (or body). The impression of an old picture/memory on the present can change with time; it can fade or grow with time.

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