FEST Log, Part 1:
Setting the Stage

"Fully Engaged Science and Technology" or "FEST" is a new research program aiming to bridge the gap between matter and mind. Inspired by the success of science in understanding matter, this program extends the same empirical methodology to study the mind. This requires developing new tools, partly inspired by philosophical and contemplative traditions of the past.

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Preface

The following entries are copied from the FEST Log (ias.edu/piet/fest/festlog), and bundled into one document, to make it easier to read without having to click from entry to entry. The first entry, #000: ManiFESTo, describes the idea behind the FEST project. The last entry, #013, gives a brief summary of the material in Part 1, and an even more brief view of what will come next in Part 2.

I gratefully acknowledge generous grants of the Hershey Family Foundation, which provided strong support for much of the research reflected in these writings. I also thank Starboard Vision for sponsoring a FEST related workshop held in Kyoto in June 2024. I thank Eiko Ikegami, the main organizer of the Kyoto workshop, for her contributions to the content as well as the structure of the workshop. I thank Mario Galarreta, Alex Englert, and Jonah Ginsburg for many helpful conversations during the last year, while I was first preparing and then writing the FEST log. Last but not least, I thank Jonah Ginsburg for his help with the design and implementation of the FEST website.

A ManiFESTo for a Science of Mind

Entry #000
February 29, 2024

Empirical studies of mind using mind

Science gives us the power of a remarkably deep knowledge of matter. In doing so it has purged many harmful superstitions. Unfortunately, as collateral damage, it has also purged much wisdom that had been accumulated and actively maintained in older cultures.

Attempts have been made in education to complement science, seen as impersonal and lacking in human values related to mind, through the humanities and arts to bridge the gap between the two. In practice, though, there still seem to be more rifts than bridges.

In this log, I will explore a radical alternative, in an experiment to combine the best of both worlds. I propose to adapt the basic methodology of science, empirical investigations using working hypotheses, to the study of mind. More precisely: while science so far has studied matter empirically using material tools, I propose to study the mind empirically using the mind.

A necessary ingredient: a technology of mind

To study the stars we use a telescope, while studying cells we use a microscope. It would make no sense to switch the two: every type of science has developed its own toolbox for empirical investigations fitting to the objects under study. What all disciplines in natural science have in common, though, is that they use tools made out of matter in order to study the behavior of matter.

For a true science of mind, we would expect to study the mind using the mind itself. We can certainly learn very interesting and useful facts about the physical composition and processes in brains, using material tools. However, we are still very far from understanding the intricate ways in which brains and minds are correlated.

An argument against using the mind to study the mind, is that such an approach would be too subjective, while using material tools is the only way in which we can produce objectively valid results. But objectivity here is shorthand for individual scientists using their own minds to study matter, and reaching intersubjective convergence in a community of peers. There is no a priori reason that with sufficient caution the same approach cannot be developed for the study of mind.

From engineering to science

In many cultures, over thousands of years, more and more detailed knowledge was acquired of novel engineering techniques. Yet unexpectedly, a more universal and more abstract approach to studying matter became available in only a few generations in Western Europe. The road toward modern science was traversed between Galileo's dropping stones from the tower of Pisa and Newton's recognizing that the Moon falls in an orbit around the Earth in a similar way as an apple falls from a tree.

My working hypothesis is that we are now in a position to make a similar transition from thousands of years of contemplative studies of the mind to a science of mind. Engineering knowledge was protected by trade secrets, and the advent of science was revolutionary in freely spreading its knowledge in an open-source way. That term became popular in the eighties for freely available software, but the idea started in the 17th century.

Like engineering, the contemplative cores of religious traditions were off limits not only to adherents of other traditions, but also to most people in the same tradition, largely for good reasons. However, in the current climate of openness and connectedness, the living remnants of older contemplative movements have no choice but to become more open as well. This makes them candidates for joining forces in establishing a science of mind.

The signs are everywhere: time to get FESTive

This manifesto is just the first step of a new program. And since programs need to have a name, I propose FEST, short for Fully Engaged Science and Technology. Fully engaged in pairing our science of matter with a fledgling science of mind in the hope to find a unification of both approaches in which practitioners can be fully engaged, qua body and mind.

And to do double duty: another reading could be Fully Empirical Science and Technology, where a science of matter uses material instruments and a science of mind uses mental instruments, such as Husserl's epoché, just to mention a rare Western philosopher who made that move. This is the end of my maniFESTo, celebrating the start of this log in a festive way, while inviting anyone interested to join me in this new adventure.

Starting Our Journey

Entry #001
March 08, 2024

Leaving The Harbor

The current log, like a logbook used by ancient mariners, will describe at somewhat irregular intervals the journey that we are about to embark on. We are going to leave the established harbor of the current state of science, which is almost exclusively using matter-based tools. With a pedigree spanning more than four centuries in its current form, it is by now a relatively safe haven. It has established ways of operation, in mostly well-defined fields and subfields.

Our first goal is to develop a complementary branch of science that mainly employs mind-based tools. In short, we will explore the use of the mind to study the mind. A more distant goal will be to explore the possibility of establishing a unified form of science that combines on equal footings matter-based and mind-based science, a Fully Engaged Science and Technology, FEST for short.

A quick overview can be found in the previous entry, a maniFESTo. Note that an important change has occurred already after entry #000, while we were still anchored in the harbor. In that entry I outlined the FEST vision, which I have nurtured in one form or another for the last 3/4 of my life. During that time I have formed or joined various small groups of like-minded people on small adventurous expeditions, still in sight of the harbor.

This time, however, my insight has matured to a quality level that I associate with the books and articles I have published in (astro)physics and other disciplines. I now feel comfortable choosing an initial direction in which to set sail, leaving the coastal waters behind. My hope is that others with similar aspirations will join, and will help to make course corrections whenever needed, given that we will soon explore unknown waters and new coastlines.

What Is Science?

Before we engage in developing extensions to science, it will help to get a clear picture of what defines current science. While looking back at the harbor, let me give a sketch of what I consider to lie at the core of science. I will base this on my own research as well as my observations while engaging in discussions with other scientists in a wide range of disciplines, during the more than twenty years since 2002 that I have been Head of the Program in Interdisciplinary Studies at the Institute for Advanced Study, where I was appointed as a Professor in Astrophysics in 1985.

What is the bar for qualifying an investigation as scientific? 1) Experiments always win out over theories. 2) Any theory has to take the form of a working hypothesis. 3) Experimental confirmation of a theory needs to be validated through intersubjective agreement between a self-governing community of peers. This excludes governing bodies that solely or mainly consist of non-scientists.

As a further refinement of the first point, we can distinguish between four different types of experiments:

- Field observations (Galileo's discovering four moons of Jupiter)
- Lab experiments (Galileo's rolling objects down inclined planes)
- Thought experiments (mental simulations, aided by pen and paper)
- Computer experiments (digital simulations on computers)

Let's have a look at these different categories.

Field work as passive experiments

Field observations may seem different from experiments, but if we take the term experiment broadly, observations in astronomy, for example, can be viewed as experiments that are performed not by us, but by nature. We may not have the power to let galaxies collide, but we live inside the Universe, which is a perfect lab in which to study the setup of two galaxies on a collision course, to study what plays out during collisions, and to analyze the remnants. A good astronomer's T-shirt could read something like:

I am a scientist
I live in my lab
My lab is the Universe

Galileo's notebooks, logs for his astronomical observations, read like lab logs. He described, for example, how the moons of Jupiter could be found in different places with respect to Jupiter, even comparing two subsequent days.

To add a footnote: readers familiar with galactic-scale train wrecks may object that such collisions take a few hundred million years to complete, an awfully long time to follow an experiment. Astronomers have a trick, though: by observing a sample of dozens or more such cosmic mishaps they can put those snapshots end to end, according to different stages of the onslaught. This way they can construct a statistical history of collisions between typical galaxies, well within the time it takes to complete a PhD.

Laboratory experiments

Lab experiments are like field experiments, but under controlled conditions. The difference between doing science in the field and in a lab is huge. Not only can you choose and finetune the initial setup of an experiment, but you can also protect the subsequent run of the experiment from dust and dirt, and whatever else may affect the outcome.

That said, within the vastly improved setting of a lab, what is actually going on remains similar in stages to that of field experiments. Scientists first play the role of nature, in setting things up. They then play the role of observers, describing (in a lab log!) what happens after things are set in motion. And finally they analyze the outcome of whatever was observed.

Their analysis involves using theories to attempt to fit the data. In the process they quite often are forced to change or at least fine tune those theories when they turn out to be inadequate. Improve experiments, which will force theories to improve in order to fit the new data, which in turn will suggest more accurate experiments in order to keep those newer theories honest, and so on: this is the ratchet of science!

Thought experiments and computer experiments

Thought experiments are similar to lab experiments. The way in which they are set up, carried out, and analyzed, follow the same playbook. There is only one difference: in these experiments, everything is done purely by thought, albeit sometimes aided by pen and paper.

And finally computer experiments are like thought experiments, but for a hypothetical person with perfect recall, who thinks billions of thoughts at the same time, and each one at the speed of light, rather than the speed of neurons, which is a few hundred million times slower than light. That's the quantitative answer.

There might be a very different qualitative answer: when deeply engaged in a thought experiment, scientists sometimes come up with completely new ideas. Whether AI will be able to replicate such "Aha!!" moments in the future is still an open question. Stay tuned!

The use of working hypotheses

Any work done in exploring anything in science ideally is based on one or more hypotheses, of a very special kind. Each hypothesis describes a possible way that nature is structured, or that nature behaves. In entertaining a possibility, the scientist does not believe that the hypothesis is true. But, equally important, the scientist does not believe that it is false. In that spirit, scientists can suspend judgment concerning the truth of such a hypothesis, and ideally in that way they will not be biased.

The beauty of science is that you can receive credit for proving a theory right as well as for proving it wrong, your own or someone else's, it doesn't matter. If you disprove your own theory you can even get double credit, as long as your theory was interesting enough to draw significant attention. As a result, there is no strong incentive to take sides or try to push your own theory like a lawyer. It is a win-win situation. So long as you clarify new aspects of the theory, pro or con, everybody wins! Footnote: scientists are also all too human. I know a few who live up to that ideal, and I've tried to do so myself, throughout my career. But I certainly know a good many who champion their own theory.

The use of working hypotheses may be unique to science. Hypotheses as such have no meaning. But once you use them as tools, and with the reward structure inherent in science, they act as ratchets to increase the quality of our theories, as we've seen already. This is definitely something we should keep in place while developing a science of mind, just as we should develop a proper lab culture and very important: lab guidelines.

Peer review

A final essential ingredient in science proper is peer review. Each individual scientist can easily make mistakes, in many different ways. To be human is to make errors. But if we have a critical mass in terms of a large group of peers, the larger the group, the less likely it is that a mistake will go undiscovered for a long time.

Here the term "peers" is essential. If one's colleagues are not qualified, as judged by their peers, there is no guarantee that science will make progress. Peers need to be selected within the community of scientists from their own community. If they are appointed for political or financial or other such reasons, science will grind to a halt.

To be clear: there are certainly examples of individuals with extraordinary intuition and creativity who lack the official credentials for being regarded as a peer in any particular field, yet who make interesting and valuable contributions to those fields all the same. In practice, such individuals, when recognized, can be elevated to peer status quite quickly.

Further ingredients

The above four aspects, theory, experiment, working hypotheses and peer review, are absolutely essential for an area to deserve recognition as a field of science.

This is not to say that these criteria are sufficient, but if one of them is lacking, then that activity can no longer be considered scientific.

There are other auxiliary ingredients, some of them very important in practice. Funding helps! For sure. A climate of respect for science in society helps too, to attract some of the brightest members of that society to become scientists. Equally important is a climate of respect for anyone who is willing and able to study science, independent of gender, color, or whatever discriminating tendencies may exist in any given culture. Related to all this: good channels of communication, in both directions, between scientists and politicians, economists, and really any sector of society is important.

The Roots, Shoots and Fruits of Science

Entry #002
March 14, 2024

<u>Historical roots of science</u>

In the previous entry I've briefly touched upon the core aspects of science: theory, experiment, working hypotheses, and peer review. These four have been in place since the beginning of modern science, roughly around 1600. Let us now have a quick look at the origins of science, stretching back millennia.

Let me emphasize the "quick" in this quick look: For now I will focus on only some of the ancient influences that are recognizable in the state of knowledge around 1600 in Europe. For example, I will not mention the significant contributions from Arabic sources, but instead go further back by one to three millennia, to the Greeks and Babylonians.

Nor will I try to outline contributions that may have been made by Indian or Chinese knowledge, transported through the Silk Road or other means. And finally, Maya astronomy with its remarkably detailed observations, in some aspects more accurate than the state of the art in Europe at the time of Columbus, unfortunately never had a chance to contribute to European science.

<u>From astrology to astronomy</u>

Science didn't start in a vacuum. When Galileo discovered the largest four moons of Jupiter in 1610, he interpreted his observations using the Copernican model for planetary motions. This model was worked out by Copernicus a century earlier, around 1510. Copernicus in turn had based his model on that of Ptolemy, with the main difference being that Copernicus placed the Sun in the middle, rather than the Earth.

Ptolemy worked out his model of planetary motion in the second century AD, based on the principles put forward by Aristotle, five centuries earlier. Greek astronomy in turn started a few centuries before Aristotle, and was based upon more than a thousand years of observations of the Babylonians. In other words, modern astronomy was based on the uninterrupted efforts of several dozens of generations of astrologers building up a reliable database over many centuries.

From alchemy to chemistry

Just as the roots of astrophysics can be found in the databases that had been developed in astrology, similarly modern chemistry did not have to start from scratch. Alchemists must have produced their own databases of chemical reactions, for many centuries.

We can imagine a chemist wading through alchemical recipes that involve mixing various ingredients, at the time of the full Moon while chanting incantations, and involving perhaps the tail of a dog. The chemist may mutter: "hold your chants, timing the Moon, and probably the dog's tail, but please tell me more precisely what you were mixing!"

A rapid succession of shoots and fruits of science

Aristotelian physics had been the dominant theory of physics for an amazingly long time, a bit less than two millennia, until it was finally dethroned in the 17th century and replaced by Newtonian mechanics. Newton's laws of motion and of gravity were the first fruits of modern mechanics, and as such of modern science.

It took less than a century for Aristotle's physics to be overturned. It started with the very simple experiments that Galileo performed, dropping objects from a tower, and rolling objects from inclined planes, timing them with his heart beat. And in 1687 Newton's Principia appeared, explaining the dynamics of the solar system.

Galileo's modest shoots matured to bear fruit in only three human generations, during less than a century. What is more, it would reign supreme for eight generations, or well over two centuries. During that long period, it remained the most accurate theory physicists had for the study of motion in general, and motion of heavenly bodies under the influence of gravity in particular. It was only when Einstein formulated his special theory of relativity, in 1905, that it became clear that Newton's theory needed to be refined.

Lessons from starting up a science of matter

Since the goal of this log is to set up a science of mind, it is a good idea to start from the lessons learned from the science of matter. The recipe seems to have two parts: 1) find an extensive database of prescientific observations and experiments, and 2) add some simple and very general new experiments.

The time and effort that went into the building up of a Babylonian database was enormous compared to what Galileo contributed with his dropping and rolling of balls. Yet Galileo's shoots brought new life to the ancient roots of astronomy, reaching down three and a half millennia in history.

The big difference was that the Babylonians studied specific properties of the motions of specific lights in the sky, whereas Galileo was after general rules of motion, valid universally. The objects of study of the Babylonians were the motions of specific planets, standing in for specific Babylonian gods, each with specific characteristics. In contrast, simple as Galileo's experiments were, they formed a basis for subsequent experiments and theories, culminating relatively quickly in Newton's laws of classical mechanics and universal gravity.

Hints for starting up a science of mind

It is not difficult to generalize from a science of matter to a science of mind. There are quite a number of contemplative traditions with rich written treasure troves of descriptions of techniques and results of what can be achieved when studying mind using one's own mind. They can be based on forms of meditation or prayer, or a combination of both.

Examples of contemplative traditions can be found in different places and times. In Europe, there are the saints in early Christianity, mystics in Medieval times, and in modern times Quakers may come closest. In Asia, there is a rich spectrum including Taoist sages, Zen masters, yogis and Sufis, to just name a few. Plenty of sources to draw upon!

A well defined task

Following the 17th century recipe for starting up a science of matter, we have already secured a very rich database of prescientific observations and experiments, step 1) of the recipe. All that is left now is step 2), to add some simple and very general new experiments.

In the next entry we will propose a specific experiment which, simple as it might seem, will go to the heart of the structure of experience. In order for experience to happen, we need three items: an experiencer (1), who can experience (2), something that is experienced (3). Just about any type of experience seems like a molecule, since it is built out of three atomic parts.

Or is it? These three always seem to be given together, like a stick (2), with a left end (1) and a right end (3). Now that is a very different image than having a molecule with three atoms, where you can take off one of its atoms. In chemistry, once you do that, you wind up with what is called a free radical, a highly reactive leftover part of a molecule that misses one of its atoms.

With a stick, however, cutting off one end does not produce a leftover stick-with-only-one-end. Whenever you cut off part of a stick, you produce two new sticks, each again with two ends. So what is it? Is experience like a molecule, or like a stick, or like yet something else?

Given that we are trying to set up a science of mind, including a science of experience, there is only one answer: we'll have to design the right kinds of experiments, carry them out, analyze their outcomes, and design theories that fit these outcomes well.

We have our work cut out for us. Stay tuned for the next log entry!

The Structure of Experience

Entry #003
March 22, 2024

Getting a first taste

The previous two entries presented an extremely condensed version of the way natural science has been conducted for the last four centuries. We are now ready to introduce a first experiment for a science of mind, using only the mind.

Here "ready" is relative. Let us remember that we have made many shortcuts to get to a point where we can begin experimenting. Even so, it seems like a good idea to start quickly if only for a first taste of what a "science of mind" could be. Afterwards, we can retrace our steps where needed.

One term that we will need from now on is the word "empirical". This term was used quite freely in entry #000, our maniFESTo, where there was not much room to define our terms. Let's look at it now.

The meaning of "empirical"

When scientists perform experiments, they are sometimes testing theories that predict the outcomes of those experiments. At other times they are just exploring new areas of study, perhaps finding phenomena that were not yet discovered before, and for which no theories have been developed yet. In both cases, once theories are put forward, no matter how tentative at first, further experimentation can test those theories. This in turn can lead to refine those theories. We called this "the ratchet of science" in entry #001.

The process of testing a theory requires reproducible experimental agreement by different scientists and in different places. Once a close agreement has been obtained between theory and experiments, such a theory is considered to be objectively true, up to a point, namely within the accuracy of experiment and theory. Technically speaking, within the combined error bars of both theory and experiment.

As noted already in entry #000, objectivity is shorthand for a two-step process: first individual scientists use their own subjective minds to study matter, after which they collectively reach intersubjective convergence within a community of peers. It is this agreement that becomes the foundation for writing textbooks telling the next generation of scientists that a certain theory has been empirically confirmed.

The word empirical is derived from the Greek word εμπειρια, empeiria, which meant "experience." So for a theory to be empirically verified literally means that the combined experience of a community of peers has confirmed the validity of that theory.

Using experience to study experience

We are looking for an empirical science to study the mind, which literally means a science that uses experience to study the mind. So what better place to plunge in right away than to use experience to study . . . experience? We already gave a hint of what that could look like at the end of the previous entry, but let us start at square one.

Now that we know that the term "empirical" implies confirmation by experience, the next question is how broad to take the term experience. Sometimes "empirical" is used to allow only sense experience, directly or with the help of material instruments, such as a telescope which amplifies our ability to observe light.

Included in such definitions are direct generalizations to radio telescopes or X ray telescopes, or even neutrino telescopes. The idea here is that human beings in principle could have "eyes" that would be sensitive to "light" in the form of electromagnetic radiation at longer or shorter wavelengths, or even sensitive to different types of radiation, such as neutrino beams. Most recently even gravitational wave detectors have joined the astronomers' toolbox.

Now the question arises of how to generalize the notion of sense experience when studying the mind. Our goal is to, first, introduce and build up a science of mind, and second, to then unify science of matter and science of mind, in order to reach a Fully Empirical Science of Technology, one of the readings of FEST in entry #000. In order to make science fully inclusive in this way, here and below we need to broaden the term "empirical" in order to make it fully inclusive as well.

Specifically, our research will include three qualitatively different ways to use experience to build up empirically tested bodies of knowledge. All three use the mind: The first uses the mind to study material objects; the second uses the mind to study virtual objects; the third uses the mind to study the mind itself.

Three types of empirical knowledge

First, there are the empirical studies in natural science, starting with physics, and including more complex fields such as chemistry and biology, which are at least partly built upon physics. These studies are all in the end based on experience obtained by human beings, using material tools to study matter.

Second, there is mathematics. It is often said that math is built upon pure logic, but of course math is designed, carried out, and handed over to future generations by mathematicians. Like natural science, the way math operates is ultimately based on the experience of the practitioners.

Third, there is the possibility of a science of mind, which is what we are now focusing on. As I have argued, a true science of mind should be just as empirical as natural science is, each in its own domain. We will get a first taste of this toward the end of this entry.

Finally, whether we want to call mathematics empirical or not is really a matter of definition. Once the axioms are decided, one might argue that in principle everything is determined, simply by laws of logic, with no role anymore for approximate insight, as in the stages of development of physics. But what about the process of deciding upon the axioms? And what about alternative ways of doing mathematics, such as Brouwer's intuitionism? We will later come back to this question when we discuss the possible role that mathematics might come to play in a science of mind.

Back to the idea of "experience"

Having done the groundwork, and having specified the terms that we will be using, let us return to the notion of "experience". In practice, human experience is what provides scientists with "room" to make observations, develop theories and do everything else that scientists do in setting up and improving bodies of scientific knowledge.

This is somewhat similar to what space and time provide. Space provides room for objects to exist in, and time is what allows them to move. Philosophers sometimes call space and time the condition of possibility for motion to occur.

Would it make sense to call experience, or the field of experience if we can make sense of such a concept, the condition of possibility for scientists to do science, whether in terms of experiments, theories, or any other aspect of what working scientists do?

Space and Time as the arena for a science of matter

In the initial stages of developing a science of matter, Newton needed to introduce an arena for Newtonian mechanics to take place in. He did so by introducing the notions of absolute space and absolute time, two rigid forms of scaffolding of nothingness: empty space and empty time.

That seemed reasonable for more than two centuries. But a bit more than a hundred years ago, Einstein showed that spacetime is not at all rigid and absolute, but rather a much more dynamic medium that allows phenomena like gravitational waves, ripples in the fabric of emptiness in spacetime.

Experience as the arena for a science of mind

Could "experience", like absolute space and time, also turn out to be far more interesting than the way used in traditional "empirical science"? Let's find out, by designing some simple experiments to study the nature of experience. We will do this in two steps. First we will introduce a bit of theory, and then we will design experiments to test that theory.

The theory will be sketchy, and will almost certainly be wrong in its details. But we need to start somewhere, and when we experimentally test that simple theory, then after each test we can find hints to improve the theory, so that it becomes less wrong. When it becomes less and less wrong to the point of fitting with what experiments tell us, we theorists have done our job.

To build a theory, it is useful to start with a working hypothesis, the concept on which all of science rests, as we saw in entry #000.

Looking for a working hypothesis

At the end of the previous entry, we noticed how every typical experience has a subject pole and an object pole. I see something. I grab something. In both cases there is an active element, a self, that engages with something or someone else, through an action. It could be a more passive action of observation like seeing, or a more active form like grabbing something.

At first we thought that all three, the experiencer that is experiencing what is experienced, in short the -er, -ing, and -ed components of any typical experience, might be like atoms that make up a molecule. But on second thought, we realized that the situation could be more complicated. Perhaps the -er and -ed parts could be like two inseparable parts of experience, like the two ends of a stick, here the central -ing in which both arise.

It is time to take a scientific approach, in which we construct a specific working hypothesis. Let us assume that there are simpler building blocks that together constitute experiences. Our whole world of experience seems to be built up out of experiences, but perhaps experiences are not the most primitive elements. In that case we would expect that each experience is built up out of those more primitive elements in some way, to be determined. Let this be our first working hypothesis, WH for short:

WH 1: there are primitive elements underlying experience

To make this more concrete, we will call upon a second working hypothesis: one form of a primitive element, upon which all experiences are based, can be called appearance. Here "appearance" means that something appears. Within a single experience the -er appears, the -ing appears, the -ed appears. All three "make their appearance", as the saying goes. They are elements of experience that appear, so let's call them appearances.

And just as we loosely used the expression "field of experience" for the stage on which experiences take place as well as the experiences themselves, we can also create an expression "field of appearance" for the stage on which appearances appear, together with the appearances themselves.

There may well be other candidates, besides appearances, and they may look very different, but I prefer to start with a single concrete example.

WH 2: appearances are primitives for any form of experience

We can now make a plan of action, in terms of experiments to design and carry out. I will list them here briefly, as experiments with the different topics that they investigate:

experiment 1): the nature of matter as experience

experiment 2): the nature of experience as appearance

experiment 3): the nature of appearance as appearances

experiment 4): the presence of appearance

It may take us a while to carry out each of those experiments, and to start taking stock of what we can learn from them. For the remainder of this entry, we start with an initial look at how to conduct the first experiment.

Experiment 1): the nature of matter as experience

Find a comfortable place to relax, perhaps first while sitting on a chair at home, but later you could also go to a quiet park, or wherever there are few distractions. Then take a few minutes to look around, so that you can "take in" what you see around you. Notice the way you experience the room, or the landscape.

You may see a stone. Notice how you normally view it as a chunk of matter.

Now try to see the stone as an experience. Just as you can shift your awareness from a painting of an apple to the paint with which it has been painted, you can shift your awareness of a stone to an awareness of your mind that has "painted" the stone as a high-quality 3D full sensory experience.

Or to use another analogy, imagine that you are watching a commercial. It may not be very interesting, but if you were a specialist in commercials, perhaps someone who makes commercials for a living, you would notice many aspects of how the commercial was designed and put together, aspects that most people wouldn't notice.

Similarly try to watch the material world in the way it is presented in our awareness like a commercial. There are things all around you, including your own body, and while you watch all that, you can become aware of how everything is presented as experiences that you have learned to interpret as material objects.

Actually performing experiment 1)

The idea is simple, as a theoretical conclusion. To make this into a true experiment, it would be good to spend a few minutes at a time watching particular objects, or a whole scene filled with objects. You can also focus on sounds, rather than images, or on the totality of all sense impressions that you receive.

As always, performing these experiments together with friends will be a good idea. Apart from it being more fun, it will expose each of you to a larger variety of outcomes. This in turn will give you the opportunity to see clearer what kind of patterns may be more universal and which may be more particular to individual experimenters. And of course, the more diverse your group of friends will be, the more likely it is that what you first thought to be universal may not be so when you include more diversity!

In the next entry we will analyze some possible outcomes of this experiment, to see what we can learn from them, before moving on to the next three experiments in that and subsequent entries.

Our Mind as a Laboratory

Entry #004
April 02, 2024

Developing a lab culture and lab guidelines

In entry #001, I listed four categories of experiments in the science of matter: field observations, laboratory experiments, thought experiments, and computer experiments. Of those four, lab experiments are the most reliable. Because of the use of controlled conditions, they are less likely to introduce errors.

A quick look at the other three types of experiments makes that clear. Starting with working in the field, there are so many other variables at work, besides the ones that we would like to test. Most of the background variables we cannot change or shut out, and we hope for the best, that they don't turn out to be important.

Thought experiments are a wonderful tool for thinking out of the box, to come up with new ideas. But unless such hints are being firmly tested in the lab, or in the field if need be (galaxies don't fit in a lab), whatever we think about how experiments could or should go, we can't very well exclude wishful thinking.

In the case of computer experiments too, there are ways in which we can go astray. We start with a mathematical approximation of the situation that we want to study, and every model introduces approximations, the consequences of which cannot always be estimated accurately. The computer programs used for the simulations can contain subtle errors in their algorithms. Or errors that are not subtle at all: whole spacecrafts have been lost by miscommunication, for example when different members of the team used metric units while others used inches, feet and pounds.

Therefore, to have any hope to develop a science of mind, there is a firm need for developing laboratory settings in which to study the mind using the mind. And with laboratory settings in this case I mean protocols for using our own mind in specific ways.

The crucial point

Physics in particular has always aimed at reaching intersubjective agreement (often misleadingly called "objective agreement") through descriptions of matter in which the presence of the human subjects using their human minds is left out. In a science of mind, similarly, we aim at descriptions of mind in which the presence of matter is left out.

Is it possible to come to conclusions about the dynamics of matter without acknowledging the fact that scientists use their minds to study that behavior? Until 1925 the assumption was that "of course!" that is possible. Since then, for a whole century, quantum mechanics has thrown doubt on that question, and matters of interpreting the role of human observers continue to be debated, not only by philosophers, but also by physicists themselves.

Is it possible to come to conclusions about the dynamics of mind without acknowledging that scientists have physical bodies, made of matter? That reverse question has been asked most sharply and experientially by the German philosopher Edmund Husserl in his book "Ideas: General Introduction to Pure Phenomenology" in 1913, a question that he spent the rest of his life on, and that continues to be debated by philosophers.

My aim is to bring that second question into the realm of a science of mind, by minimally extending the physics methodology, while also acknowledging crucial differences between the nature of matter and mind. Is it really possible to use the mind to study the mind? Let's find out! In the same entry #001, under the heading of "The use of working hypotheses", I mentioned that for the science of mind, too, the crucial point is: "we should develop a proper lab culture and very important: lab guidelines."

Setting up a laboratory for mind studying mind

We are now ready to construct a mind lab, in analogy to matter labs, as have been used in natural science since the 17th century. To start with the latter, if we want to carry out sensitive experiments with sound, we build laboratories with walls that are constructed to be maximally soundproof. In order to do sensitive experiments using magnetism or radioactivity, again we use building materials for the walls of such labs that are minimally magnetic or emit a minimal amount of background radiation. How does that translate into the use of our minds like a lab?

Ideally we would find ourselves living in a "room" or even a "world" in which everything around us is "made of" experience, the "stuff" of the mind. But how?

In the previous entry (#003), we ended by introducing our first experiment, as the very first step on the road toward developing an empirical science of mind: experiment 1): the nature of matter as experience. Following some simple lab instructions, we started to explore ways to shift from seeing a stone *as a stone* to seeing a stone *as an experience*, namely the experience of dealing with a stone in front of us.

So far so good: we can learn to shift between two ways of viewing a stone, but how does that help us?

Learning to become fully empirical

The answer is simple. Given that we are looking for an *empirical* science of mind, only one of the two ways is admissible! When viewing the stone as an experience we can study that very experience fully, because that experience is fully there, self contained as an experience, and fully accessible for us.

In contrast, viewing a stone as a material object is an extrapolation from the experience that we have on seeing it. That is what natural scientists do, and that is what all of us do in daily life. But we have to leave all that behind. Looking at a stone, we feel a natural certainty that the invisible back side is there as we think it is. Similarly we feel certain that the inside is all stone, and not something else. But those 'certainties' are extrapolations, beliefs, not *empirical* certainties.

In every moment of our life we face a reality that can be attended to in terms of material or mental features. Physics, the simplest and most basic discipline of the study of matter, has made tremendous progress by rigorously focusing on the matter side of each situation. Our task now is to start a science of mind in an equally basic way by rigorously focusing on the mind side of each situation.

Spoiler alert: before too long we will begin to make some conjectures about what might happen if we try to unify a science of matter with a science of mind. But we shouldn't hurry to that next step. Only when a science of mind has taken a reasonably well defined shape will it make sense to begin to speculate what a science of reality could possibly look like.

Edmund Husserl

In the history of Western philosophy there is one philosopher who came closest to what I sketched above, taking any situation and admitting only what was given in experience, nothing more and nothing less. This was Husserl, who published a basic technology for turning the world into a laboratory for the mind. As a tool to be used in his lab, he introduced the 'epoché', pronounced 'epokhē', from the Greek word 'suspension' (ἐποχή). It was a method of suspension of judgment with respect to the physical reality of our material world. Instead he suggested to switch our attention to the direct empirical evidence we have of our world.

As an analogy, let us take the way a blind person experiences the world. Navigating in a room with a stick, he may feel the presence of tables and chairs by means of the vibrations in his stick. But what he is directly aware of is "this is a table" and "that is a chair", without focusing on the vibrations in the stick. Husserl's epoché is akin to shifting attention from the furniture to the vibration in the stick.

This is not the place to give an introduction to the Husserlian idea of transcendental phenomenology, as he called it, let alone to the large diversity of opinions of his students as to what exactly that might mean. What I described in very simple terms so far is good enough to use as a simple Ansatz, a German word widely used in physics for a kind of starting point from which to construct a new theory.

There is one other aspect, though, that I would like to introduce here, that is the tangible sense of awe that Husserl expressed towards the end of his life. He went so far as to describe the epoché as a `complete personal transformation, comparable in the beginning to a religious conversion' [The Crisis of European Sciences, 1970, Northwestern Univ. Pr., p. 137].

Conversion or deconversion?

Why did Husserl use the term conversion? My guess is that he was actually talking about a deconversion experience, in which you lose a faith that you may have had for most of your life. That last one can be equally intense. In a conversion experience you feel the freedom and openness of having found a whole new world. And in a deconversion experience you may feel the freedom and openness of dropping the limitations of what your previous belief system implied.

In Husserl's case, his sense of liberation was the discovery that he could drop what he called the "natural attitude". This was the term he used for our normally unquestioned belief that everything in our experience has to fit into a large universe made out of matter, in which our mind plays a minor role which is restricted by and adapted to the rules of matter. In contrast, entering the epoché, as a working hypothesis, he found a way to decouple from those restrictions.

It is very important, in discussing Husserl's epoché, to realize that he is not denying the existence of matter, nor is he suggesting that we live "as if" there is no matter. We talked about a sound lab, where we want to make the walls soundproof, in order to exclude noise from the outside. Similarly, Husserl wants us to be aware of how our interactions with matter, which pervade our lives, are tacitly "contaminated" with many subtle prejudices about what matter is and does. Performing the epoché is his way to "purify" our interactions, in order to make explicit what we actually experience in those interactions. And in that process, we can free ourselves from what we add by our habitual dogmatic views of matter, well beyond what empirical evidence tells us.

Continuing experiment 1): matter as experience

Meanwhile, let us spend some more time playing in Husserl's garden, watching individual objects releasing their nature as experience, and perhaps even traveling through Husserl's universe, in which everything turns to a kind of gold, namely experience.

From Experience to Appearance

Entry #005
April 14, 2024

Primitive elements underlying experience

In entry #003 I introduced two working hypotheses. The first one was "WH 1: there are primitive elements underlying experience." We talked about the presence of an experiencer who is experiencing something that is experienced, suggesting at least three elements: the -er, -ing and -ed element. That said, we have no clear idea what those elements can be, apart from the linguistic names subject and object and something that connects them.

The second one was "WH 2: appearances are primitives for any form of experience." Our definition was simple: "appearance" means that something appears. Within a typical experience, a subject appears, an object appears and some form of interaction between the two. And in addition, there may well be atypical experiences, in which subject and/or objects are hardly or not at all empirically present. In a suddenly very dangerous situation all one's intention may be focused on survival, for example. But usually, one's awareness of being the subject of the experience is there, even if only tacitly in the background. But even in an atypical experience, there is something there, and in our example very vividly there, namely DANGER.

This is not the place to try to further define what appearance is. In science we start somewhere, play with some simple experiments, sketch some simple ideas for possible theories, and then the "rachet of science" as I called it in entry #001 starts doing its work, while clarifying and refining both theory and experiment in the process.

In the same entry #003, I sketched four different experiments to start with. The first one was called "experiment 1): the nature of matter as experience." We started exploring how matter and experience of matter are related at the end of entry #003. At the end of entry #004 we explored whether we could use our mind as a lab in which to deemphasize the notion of the presence of matter. The goal there was to exclusively focus on the way in which matter is given in experience, in a radically empirical way, pioneered in great detail by the philosopher Husserl.

Let us now turn to the second experiment suggested in entry #003.

Entering a laboratory for exploring appearances

Let us start very gently, just dipping a toe into the waters of appearance, in a place that can play the role of a laboratory, isolated from disturbances. It is a good idea to try this at home at first, sitting on a chair or cushion, perhaps starting with an attention on your breathing in order to slow down a bit the inner dialogues that most of us are running in the background.

Experiment 2): the nature of experience as appearance

Even when you sit quietly, and your mind is relatively calm, every moment something appears: a distant sound, a fleeting thought, your breathing. Gently be aware of all those appearances appearing. You can just observe them, at first. If you feel like it, you can invite them, greet them in some way, and play with them. It is often said that scientists are like children, or equivalently, that children are like scientists, exploring the world. So if this is a novel experiment for you, the main instruction is simple: enjoy the relaxation and whatever aspects pop up. No need to distinguish between good and bad appearances, no need for any judgment at all. You can try to do this a few times for a few minutes, or longer, as you wish.

It would be good to have a log in which you enter the date and place of your experiment, and just a few lines of what you encountered, together with your reflections, if any, upon those encounters. You could again take a stone. Instead of switching between seeing the stone as a stone, or as an experience of a stone, try to find an even more minimal way of seeing stone as "something that appears", nothing more and nothing less.

In addition, the advice that I gave with the introduction of Experiment 1): the nature of matter as experience, in entry #003, holds here as well: performing these experiments together with friends will be a good idea. Apart from it being more fun, it will expose each of you to a larger variety of outcomes. Without a group of peers, science is not science.

A two-step experiment

Now that we have started to get some familiarity with the second experiment, let us combine the first and second one:

Experiment 1+2): matter as experience as appearance

In entry #004, we tried to "lift" ourselves from our normal sense of living in a material world in order to view, and really experience, the transition to finding ourselves in a world of experience. Having teleported ourselves, so to speak, from a matter world to an experience world, we can choose to not stop there, but in a continuous flow we can make another "lifting" move, into the world of appearance. Adding those two moves successively in a smooth movement may add yet another dimension to the separate moves.

Like riding a two-stage rocket, as soon as the first stage has done its job, without further ado we can jettison that one and continue our climb using the second stage. Can you feel the difference between those two stages?

Let us review again briefly the ride during the first stage. At a very young age we have learned to reify what we see around us. 'Reify' literally means 'making into a thing'. When we try to neutralize that move, and see the direct experience of a stone as an experience, we are counteracting a life-long habit of reifying. Just becoming aware of the moment in which we switch from seeing a stone, a material object outside us, to focusing on the actual act of experiencing may take some practice to get used to. The simplest trick to mark the difference is to briefly close your eyes: you then realize that the experience is gone, while of course you don't consider the stone as a material object to be gone.

For the second stage to set in, there is no such simple trick. It would be nice if we could close our "experiencing eyes" in order to reveal what appears, as a form of "pure appearing" while deemphasizing the need for a subject for whom this appearing appears. For this the lab recipe that Husserl provided us with, his epoché, may not go far enough. Leaving the "natural attitude" behind, he invites us to experience a remarkably different world, but still a world that could be experienced in some way.

Kitaro Nishida

For a description of what it feels like to make our second stage journey, we have to go beyond Husserl's already glowing report of the wonders of the first stage, which we encountered in entry #004. Around the same time that Husserl published his Ideas, describing the epoché, Kitaro Nishida, a Japanese philosopher roughly ten years younger than Husserl, published "An Inquiry into the Good", in 1911. A key point in this book was: we tend to say "I have an experience", but it is more accurate to say "Experience has me".

This one sentence has the power to open a whole new door, with a vista more far reaching than the door that Husserl provided to enter into his garden.

To begin to unpack that sentence, let us return to the description above, under the heading "Experiment 2): the nature of experience as appearance". That whole recipe was filled with advice to a "you" who was supposed to "do" the experiment. Implicit in the lab instructions was the expectation that "going from experience to appearance" meant that the experimenter was supposed to focus on the way "appearance" was experienced.

When we admire a brilliant rainbow, we tend to say that "the rainbow appears" without being real, and without even having a fixed place: it "appears" to happen in different places for different observers. But this use of the word "appearance" is not what is meant in our explorations. We are not talking about the "mere appearance" of a rainbow, as a kind of optical illusion. Rather we are pointing to Nishida's "sheer appearance", appearance as such, more stunning and in some way more "brilliant" than the way a rainbow can possibly appear in experience.

Nishida's expression for what is called "appearance" here is 純粋経験, junsui keiken, pure experience in usual translations, but in our vocabulary here it points to "pure appearance". That means appearance without there being a subject to whom an appearance appears. This notion of the absence of a subject, or put differently, the absence of a self in the case of pure appearance, was at least partly inspired by Nishida's familiarity with Zen Buddhism, in which "no self" is a central theme.

Looking back and looking ahead

In the first two entries I presented a very brief summary of what I consider to be central in the methodology of natural science, followed by a mention of some prescientific foundations in the form of experimental facts that were essential to get science going in the 17th century.

In entry #003 I suggested studying the nature of experience, as our first empirical investigation toward a science of mind. At the end of that entry I listed four experiments, to start with, two of which we have started to explore in entry #004 and the current entry, respectively.

The two remaining experiments are: "experiment 3): the nature of appearance as appearances" and "experiment 4): the presence of appearance".

Following those, I will introduce various diagrams to illustrate the relationships between what is generally classified to be objective reality, as opposed to subjective experience, in the light of what we will have covered by then in terms of investigations of appearance. The use of such illustrations will form one more parallel with the science of matter, in the way it was conceived in the 17th century.

Specifically, I will present several new diagrams as an attempt to map parallels between the analyses given by philosophers studying the mind, such as Husserl and Nishida, and natural scientists from Galileo to Newton, who in those days were called natural philosophers.

In Search of a Theory

Entry #006
April 30, 2024

Experimental introductions to experience and appearance

In the last three entries I have introduced two different experiments as initial examples of what experimentation might look like in a science of mind. In entry #003 I introduced the first one, a way of using experience to study experience. I called it "Experiment 1): the nature of matter as experience". The main idea was to turn the tables with respect to how we function in daily life.

Whatever it is that we experience, we normally focus on *what* it is that we experience. The invitation of the first experiment is to shift our focus to *how* we use our experience. We usually see a stone *as* a material object, but we have the freedom to see the experience of "seeing a stone" as an experience, rather than the presence of a stone. I compared it to shifting our attention from a painting to the paint, with our mind providing the mental paint for the mental painting of the physical object that we are aware of.

In entry #004 I presented a very brief vignette of Husserl's pioneering work of focusing attention to the mind side of reality, rather than the matter side, using what he called the epoché, a mental lab tool for studying the mind. The second half of his life was dedicated to exploring how that tool could be used, by using experience to study experience.

In entry #005 I introduced "Experiment 2): the nature of experience as appearance", picking up a thread that I had started already in entry #003. I gave a brief description in order to convey a feeling for such an experiment, with a warning that it was only an initial hint for "dipping a toe into the waters of appearance." I also provided an even shorter vignette of Nishida's way of pointing beyond experience to a more elementary presence of appearance constituting experience.

Back to the ratchet of science

We are now ready to explore the notions of experience and appearance using theory and experiment. In that way we can find out how useful those two notions may be in setting up a framework for a science of mind, our main topic as summarized in the ManiFESTo presented in entry #000.

In entry #001, I introduced what I called the "ratchet of science": the use of exploratory experiments or field observations in order to construct an initial theory, followed by more experimentation to test this theory. The next step is then to adjust the theory in order to obtain a better fit with the results of the newer experiments, and so on.

Having done some exploratory experimentation starting in entry #003 through #005, it is now time to formulate an initial type of theory. With that theory in hand, we can then return to the initial two experiments, to give more precise instructions of what to look for, and how to analyze the results of our experiments.

In order to develop a theory to describe experience and appearance, where to start?

Using science of matter as inspiration

Compared to science of matter, setting up a science of mind may seem far more difficult, if not impossible. When comparing the two, it is clear that science of matter is the low hanging fruit: you can hold a stone in your hand, weigh it and measure it, but dealing with thoughts and feelings presents more of a challenge.

At the same time, one could also argue that in fact a science of mind has become the remaining low hanging fruit, now that science of matter presents us with a tremendously successful example of how to set up the first type of science. Insofar as every moment of our life we are confronted with matter aspects and mind aspects of our world, science of matter just begs to be followed up by a science of mind.

So let us use the science of matter as inspiration. In physics any new discovery of a more fundamental theory should be compatible with the previous discovery. Could there be a parallel between our progression from matter to experience to appearance? If so, each next insight should leave the previous one largely intact, while at the same time offering deeper insight into aspects of that previous insight.

A natural example in the case of physics would be to start with Aristotle's view of matter and motion, next to compare that to Newton's classical mechanics and universal gravity, and then to move on to Einstein's relativity theories, both special and general relativity.

Just as it took us three entries to introduce even the basic ideas behind the moves made a century ago by Husserl and Nishida, it will take some time to unpack the parallel suggested above.

From Aristotle to Newton

According to Aristotle's theory, in the realm below the Moon, including all phenomena we witness on Earth, the natural motion for objects is to fall toward the center of the Earth. We can throw a ball, and for a while it may move upwards and sideways, but before long it runs out of steam, so to speak, and winds up falling straight down. And indeed, his theory was in agreement with what we see happening, because of the friction between moving objects and the air, decreasing the speed of any initial motion, leaving gravity to determine the downwards motion.

In contrast to everyday objects, Aristotle assumed that completely different laws of motion hold for objects moving beyond the orbit of the Moon. There he posited that natural motion is not linearly directed to the center of the Earth. Instead, heavenly bodies move around the Earth in circles, seen as the most perfect geometrical figures. This again was roughly in accord with observations.

As a result, in Aristotle's system the cosmos was split into two very different parts. In the lower sublunar realm everything eventually runs out of steam: any movement that is not sustained comes to a natural state of rest by ending up on the surface of the Earth, and any form of life eventually decays. In contrast, movement in the supralunar, heavenly realm perpetuates itself in an eternal fashion.

It took two thousand years before a more accurate theory was introduced by Newton, a theory that at first sight was in flagrant contradiction with every normal observation of motion in our vicinity. Newton's laws tell us that an object, once in motion and left undisturbed, will continue to move in a straight line in the original direction. He had to assume that air friction only exists close to the Earth, and planets and their moons move in a large vacuum that fills the whole solar system.

Having made that assumption, he could suddenly explain in a quantitative way all the observed movements of any celestial object, including comets. By assuming that the force of gravity between two objects drops off with the inverse square of their distance, suddenly everything could be calculated and then checked that it all confirmed his theory to high accuracy.

<u>Extending validity and accuracy</u>

It is important to realize that Newton's theory in many important ways did not disprove Aristotle's theory. On the contrary, under normal circumstances in daily life objects do lose their original form of movement, and fall down toward the center of the Earth. To test Newton's laws on Earth, one would have to develop a theory of air friction, adding significant complexity to the simplicity of Newton's laws.

However, when applied to orbits in the solar system, Newton's laws of motion and of universal gravity naturally show how the Moon and planets obey the same laws as an apple falling from a tree. The enormous extrapolation from an apple falling a few meters, to the Moon traveling more than a million miles in its monthly orbit, yet following the same law of gravity, was the first "grand unification" in the history of physics. It showed once and for all the unity of the two realms posited by Aristotle as being totally different. It would be the first in a long string of unifications of two or more seemingly different theories into an overarching inclusive new theory.

Yet we should not forget that Aristotle's theories were not plain wrong. They did form a reasonable approximation to many aspects of motion, both on a very small and a very large scale.

This pattern would be repeated over and over again, whenever physicists discovered new theories. The older theories were not just discarded. Rather they retained their approximate validity in the realms in which they were originally tested.

Science in the news

What else could we expect? Once a theory is tested, in particular situations and to a specified accuracy, and tested independently in different experiments in different places by different scientists, how could a future group of scientists objectively (in practice always intersubjectively) repeat that kind of test and get different values?

Newspaper headlines of the type "theory X has been proven wrong" can be quite misleading. A more accurate statement would be an admittedly rather clumsy description of the type "theory X, previous tested and confirmed to an accuracy of Y under conditions Z, needs to be modified, now that new tests under higher accuracy Y' and/or different conditions Z' have shown that the theory's predictions fall outside the error bars of the observed results, not only once but repeatedly in different experiments performed by different teams."

Given the alternative, we can have some sympathy for the choice of the shorter headline, which is also likely to provide greater revenue for the newspaper by adding a flavor of a sport's match with winners and losers. In practice, in science there are only winners, when better tests are applied to theories. Theories are abstract constructs, while scientists are human beings, collaborating in a global community of peers aimed at improving the storehouse of knowledge that is humanity's most important asset.

The attentive reader may have noticed that the last sentence neglects peer pressure, in the same way that Newton neglected air pressure, for non-perfect peers.

After Newton

It took 2,000 years for Aristotle's theory to be replaced by Newton's theory. As a measure of the increasing speed of innovation, made possible by the advance of science, it took only 250 years for Newton's theory to be replaced by Einstein's theories of relativity.

Ten generations is still a long time, though, and a lot of cultural damage was done by the insistence of many scientists that "we now know that the underlying reality of our world is that of a mechanism". Worse, they typically did not speak for themselves, but rather made statements like "Science tells us that . . . "

Yes, science is an amazing achievement, one of the most amazing of all that humans have ever produced, and one that does not depend on specific materials, places or cultures, once it is shared globally. But no, science does not talk. As often happens, once a bright spotlight illuminates some part of a culture, the rest seems to retreat into relative darkness. Success invites hubris, and scientists are human, not immune to such temptations.

Around 1800, artists and poets like William Blake in England and Johann Wolfgang von Goethe in what later would become Germany, bemoaned the limitations of a mechanistic worldview. They realized that it was transferred well beyond the boundaries of physics, as a model for just about any aspect of modern life.

I count myself lucky to have been born in the twentieth century, rather than one or two centuries earlier. Soon after 1900, relativity and quantum mechanics showed the glaring limitations of mechanistic approximations to descriptions of matter. In principle, that should have eased communication between natural scientists and artists, as well as scholars in the humanities and social science. In practice, though, deeply ingrained habits of thought die slowly, as we still witness.

From Newton to Einstein, act 1: special relativity

In 1905 Einstein published his special theory of relativity, which gave a totally new description of motion. Triggered by loose ends in the interpretation of Maxwell's theory of electromagnetism, something we will soon discuss in more detail, Einstein concluded that Newton's absolute space and time were only approximations. One dramatic consequence is that there is no absolute time frame, as illustrated by the twin paradox.

When two twins decide to let one of them travel far and fast, and the traveling twin then stops and returns at the same speed, they will no longer be the same age. When the speed of the traveler is close to the speed of light, the one staying at home may be older by many years, while the traveler may have barely aged, and so is much younger upon return than the one staying put. There is actually nothing paradoxical about it, from the point of view of relativity theory, which in itself is as consistent as Newtonian mechanics is. The name "twin paradox" indicates the unexpected outcome for someone used only to the consistency of Newton's theory.

Another consequence has had a much more dramatic impact than retarded aging. Einstein's famous formula E = m c^2 opened the door for a realization that a very small amount of matter could harbor the potential to unleash an undreamt amount of energy.

From Newton to Einstein, act 2: general relativity

In 1915 Einstein followed up with his general theory of relativity. He showed how we can interpret the phenomenon of gravity as the consequence of curvature of spacetime, the four-dimensional structure of space and time taken together into what mathematicians call a manifold.

In Einstein's formulation gravity is not a force field that operates in space and time, like electricity that acts only on electrically charged particles. What seems to act as a gravitational force field is a consequence of the way that curvature of spacetime makes it impossible for any object to move in a straight line. Instead, any object will try to move on as straight a line as it can find within the restrictions of the curvature around it.

As a result an apparent gravitational force seems to be created, a force that causes an acceleration for any object at any given place and time that is independent of its mass, as demonstrated first by Galileo. In Einstein's view the apparent force is nothing but a response to the curvature of space and time in the neighborhood of the object, independent of the nature of the object.

From Aristotle to Newton to Einstein to Einstein

As we saw above, phenomena confirmed under certain conditions in one theory should be predicted by more accurate theories to the same accuracy as found before. This should also hold true for the transition from Newtonian mechanics to Einstein's theories of relativity.

Specifically, general relativity should reproduce results of special relativity in the limit of a weak gravitational field. And in turn special relativity should reproduce results predicted in Newton's classical mechanics and universal gravity in the limit of velocities small compared to the speed of light. And indeed, they both do.

In fact, it can be rigorously proved mathematically that the above two limiting cases, in a cascade from general to special relativity, and then to Newton's theory correspond exactly. This is highly non-trivial, since the underlying structures of those three theories are described by quite different mathematical formalisms. Given these exact correspondences in limiting cases, there is no need to perform additional experimental tests, as long as a more advanced theory corresponds in detail to any earlier theory, within the limits of accuracy specified.

Similarly, for any future theory the first requirement, before any attempt at experimental testing, is that the mathematical limit of the new theory under less extreme conditions corresponds to that of the earlier theory.

While this holds mathematically for any scientific theory, a comparison with Aristotle's theory is more difficult to make. Aristotle's theory is prescientific in that some of the predictions made turn out to be incorrect, as Galileo showed by dropping objects from a leaning tower. This means that there is no mathematical theory of Aristotelian mechanics to which Newtonian theory should correspond to in any limit that can be defined. This is why I stated above a more qualified correspondence, namely a requirement that Newton's theory "in many important ways" did not disprove Aristotle's theory, but certainly not in all ways.

Parallels with a science of mind

We can now come back to the question we asked near the beginning of this entry. In the process of constructing a candidate for a new science of mind, we needed to provide at least a few simple experiments together with a simple theory to make some sense of those experiments. Entries #001 and #002 provided a summary of the science of matter. Entries #003, #004 and #005 described two candidates for basic experiments in a science of mind. In this entry we have started to prepare the ground for a first candidate for a basic theory that we could use in tandem with those experiments.

In the next entry we will return to this very abbreviated history of physics, from Aristotle to Newton to Einstein. There we will have a more detailed look at the ontologies of matter, as reflected in the structure of the theories we have reviewed here. Could they at least provide some hint or hints as to the kind of Ansatz that might turn out to be useful? Here Ansatz is a term that I introduced in entry #004, to indicate a starting point for constructing a new idea in physics when exploring new areas. Let's try to find out.

Unanticipated Discoveries in Science

Entry #007
May 10, 2024

The mystery of gravity

In the previous entry I presented a short narrative of the first three centuries of natural science, the science of matter. The two highlights of radically new theory formation were Newton's laws of motion and of universal gravity, and Einstein's special and general relativity theories. I described how Newton unified the dynamics of Aristotle's separate views of Earthly and celestial phenomena, and how Einstein unified space and time, as well as matter and energy, according to special relativity.

In addition, I mentioned how general relativity is even weirder and its results were even more unexpected. It completely changed our view of what gravity *is*. Let me repeat in more detail the fact-of-the-matter description I gave in entry #006, to try and convey more of a sense of the enormity of the revolution implicit in general relativity. In short: while gravity was seen and felt as a force by Newton, albeit a mysterious force acting at a distance, suddenly it was no longer considered a force in its own right. Rather, the status of gravity was relegated to a side effect.

A side effect of what? Something even more powerful than the crushing forces of gravity that are everywhere and govern anything in the Universe? What could that possibly be?

Spacetime, it turned out.

The mysteries of space and time

Long seen as non-physical and non-substantial, space as an ungraspable empty stage or container for anything physical, was discovered by Einstein as conspiring with time, the equally non-physical and non-substantial inexorable whatever-it-is that seems to let us age and that makes motion in space possible.

Both pure potential, three-dimensional space allows objects to be, and one-dimensional time allows objects to change. Philosophically the two can be classified as innocently sounding abstract concepts called "conditions of possibility". Space and time are the two enabling somethings for anything to happen. Or more accurately some-non-things enabling any-thing to happen.

When space and time present themselves as a carefully woven four-dimensional unity, mathematically defined as a differentiable four-dimensional pseudo-Riemannian manifold, voilà, we can make an accurate representation of the world we live in.

When you live and move in a dynamical four-dimensional spacetime, its curvature prevents you from going in a straight line. Why? Well, you just can't draw a really straight line on a curved surface.

Gravity without gravity

Generalized to a 3-dimensional non-flat space or 4-dimensional non-flat spacetime, the same is true: there just aren't any straight lines. The best you can do is move on a line that is as straight as possible, but still a minimally curved line. That is the closest you can get to Newton's law of inertia in a space with no masses and hence no gravity. In that case Newton tells you that you will move in a straight line if there are no other forces acting on you.

When there are masses, Einstein offers a precise description of how those masses curve spacetime. Having mapped out the bumpy terrain around you, it becomes possible to translate the side effects of traveling in that uneven environment as if there was a mysterious force called gravity, acting on you.

It is those side effects that toss and turn you as in a car on a bumpy road. Moving in a spaceship through the solar system, for example, the Sun warps spacetime like a giant pothole, while each planet adds its own bump to the spacetime scenery -- all in 4-D, mind you, the mathematics of it takes a while to get familiar with. Even so, gravity is benign, in that it still makes your journey as straight and undisturbed as can be, given the world you happen to live in.

As John Wheeler, the greatest popularizer of complex physics in simple terms of the second half of the 20th century, expressed it: the result is "gravity without gravity". Just think about it. The gravity that you feel while reading this, sitting, standing, or lying down, is a constant reminder that you are traveling through space and time. You came into this world inside a bumpy background of four dimensions, partly acting as a space-like container, partly acting like a time-like one-way conveyor belt. Neither space-as-such or time-as-such, but an extremely complex four-dimensional unification of space-like and time-like properties, producing gravity as a side effect.

Who could have thought?

However, gravity without gravity, while presenting itself as a deep mystery, was only one in a series of mysteries, unveiled by science during the last few centuries. Each of those came as a complete surprise.

An early surprise: universal gravity

The whole history of physics, and of science in general, is one of discovering mysteries in ways that, time and again, no scientist had anticipated, or could have anticipated, given what they knew. But given that physics is the simplest, and hence also the oldest, of disciplines in modern science, let us start with physics.

Where did modern science start? One milestone was reached by Copernicus, who placed the Sun in the center of the planetary system, rather than the Earth. But he was not the first to do so. Aristarchus, some eighteen centuries earlier, had proposed the same swap on the chessboard of the solar system. The idea behind what is often called the Copernican revolution, was indeed revolutionary, but not in itself completely original.

In contrast, what was totally unanticipated was Newton's proposal that the laws of motion as well as the law of gravity applied exactly in the same way on Earth as well as among the heavenly bodies: the Moon, planets, moons of planets and comets. The idea of universal gravity was shockingly new: one concept governed by one simple equation, telling us that the strength of gravity falls off as the inverse square of distance.

A 19th century surprise: the role of atoms

Philosophers in different cultures had speculated that matter consists of atoms. This is not surprising, really, given that it was the most conservative choice. The alternative would have been to imagine that matter can be divided infinitely often, which is harder to imagine than the presence of a finite limit to divisibility.

What was really surprising, and could have hardly been guessed, is that real atoms turned out not to carry properties like earth, water, air or fire, as had been generally assumed. Unlike the lucky guesses of ancient philosophers, we learned that a single type of atom or molecule, like H2O, can behave as a solid, liquid, gas, or even plasma when ionized into H and O atoms, solely depending on pressure and density. It was the 19th century theory of thermodynamics that made this clear.

Nobody had guessed that those four phases, as physicists call them, did not reflect built-in properties of atoms, but rather processes between large aggregates of atoms. And even more surprising, those starkly different phases can spontaneously appear whenever we turn up a single dial, for example temperature.

More unpredictable surprises in the science of matter

We have just seen three surprises that for all intents and purposes can be classified as unpredictable: Newton's universal gravity, the atomic nature of matter as producing phenomenology through processes rather than properties, and Einstein's gravity without gravity.

The list goes on. Maxwell discovered that light is a wavelike phenomenon, and naturally he assumed that light would consist of waves in a medium, which he called aether. But he was wrong, as again Einstein showed, in his special theory or relativity. No medium could possibly have the characteristics necessary to produce light or any electromagnetic radiation obeying Maxwell's equations.

Practically speaking nobody could have predicted that yes, light behaves like a wave, but no, not in any kind of medium to make waves in. Or, alternatively, if it were a medium, it was not any medium in space that showed waves happening in time. And it would not have any mass. It would literally be an empty medium, which is why it was dropped as unnecessary.

Other totally unanticipated surprises would follow in rapid succession, during the twentieth century. Quantum mechanics was and is the most mysterious of all, definitely not predicted or even conjectured in any way. That nuclear processes can provide a million times more energy than chemical processes in the same amount of fuel, similarly was unimaginable, until it was discovered and used, for better and for much worse.

Art and science: different goals, similar creativity

Artists desperately want to be original, adding to what has already been produced by humanity in new and ever more creative ways. Scientists, on the contrary, desperately want to avoid unnecessary originality. They want to discover more of the depths of the nature of reality. Peering deeper into how the world of matter works is the holy grail, and the simpler the theories and explanations, the better.

In science, flamboyant and highly original ideas as such are not valued at all. On the contrary, those will be either just ignored, or attacked in the most critical ways to see whether and where they fail. Only if a new theory holds up in a variety of experiments, will it become a candidate for acceptance over time.

Yet, against all their intentions, over the last few centuries scientists have been producing the most stunningly original and totally unanticipated ideas humanity has ever stumbled upon and verified in objective, more accurately intersubjective, ways.

Science as a multigenerational enterprise

The eighteenth century came and went, and so did the nineteenth century. During all that time, while the world changed dramatically, for a large part through enormous advances in science and technology, one thing did not change: the dogmatic scientific belief in viewing the material world as a mechanism, and by extension the whole of reality. How could that finally come to an end? Protesting artists were ignored, as we saw in section "After Newton" in entry #006 in this log. It was only when scientists were forced, kicking and screaming, to accept that, no, reality is not at all like a clockwork or whatever mechanism it was believed to be like.

The greatest thing about science is that they *did* eventually change their minds, by their own lights, in decisions made collectively as a self-governing group of peers. In entry #001, I listed this as the fourth and last characteristic of science, when I wrote: "The above four aspects, theory, experiment, working hypotheses and peer review, are absolutely essential for an area to deserve recognition as a field of science."

Science is a multigenerational enterprise. Sometimes change comes slowly, but when it comes, and is finally generally accepted, there is no turning back. In entry #003 I have described the process as the essence of science being called empirical, within a given accuracy. Also, in entry #006, in the section "Extending validity and accuracy", I have come back to this point while making a plea against hype in presenting novel theories.

In that same entry, in the section "Using science of matter as inspiration", I explained why I was going to make a detour through the history of science of matter, before continuing with our attempt to start up a science of mind. Having reached, for now at least, the end of the detour, in the form of a rich exhibition of mysteries, it is time to take stock of possible lessons that we may have learned, to inspire us in designing new theories and experiments for use in a science of mind.

We will do so in the next entry, where we will return to the theme of entry #005, where we started to experiment with shifts in perspectives on any material object, from seeing it as matter to seeing it as experience to seeing it as appearance. There we will start to explore whether shifts in perspectives on gravity, from Aristotle to Newton to Einstein, may have anything in common with the shifts toward experience, first, and then toward appearance.

A Picture Book of Physics Theories

Entry #008
May 19, 2024

Clarifying diagrams

Many profound discoveries in physics and mathematics were initially presented in hard to understand jargon without clear illustrations of the key points. Only years or sometimes decades later would deeper insight lead to simpler pictures, and vice versa: diagrams that were easy to interpret made it easier to get a sense of the deeper meaning of a theory.

Some profound illustrative figures in physics are Minkowski diagrams (1908) and Penrose diagrams (1963) depicting relationships in space and time. A somewhat different type is formed by Feynman diagrams (1948). In mathematics the approach of category theory is altogether based on diagrams as its building blocks.

Each of the first three examples offered profound new perspectives on the physics underlying processes related to the behavior of matter. My goal in this and following entries will be to provide diagrams that similarly shed light on the way our minds are functioning.

My initial attempts will naturally be simpler than the physics examples mentioned above, given that I am starting from scratch. My hope is that soon we can nurture a community of scientists and scholars, each with a background in science and/or contemplation, which collectively will vastly improve upon the initial ideas that I will offer here.

Matter, Experience and Appearance

As a reminder, in entry #006 I started a search for a theory, to go with the preliminary experiments 1) and 2), discussed in entry #005. I used the history of physics as the most obvious example to start with in order to get some inspiration.

In entry #007 I made the prediction that whatever we find will likely be completely unexpected, and utterly different from the way we have learned to deal with our own minds in our culture.

That last suggestion is the most conservative way of extrapolating to a science of mind the way in which science of matter has shown a progression of ever more surprising discoveries. Another conservative extrapolation can be made from reading accounts of the most respected contemplatives in various traditions. The one thing they all have in common, whatever their particular tradition happened to be, is a sense of awe that is very reminiscent of the awe scientists expressed whenever they explored their own topics to greater and greater depth.

What has held back a straightforward comparison of insights in matter and mind, between scientists and contemplatives? It is that contemplatives have not yet reached agreement on any clear correspondence between their own tradition and quite different traditions. Like the prescientific state of engineering, with insights locked up within specific guilds working on specific topics, with very few exceptions no systematic attempts have been made to build real bridges, let alone to meet each other into the trenches or canyons way below such bridges.

The miracle of the science of matter was the way that a more abstract non-physical ingredient, mathematics, added to the purely physical investigations, could open doors to completely unexpected insights. Could it be that a science of mind is also still waiting for a missing ingredient? At this point we are not yet in a position to even guess what that might be. Rather than guessing, let us do some work. In other words, let's start with a working hypothesis, and take it from there.

From working hypotheses and theories to experiments

In entry #003 I introduced two working hypotheses:

WH 1: there are primitive elements underlying experience

WH 2: appearances are primitives for any form of experience

In addition, I now propose a third one:

WH 3: the shifts in perspectives between viewing objects as matter, experience, or appearance, might have analogies in the shifts of perspectives between subsequent theories in physics.

WH 3 may or may not turn out to bring us closer to a useful theory to start with. Either way, we will learn from the exercise. If it is helpful, and the analogy helps us to build such a theory, great! And if not, by seeing where the analogy fails, we are likely to at least get some hints of where else to look.

The shifts in perspective that WH 3 points are those described briefly in entry #005, corresponding to:

experiment 1): the nature of matter as experience

experiment 2): the nature of experience as appearance

There we didn't really get underway with the experiments, which would have required a more detailed description of the setups, analyses and results, as well as discussions and conclusions. We could not really do so yet, since we didn't have any theory to compare the outcomes of the experiments with. That was the reason that in the next entry, #006, we turned to physics for initial inspiration to set up a simple theory to guide the two experiments above. And now we're in a position to use WH 3 to provide a theory as a framework for performing experiments 1) and 2).

Figuring things out

Following our working hypothesis WH 3, I will present some diagrams, in a meta analogy to the three physics diagrams I mentioned at the start of this entry. Instead of mapping out physics *processes* in physical space and time, as those three diagrams did in different ways, I will present the progression of physics *perspectives* themselves diagrammatically in calendar time.

My first diagram is very simple: a straight line with two arrows. The first arrow indicates the inspiration that the Greeks received from the Babylonians, whose millennium's worth of observations of the motions of Sun, Moon and planets provided a valuable database that allowed them to construct models of the planetary system. The second arrow indicates the inspiration that Aristotle received from the Pre-Socratics, philosophers like Pythagoras, Heraclitus, Zeno and Democritus. I have added some indication of the time around which they were active.

```
+=====================================================+
|                                                     |
|        BA ---> PS ---> AM : Physics (300 BC)        |
|   (1500 BC)  (500 BC)  (300 BC)                     |
|                                                     |
+-----------------------------------------------------+
|  Fig. 1: The state of physics around 300 BC,        |
|  as described by Aristotle, inspired by earlier     |
|  philosophers, while even earlier data had been     |
|  gathered by Babylonian observers, which later      |
|  would be used in refining Aristotle's model of     |
|  the motions of Sun, Moon and planets, which in     |
|  turn was refined by Hipparchus and Ptolemy.        |
|                                                     |
|  AM: Aristotelian Mechanics (300 BC)                |
|      Aristotle's view of physics                    |
|                                                     |
|  PS: Pre-Socratics (~500 BC to ~300 BC)             |
|      Various theories of the nature of matter       |
|                                                     |
|  BA: Babylonian database (~1500 to ~500 BC) with    |
|      algorithms to predict the motion of planets    |
+=====================================================+
```

The Second diagram introduces the first modern scientific model of motions of objects that exert forces on each other, Newton's classical mechanics, CM. In addition it includes the formula for the force of gravity, as derived by Newton, also called universal gravity, UG, since it described the effects of gravity from the smallest to the largest distances then known.

```
+=====================================================+
|                                                     |
|      AM ---> {CM + UG} : Physics (1700)             |
|    (300 BC)                                         |
|                                                     |
+-----------------------------------------------------+
|  Fig. 2: The state of physics around 1700 after     |
|  Newton published the Principia, which unified      |
|  the understanding of motion and gravity through    |
|  a few simple equations that applied to phenomena   |
|  on Earth as well as anywhere in the solar system.  |
|                                                     |
|  CM: Newton's three Laws of Motion: (1687)          |
|      Classical Mechanics                            |
|                                                     |
|  UG: Newton's inverse square law of gravity (1687)  |
|      Newton's law of universal gravitation          |
|                                                     |
+=====================================================+
```

Adding an extra dimension

In Fig. 2, the plus sign between CM and UG is not very informative. The reason to mention mechanics and gravity separately is that classical mechanics alone is already sufficient to describe local forces. To predict the motion of billiard balls, for example, classical mechanics as such suffices to determine their trajectories on a pool table. Only when they touch each other or touch the edge of the pool table can their motions be changed from the straight lines on which they otherwise would move.

In contrast, gravity is a force that acts at a distance. Any motion of any object on or near Earth is affected by the gravitational pull that the Earth exerts on that object. To make Fig.2 into a real diagram, in Fig.3 a new dimension has been added in the vertical direction. AM -> CM now indicates how Aristotelian mechanics was replaced by Newton's classical mechanics, and how universal gravity UG added a separate embellishment, as the only force known to act in a distance.

Between Newton's classical mechanics and his universal gravity, physics was thought to be complete. This was the state of the art of physics around 1700.

```
+=====================================================+
|                                                     |
|                   UG__                              |
|                  /    \                             |
|                 /      Physics (1700)               |
|       AM ---> CM______/                             |
|                                                     |
+-----------------------------------------------------+
|  Fig. 3: The state of physics around 1700 after     |
|  Newton published the Principia, which unified      |
|  the understanding of motion and gravity through    |
|  a few simple equations that applied to phenomena   |
|  on Earth as well as anywhere in the solar system.  |
|                                                     |
|  CM: Newton's three Laws of Motion: (1687)          |
|      Classical Mechanics                            |
|                                                     |
|  UG: Newton's inverse square law of gravity (1687)  |
|      known as the law of universal gravitation      |
|                                                     |
|  CM is the default when gravity is unimportant.     |
|  CM + UG provide a complete picture of the state    |
|  of the art of physics around 1700                  |
|                                                     |
+=====================================================+
```

Extra forces: electricity and magnetism

Physics seemed finished and self-contained, with Newton's three laws and Newton's law of gravity. During the next century, though, two more forces were discovered to act at a distance. Not only that, they were similar in the way their forces fell off with distance, namely as the inverse square.

They were electricity and magnetism. Both were known since antiquity. Thales, one of the most prominent Pre-Socratics, described both of them, but without further detailed study. The earliest mention of the effects of electricity was already in an Egyptian text, a full two thousand years before Thales, describing how certain types of fish produced electric shocks.

The use of magnetism to build a compass was invented by the Chinese two thousand years ago, and became in use in Europe a thousand years later. William Gilbert, a contemporary of Galileo, published detailed studies of electricity and magnetism. He concluded that the Earth itself was a giant magnet, creating the Earth's magnetic field.

It was only later, in 1819, through the work of Ørsted, that relationships between electricity and magnetism became known. Fig. 4 shows the state of the art of physics, a hundred years later than Fig. 3. By then gravity had acquired two companions, also working through action at a distance, but without any clear connection between the two. Note that the simpler contact forces of CM, that are contributing to the physics of 1800, are left out for simplicity.

```
+====================================================+
|                                                    |
|                  UG____                            |
|                 /      \                           |
|                /        \                          |
|       AM --> CM        _ Physics (1800)            |
|                \    E_/ /                          |
|                 \  /   /                           |
|                  XF   /                            |
|                    \ /                             |
|                     M                              |
|                                                    |
+----------------------------------------------------+
|  Fig. 4: The state of physics around 1800 after    |
|  the discovery of two extra force fields besides   |
|  gravity: electricity and magnetism.  Both of      |
|  these fields were successfully modeled on         |
|  Newton's inverse square law of gravity.           |
|                                                    |
|  XF: Extra Fields, besides gravity                 |
|                                                    |
|  E: Electricity                                    |
|                                                    |
|  M: Magnetism                                      |
|                                                    |
+====================================================+
```

Maxwell's unification: electromagnetism

The more physicists understood the properties of electricity and magnetism and their relationships, the more it became clear that there was a strong parallel between both. There was only one glaring difference: we find electric charges in nature, but nobody has ever found magnetic "charges". Instead, a north pole and a south pole, the parallel between an electric positive and negative charge, always appear together; hence the name "poles", rather than "charges". So far, we have never found a single pole, even though we already have made up a name for one, if it were found: a magnetic monopole.

A major breakthrough was made by Maxwell's discovery of the equations of electromagnetism, a unified way to present the effects of electricity and magnetism. Apart from the absence of magnetic charges, electricity and magnetism played a very similar role in his equations. Fig. 5 shows the state of the art of physics after Maxwell's discovery.

```
+=====================================================+
|                                                     |
|                  UG_____                            |
|                 /       \                           |
|                /         \                          |
|       AM --> CM           Physics (1865)            |
|               \    E    /                           |
|                \  / \  /                            |
|                 XF   EM + aether                    |
|                    \ /                              |
|                     M                               |
|                                                     |
+-----------------------------------------------------+
|  Fig. 5: The state of physics in 1865 following     |
|  Maxwell's theory of electromagnetism, which        !
|  unified the two new theories of electricity and    |
|  magnetism.  Electromagnetism described light as    |
|  waves in an as yet unknown medium, called aether.  |
|                                                     |
|  EM: Electromagnetism                               |
|                                                     |
+=====================================================+
```

One result of Maxwell's equations was the discovery that light is a form of electromagnetic radiation, which suggested that there would be other forms, outside the narrow wavelength band of visible light. Indeed, besides infrared and ultraviolet light, at the much longer wavelength side were radio waves, discovered by Hertz in 1888, and at the much shorter wavelength side X-rays, discovered by Röntgen in 1895.

Maxwell postulated that space is filled everywhere by a very rarified medium, called aether. It was thought that any type of waves would require a medium in which to form waves in, and that it would be just a matter of time to determine the properties of that medium.

A more compact version of Fig. 5 is presented in Fig. 6, which shows a parallel with the state of physics of Fig. 3, with the first action-at-a-distant force field of gravity receiving company by a similar but more complicated field, that of electromagnetism.

```
+====================================================+
|                                                    |
|                   UG                               |
|                  /  \                              |
|                 /    \                             |
|       AM --> CM       Physics (1865)               |
|                 \    /                             |
|                  \  /                              |
|                   EM + aether                      |
|                                                    |
+----------------------------------------------------+
|  Fig. 6: The state of physics in 1865 written in   |
|  a more compact form.  Only one more field was     |
|  now added to the field of gravity, and one more   |
|  medium, the postulated aether                     |
|                                                    |
+====================================================+
```

A First hint from physics for creating a science of mind

Coming back to our goal of setting up, and trying out, initial theories in a science of mind, so far we can already find three hints that might turn out to be useful -- or not, we don't know yet.

First, when separate descriptions seem to be necessary for somewhat similar phenomena, there can be a payoff in terms of a simplification if we can construct a unification of two or more theories.

One example was the transition from Aristotelian to Newtonian mechanics. Where Aristotle's theory included two different realms, below and above the Moon, with completely different laws of motion, Newton's theory replaced both by a single theory.

A second example was the unification of electricity and magnetism into one single theory, showing unexpected symmetries between the two. A surprising result was that the stark difference between the presence of electric charges and the absence of magnetic monopoles turned out to be less fundamental than the way both forces played a completely symmetric role in Maxwell's equations.

A second hint

Apart from the economy and elegance of theoretical descriptions, there were more concrete payoffs as well.

In terms of the first example, the unification of gravity "up there" and "here below" immediately clarified the nature of comets, as well as the nature of tides. And ultimately it allowed us to move into the "up there" ourselves, with the first moonwalk.

As for the second example, nobody could have guessed that unification of electricity and magnetism would give an enormous bonus in understanding the nature of light, which in turn enabled the discovery of radio waves. The technological and social implications would cause a communication revolution in the early twentieth century.

A third hint

The third and last hint concerns the very nature of space and time, the stage on which physics plays out.

In the transition from Aristotle to Newton, the segregation of space into eternal motion "up there" and every motion running out of steam "down here" was abandoned. There was nothing special about the space above the Moon. Aristotle had introduced a subtle refined element, which he called aether, residing only in the heavenly realm and propelling Sun, Moon and planets in their circular orbits. With Newton space became much simpler: a sheer emptiness as an extended vacuum, no further frills needed.

In the transition from Newton to Maxwell, it seemed necessary to go back to Aristotle in spirit, and posit a new space filling material. Maxwell for convenience used the same Greek term aether. After two thousand years of Aristotle's aether and two centuries of Newton's empty vacuum, a new type of aether was introduced. We will see in the next entry that this new version only held sway for a mere forty years, till Einstein's new views of space and time showed that there was no longer a need for an aether, at least not in three dimensions. With Einstein the fundamental stage had become an altogether different one, a four dimensional spacetime, combining some space characteristics and some time characteristics into a whole new type of manifold.

More hints to come

In our picture book, we have progressed a few thousand years, up to 1865. In our next entry we will start our journey at 1900, and we will see that every 25 years from then on basic physics would go through a new and each time unexpected revolution.

However, we will also see that all that progress in theory building stopped after 1975, at least on the level of experimentally verified theory building. 2000 came and went. And soon 2025 will come, without any sign that it will not come and go as well.

It may be that the main reason is that it has become harder and harder to build ever more powerful particle accelerators. Or perhaps the next level of surprise will be out of reach by so many orders of magnitude in energy that there is no hope to make experimental progress in the foreseeable future.

Or . . . perhaps the artificial split between a science of "objective" matter and "subjective" mind no longer holds when one or both of these are reaching a limit of validity of that artificial split. We simply don't know.

For now, as a next step, let's enter the twentieth century in our next Log entry, and in the process gather a few more hints.

From Maxwell to Einstein

Entry #009
June 03, 2024

The State of Physics in 1865

This entry is a sequel to entry #008, "A Picture Book of Physics Theories." There we followed the history of science starting from its prescientific roots till 1865, when Maxwell published his equations of electromagnetism. This unification of the theories of electricity and magnetism led to an explanation of the nature of light, which in turn enabled wireless communication, from early radio and tv to the daily use of our cell phones.

Our last two diagrams were Fig. 5 and its more compact version, Fig. 6, reproduced here below. As a reminder: AM was superseded by CM as the description of motion in space and time under the influence of UG; after a while extra force fields were measured and described, E and M; and in 1865 Maxwell unified the theories of E amd M into one unified theory of EM. The totality of these theories forms a skeleton summary of the state of the art of Physics in 1865.

```
+====================================================+
|                                                    |
|                  UG_____                           |
|                 /       \                          |
|                /         \                         |
|       AM --> CM           Physics (1865)           |
|                \    E    /                         |
|                 \  / \  /                          |
|                  XF   EM + aether                  |
|                    \ /                             |
|                     M                              |
|                                                    |
+----------------------------------------------------+
|  Fig. 5: The state of physics in 1865 following    |
|  Maxwell's theory of electromagnetism, which       !
|  unified the two new theories of electricity and   |
|  magnetism.  Electromagnetism described light as   |
|  waves in an as yet unknown medium, called aether. |
|                                                    |
|  AM: Aristotelian Mechanics (300 BC)               |
|      Aristotle's view of physics                   |
|  CM: Newton's Classical Mechanics (1687)           |
|  UG: Newton's law of universal gravitation (1687)  |
|  XF: Extra Fields, besides gravity                 |
|  E: Electricity                                    |
|  M: Magnetism                                      |
|  EM: Electromagnetism (1865)                       |
|                                                    |
+====================================================+
```

```
+====================================================+
|                                                    |
|                  UG                                |
|                 /  \                               |
|                /    \                              |
|       AM --> CM      Physics (1865)                |
|                \    /                              |
|                 \  /                               |
|                  EM + aether                       |
|                                                    |
+----------------------------------------------------+
|  Fig. 6: The state of physics in 1865 written in   |
|  a more compact form.  Only one more field was     |
|  now added to the field of gravity, and one more   |
|  medium, the aether, postulated as the carrier for |
|  electromagnetic waves.                            |
|                                                    |
+====================================================+
```

Physics in 1900: the problem of the aether

By the turn of the century, in 1900, that same picture still held, but there was only one problem: efforts to determine the presence of an aether were unsuccessful. Whatever the characteristic of that medium might have been, the changing speed and direction of the motion of the Earth with respect to the aether, at different times of year, should have been measurable. However, increasingly accurate measurements all gave the same null result: no difference was detected.

Maxwell's theory had convincingly explained that light is formed by electromagnetic waves. A decade later Hertz had figured out how to generate and detect radio waves. There was no doubt anymore that the electromagnetic field could exhibit waves, in a real and practical sense. But how could there be waves without there being a medium, a "carrier" to "carry" the waves? At first, this seemed like an annoying blemish question mark, as depicted by the question mark in Fig. 7, which otherwise is identical to Fig. 6, a snapshot taken 35 years earlier.

```
+=====================================================+
|                                                     |
|                   UG                                |
|                  /  \                               |
|                 /    \                              |
|       AM --> CM       Physics (1900)                |
|                 \    /                              |
|                  \  /                               |
|                   EM + aether ?                     |
|                                                     |
+-----------------------------------------------------+
|  Fig. 7: The state of physics in 1900.  The only    |
|  change during the previous 35 years was the        |
|  puzzling absence of any measurable effect of       |
|  the presence of an aether, a harbinger of an       |
|  entirely unanticipated change in the very          |
|  foundations of physics, five years later.          |
|                                                     |
+=====================================================+
```

1905: The aether resolved; now the problem of gravity

Before long, in 1905 Einstein came up with an idea that seemed even more preposterous than waves without something to make waves in. He proposed that space and time itself were not absolute, as Newton had assumed, but relative to the state of motion of individual observers. His theory of relativity changed not only the dynamical play of motion, performed by physical objects on the stage of space and time; it changed the stage itself!

Changes that dramatic had occurred only twice in the last 2200 years: first by Aristotle who described a stage with two layers, the Earthly and the Heavenly realm, below and above the orbit of the Moon; and then by Newton, whose unified synthesis introduced a single unified stage.

The third stage that Einstein introduced was of a completely new type: a 4-dimensional spacetime as a continuum that would allow different 3-dimensional ways of providing space and time axes for cutting up the 4-dimensional cake, different depending on the state of motion for each observer. This is indicated in Fig. 8.

```
+=====================================================+
|                                                     |
|                  UG___                              |
|                 /     \                             |
|                /       ???  (1905)                  |
|       AM --> CM       /                             |
|                \    SR                              |
|                 \  /                                |
|                  EM, no aether !                    |
|                                                     |
+-----------------------------------------------------+
|  Fig. 8: The state of physics in 1905.  Einstein    |
|  showed that Maxwell's electromagnetism implied     |
|  that space and time only had relative meaning,     |
|  in contrast with Newton's classical mechanics.     |
|  His solution, the theory of special relativity,    |
|  SR, replaced classical mechanics, CM, but was      |
|  incompatible with UG, Newton's universal gravity.  |
|                                                     |
|  Meanwhile: the question mark about the nature of   |
|  the aether was replaced by an even more puzzling   |
|  exclamation mark: no 3-dimensional medium is       |
|  compatible with exhibiting electromagnetic waves.  |
|                                                     |
|  SR: Special Relativity                             |
|                                                     |
+=====================================================+
```

However, the "???" mark in Fig. 8 indicates that Fig. 6 no longer holds. Maxwell's beautiful unification of electricity and magnetism into electromagnetism, EM, was no longer compatible with the other long-range field, that of universal gravity, UG, which was based on Newtonian absolute space and time. Even though EM was invented as a theory within classical mechanics, CM, it forced a new theory of space and time, SR, as a new home for EM to live in, superseding CM.

Fig. 9 shows this clash between CM and SR, indicated by the vertically placed question marks in "->?" and "?<-".

```
+====================================================+
|                                                    |
|                  UG_______                         |
|                 /         \                        |
|                /           ???  (1905)             |
|       AM --> CM..->?      /                        |
|                \   ?<-..SR                         |
|                 \__  __/                           |
|                    EM                              |
|                                                    |
+----------------------------------------------------+
|  Fig. 9: Physics in crisis in 1905.  SR was now    |
|  incompatible with classical mechanics, as the     |
|  >? and ?< indicate, and it was also incompatible  |
|  with Newtonian gravity, as the ??? indicate.      |
|                                                    |
|  SR: Special Relativity                            |
|                                                    |
+====================================================+
```

The search for an answer

A few years after discovering what later would be called the theory of *special* relativity, Einstein began to search for a more *general* theory, indicated in Fig. 10 with "??", in order to solve the problem of "???". If only Newtonian gravity could be replaced by a theory of gravity that would be compatible with special relativity in the limit of weak gravitational fields (weak compared to that of black holes, as we would expressed it now), all would be well again.

Fig. 11 shows how such a new theory could be seen as a unification of UG and SR, somewhat similar to the unification of E and M into EM.

```
+=====================================================+
|                                                     |
|                  UG___??                            |
|                 /    /  \                           |
|                /    /    \                          |
|       AM --> CM___SR      ???  (1910)               |
|                     \    /                          |
|                      \  /                           |
|                       EM                            |
|                                                     |
+-----------------------------------------------------+
|  Fig. 10: In 1905 theories of space and time, as    |
|  the background stage for physical processes, had   |
|  evolved from Aristotle to Newton to Einstein, but  |
|  Newtonian gravity was no longer compatible with    |
|  SR (??) -> physics was no longer consistent (???). |
|                                                     |
+=====================================================+
```

```
+=====================================================+
|                                                     |
|                  UG_____??                          |
|                 /      /  \                         |
|                /      /    \                        |
|       AM --> CM_____SR      ???  (1910)             |
|                \      \    /                        |
|                 \  E_  \  /                         |
|                  \/  \__EM                          |
|                   \ _/                              |
|                    M                                |
|                                                     |
+-----------------------------------------------------+
|  Fig. 11: When we add electricity and magnetism     |
|  theories before they were unified into EM, we see  |
|  that CM was compatible with three forces, but SR   |
|  is now only compatible with one force, EM, and no  |
|  longer compatible with the other force, gravity.   |
|                                                     |
+=====================================================+
```

The answer, in the way it leads us back to 1865

In 1915, Einstein found the answer. As I already discussed in entry #007, general relativity added curvature and elasticity to the 4-dimensional fabric of special relativity. Gravity no longer was a force acting between players on an otherwise passive stage. It was the dynamics of the stage that completely explained the effects of the force of gravity, with no need for anything else: gravity without gravity.

General Relativity, GR in Fig. 12, restored physics as a consistent, and seemingly complete, theory for all of the long-range forces across space and time. By replacing "??" by GR, suddenly physics became as complete as it had been in Fig. 5.

```
+=====================================================+
|                                  \ FAMILY PORTRAIT |
|                  UG_____GR        `----------------|
|                 /      /  \                        |
|                /      /    \                       |
|       AM --> CM_____SR      Physics (1915)         |
|                \      \    /                       |
|                 \  E_  \  /                        |
|                  \/  \__EM                         |
|                   \ _/                             |
|                    M                               |
|                                                    |
+-----------------------------------------------------+
|  Fig. 12: The state of physics in 1915: finally,    |
|  half a century after Maxwell, physics was fully    |
|  consistent again, with GR as an extension of SR.   |
|  Here is a portrait of the happy family of forces   |
|  united with their spatiotemporal backgrounds.      |
|                                                     |
|  GR: General Relativity                             |
|                                                     |
+=====================================================+
```

To compare the state of completion of physics in 1865 and 50 years later, in 1915, we can plot the two in compact form in Fig. 13. Both situations looked the same in diagram form. In fact, the success of general relativity shows it was even more complete, since there was no longer the nagging question of what the aether was and how to detect it.

```
+=====================================================+
|                                                     |
|                  UG                                 |
|                 /  \                                |
|                /    \                               |
|        AM --> CM      Physics (1865)                |
|                \    /                               |
|                 \  /                                |
|                  EM + aether                        |
|                                                     |
|                                                     |
|                                                     |
|                  GR                                 |
|                 /  \                                |
|                /    \                               |
|        CM --> SR      Physics (1915)                |
|                \    /                               |
|                 \  /                                |
|                  EM                                 |
|                                                     |
+-----------------------------------------------------+
|  Fig. 13: The state of physics in 1915 compared    |
|  with the one 50 years earlier.                     |
|                                                     |
+=====================================================+
```

<u>The answer, in the way it leads us back to 1700</u>

An alternative way of depicting the revolutionary aspects of GR is given in Fig. 14. So far, the central horizontal lines in our diagrams have depicted the changing role of the stage of space and time. In contrast, the force fields acting across space and time were shown above and below that line, as players on that stage. However, now that GR had become both a new field explaining the *force* of gravity as well as a new and more powerful description of the nature of *spacetime*, we can equally well put GR on the horizontal center line, as an increasingly more accurate way to represent space and time. So let us adapt Fig. 12, to highlight the fundamental spacetime role of GR, to produce Fig. 14 instead.

```
+====================================================+
|                                  \ FAMILY PORTRAIT |
|                  UG___            `----------------|
|                 /     \___                         |
|                /          \                        |
|       AM --> CM_____SR_____GR                      |
|                \      \      \                     |
|                 \  E_  \      Physics (1915)       |
|                  \/  \__EM___/                     |
|                   \ _/                             |
|                    M                               |
|                                                    |
+----------------------------------------------------+
|  Fig. 14: as Fig. 12, but since General Relativity |
|  is a theory of spacetime, superseding that of SR, |
|  it is more appropriate to put it on the same line |
|  with AR, CM, and SR.                              |
|                                                    |
+====================================================+
```

At this point we can go even further back in time, to 1700, the time of Newton. We have seen in entry #008, in Fig. 3, how the state of the art of physics can be summarized with one stage, classical mechanics, and one long-range force, universal gravity. Fig. 3 is reproduced in the top half of Fig. 15, while Fig. 14 is reproduced in compact form in the bottom half of Fig. 15.

```
+=====================================================+
|                                                     |
|                   UG__                              |
|                  /    \                             |
|                 /      Physics (1700)               |
|       AM ---> CM______/                             |
|                                                     |
|                                                     |
|                                                     |
|       AM ---> CM__SR__GR______                      |
|                         \     \                     |
|                          \     Physics (1915)       |
|                           EM__/                     |
|                                                     |
+-----------------------------------------------------+
|  Fig. 15: The states of physics in 1700 and 1915    |
|  showing a great deal of similarity.                |
|  In 1700 we knew of only one spatiotemporal         |
|  background, classical mechanics (CM) and one       |
|  force field, that of universal gravity (UG),       |
|  operating in the background of CM.                 |
|  In 1915 CM was recognized as an approximation      |
|  of special relativity (SR), which in turn was      |
|  recognized as an approximation of general          |
|  relativity (GR), while the only remaining force    |
|  field was that of electromagnetism (EM), since     |
|  gravity was seen as a side effect of GR.           |
|                                                     |
+=====================================================+
```

This single figure shows why and how Einstein was considered the "new Newton" in the nineteen twenties. When his general relativity theory was observationally confirmed through the measurements of the bending of starlight near the sun during an eclipse in 2019, physics regained a state of wholeness and simplicity, both, that had not been seen since Newton.

A glimpse of the future, from 1925 onwards

Alas, this happy state of affairs would only last a mere ten years . . . the only period, so far, that humanity has possessed a single consistent theory of space, time, gravity and electromagnetism. In the next entry, #010, we will see what happened in 1925, when quantum mechanics appeared on the stage. Or, to stay with the previous metaphors, demolished the stage.

<u>From family portraits to genealogy</u>

But before going there, let me add the historical perspective of a genealogy of theories. In Figs. 12 and 14 we saw two family portraits taken in the period 1915 to 1925. They were snapshots. If we want to trace the genealogy of ideas, from Newton to Einstein, we get a different picture, that of Fig. 16. To give GR a balanced place in this figure, starting from CM, I have given GR a place halfway the middle line of space and time and the upper line where gravity would be placed as a force. It really belongs to both.

As for SR, note the difference between its place in Figs. 12 and 14, where it directly follows Newton's GR, at the left, and in Fig. 16, where it is placed as the offspring of EM. Even though SR is more fundamental, in retrospect, than EM, it was EM that historically led to SR.

```
+====================================================+
|                                        \ GENEALOGY |
|              UG____________             `----------|
|              /             \                       |
|            _/               GR  :  Physics (1915)  |
|   AM --> CM_               /                       |
|             \    E      _SR                        |
|              \  / \_  _/                           |
|              XF   _EM                              |
|                 \ /                                |
|                  M                                 |
|                                                    |
+----------------------------------------------------+
|  Fig. 16: The state of physics in 1915, with full  |
|  detail of the discoveries and unifications.       |
|  Note: the order and meaning here is different     |
|  from that in Figs. 12 and 14, where SR -> EM,     |
|  where SR was the condition of possibility for EM. |
|  In contrast, here EM -> SR: the *discovery* of EM |
|  led to the *discovery* of SR, as the necessary    |
|  structure of space and time in order to make EM   |
|  work as it does.                                  |
|                                                    |
+====================================================+
```

And as a farewell to the classical period of physics, from 1687, when Newton's Principia was published, all the way to 1915, let me take stock of the developments during that period in Fig. 17, in the form of boxes superimposed on Fig. 16. Seven discoveries and unifications stand out.

There was Newton's unification of Aristotle's separate laws of motion in heavens and on Earth, in the first box. The second box shows the discovery of theories for gravity, electricity and magnetism. The third box shows three more successful unifications, of electricity and magnetism into electromagnetism, of space and time into spacetime, and of spacetime and gravity into a dynamic form of spacetime.

Note that of the seven highlights, more than half were made by Newton and Einstein, CM & UG and SR & GR, respectively, one by Maxwell, EM, and the remaining two, theories of E and M, electricity and magnetism, as well as aspects of their interactions, were the result of a number of different individuals. Of course, all of the seven milestones could only have been reached by building on the foundations laid by many others, whose contributions were crucial in clearing paths towards new insights.

```
+=====================================================+
|               __     __________         \ GENEALOGY |
|          __  |UG|___|________  |         `----------|
|         |  | /  |   |       \  |                    |
|         |  _/|   \  |        GR| :  Physics (1915)  |
|   AM -->|CM_ |    | |       /  |                    |
|         |  |\|   E| |    _SR   |                    |
|         |__| \  / \_|  _/      |                    |
|              |XF  |_|EM        |                    |
|              |  \ / |__________|                    |
|              |   M|                                 |
|              |____|                                 |
|                                                     |
+-----------------------------------------------------+
|  Fig. 17: as Fig. 16, but highlighting the various  |
|  discoveries and unifications.  3 discoveries of    |
|  theories of forces: UG, E, M.  4 unifications of   |
|  earlier theories: CM, EM, SR, GR.                  |
|                                                     |
+=====================================================+
```

<u>The end of physics, act 1: the world as a mechanism</u>

We have now reached the end of what is called "classical physics", the first Act in the Play of physics as the Science of matter. In the next entry we will move on to physics, act 2, which is "quantum mechanics", an act that started in 1925. Quantum mechanics, QM in our abbreviated diagram notation, is really a misnomer. Yes, what is called quantum mechanics lies at the basis of quantum physics, but in no way does it resemble a mechanism. It was only (Newtonian?)

inertia that kept the term "mechanics" in use, since the quantum world is anything but a mechanism, as we will see.

The first mechanical model appeared with what is called Aristotelian mechanics (AM), around 300 BC, prescientific in being partly untestable speculation. Science as we know it, using working hypotheses, got started in the 17th century with Newton's classical mechanics (CM). Maxwell's electromagnetism (EM) was a further extension, still structured as a mechanism, but based on an almost immaterial medium, called the aether, an idea that was dropped when no longer needed in Einstein's special relativity (SR) theory. It was only with Einstein's general relativity (GR) theory that a new fully consistent picture of the physical world had been developed.

General relativity could still be viewed as a kind of mechanical theory, but mechanical in a very different way that the term had been used so far. The reference "mechanical" did not point to the way or working of three-dimensional machines, existing in space and doing their work in time. Rather, the term "mechanics" applied to fully four-dimensional entities, existing in spacetime. However, the theory remained deterministic and in that sense it was still "mechanical".

Beyond mechanistic foundations of physics

The succession of updated physics theories of the physical world, illustrated by the four arrows in the sequence "AM -> CM -> EM -> GR -> QM", consisted of changes happening after ever shorter intervals in time of {2000, 200, 50, 10} years, respectively. The last number indicates the decade from the introduction of general relativity in 1915 to the first formulation of quantum mechanics in 1925.

No, the next shocking new discovery did not take place 2 or 3 years after 1925, as the above series might have suggested. It still has not taken place, 100 years later. And what is more, unlike was the case after earlier shocks, how to interpret quantum physics is still an open debate. It remains a question about which hundreds of books have been written, and several conferences and workshops are organized each year. That hasn't happened with any of the previous updates in a scientific theory of the physical world.

The main disagreement centers around the role of the observer in any experiment involving quantum physics. The end of mechanistic thinking was also the end of the unquestioned acceptance of an objective reality. Seen in that way, the need for a science of mind is a logical outcome of progress in physics, made by physicists and made by their own lights. We will now look at the state of physics in 1925, in our next entry.

The State of Physics in 1925

Entry #010
June 13, 2024

The opening of physics, act 2: a quantum world

At the end of the previous entry, #009, I described how the curtain dropped on physics, act 1: a classical world. The second act of physics started in 1925 with the discovery of "quantum mechanics", a radical break from "classical mechanics", which was the name of the game of physics from Newton, via Maxwell, and through Einstein's special relativity and general relativity.

Of course, physicists before 1925 didn't know they were doing research in classical physics, just as ancient Greek and Roman writers didn't know at the time that they were writing "classic" literature. Nor did Thomas Aquinas know that he was a "Medieval" writer.

Here the analogy breaks down, though. From the beginning of the era of quantum mechanics, it was clear that there were serious problems, which seemed to point to solutions that had to be more radical, whatever their nature was going to be. In that sense, physicists knew that they had entered a kind of "Middle Ages" which were likely to end, sooner or later, when deeper insight would be obtained.

In this and the next two entries I will sketch the state of the art of fundamental physics in 1925, 1950 and 1975, respectively. At each of those last two moments in time a major breakthrough was made in clearing up some of the fog that had descended in 1925. But, with a spoiler alert: no comparable breakthrough has happened in 2000, nor is it obvious that it may happen in 2025 or anytime soon thereafter.

So it seems that we'll remain in the "Middle Ages" more than a century after the end of the "Classical Period". Even so, there are plenty of hopeful signs that fundamentally new insights will be reached, either through theoretical or experimental breakthroughs, or even better, through both.

A happy family and an unexpected new arrival

To prepare the stage for the events that shook physics in 1925, I am presenting here again Fig. 12 from entry #009, the "family portrait" of all the interlocking parts of the four-dimensional machinery of physics in 1915.

```
+====================================================+
|                                  \ FAMILY PORTRAIT |
|                  UG_____GR        `----------------|
|                 /      /  \                        |
|                /      /    \                       |
|       AM --> CM_____SR      Physics (1915)         |
|                \      \    /                       |
|                 \  E_  \  /                        |
|                  \/  \__EM                         |
|                   \ _/                             |
|                    M                               |
|                                                    |
+----------------------------------------------------+
|  Fig. 12: The state of physics in 1915: finally,   |
|  half a century after Maxwell, physics was fully   |
|  consistent again, with GR as an extension of SR.  |
|  A happy family portrait.                          |
|                                                    |
|  AM: Aristotelian Mechanics (300 BC)               |
|      Aristotle's view of physics                   |
|  CM: Newton's Classical Mechanics (1687)           |
|  UG: Newton's law of universal gravitation (1687)  |
|  E: Electricity                                    |
|  M: Magnetism                                      |
|  EM: Electromagnetism (1865)                       |
|  SR: Special Relativity                            |
|  GR: General Relativity                            |
|                                                    |
+====================================================+
```

In this figure, you can see that Maxwell's theory of electromagnetism (EM) was not only a unification of the various effects already known for the interplay between electricity (E) and magnetism (M). Unbeknownst to Maxwell, Newtonian classical mechanics (CM) was not able to explain the observations of waves in the electromagnetic field until CM was replaced by the theory of special relativity (SR). Without the combined help of SR and EM, there would have been no way to unify the theories of E and M, as depicted in Fig. 18.

```
+====================================================+
|                                                    |
|                UG______GR___                       |
|               /       /     \                      |
|              /       /       Physics (1915)        |
|             /       SR__EM__/                      |
|            /       /                               |
|   AM --> CM_______/                                |
|            \                                       |
|             \  E                                   |
|              \/                                    |
|               \                                    |
|                M                                   |
|                                                    |
+----------------------------------------------------+
|  Fig. 18: as Fig. 12, leaving out the unification  |
|  process leading to EM.                            |
|                                                    |
+====================================================+
```

I have presented Fig. 18 here as a first step toward introducing the new arrival "out of nowhere" who joined the happy family of Fig. 12. In Fig. 19 we fast forward to 1925, where quantum mechanics (QM) is introduced.

```
+====================================================+
|                                                    |
|                UG______GR___                       |
|               /       /     \                      |
|              /       /       Physics (1915)        |
|             /       SR__EM__/                      |
|            /       /                               |
|   AM --> CM_______/            ??? (1925)          |
|            \      \                                |
|             \  E   \     E                         |
|              \/     QM__/                          |
|               \         \                          |
|                M         M                         |
|                                                    |
+----------------------------------------------------+
|  Fig. 19: The appearance of a second type of       |
|  generalization of Newton's classical mechanics,   |
|  in addition to special relativity, namely         |
|  nonrelativistic quantum mechanics, with no clear  |
|  connection with relativistic electromagnetism.    |
|  For low velocities & small distances, QM -> CM.   |
|  For high velocities & large distances, SR -> CM.  |
|  No unified theory known yet for QM and SR.        |
|                                                    |
|  QM: Quantum Mechanics                             |
|                                                    |
+====================================================+
```

Quantum mechanics . . .

Where Newton had built a firm stage made of absolute space and time to let objects dance on, under the influence of gravity, Einstein had created a flexible stage. It was a stage that itself partook in the dance, more like a kind of trampoline, made of a dynamic spacetime, that could stretch and twist and turn. But a decade later, an even much more revolutionary theory was put forward. Quantum mechanics corresponded to a move to an altogether different theory -- through the looking glass into a world more like that of a fairy tale.

From a dance on a fixed stage with fixed rules, to a stage that was dancing with its players, but still with fixed rules, to a dreamlike world in which everything is possible -- but with fixed rules for the probability of anything to happen. The mathematical background spaces for quantum mechanics are altogether different from anything classical. The spaces used to calculate probabilities for any type of outcome are no longer given in terms of space and time, but rather in terms of abstract complex high-dimensional Hilbert spaces.

Instead of moving to a different stage, as physics had done twice, in 1905 and 1915, in 1925 physics moved into an altogether different theater building, if not into an altogether different world. This is not the place to present an introduction to quantum mechanics, but there are plenty of introductions available on the internet and in book form, on many different levels.

The bottom line is that from 1925 onwards, physical reality on its most fundamental level had no longer any clear meaning. Sure, twenty years earlier, already with the disappearance of an aether, there was no clear picture of how there could be waves in a field without there being a medium -- electromagnetic waves just seemed to be "waving" in a total vacuum. But at least there was a comfortably objective picture to describe those waves, one that everybody could agree on.

```
+====================================================+
|                                                    |
|                UG_______GR___                      |
|               /        /    /                      |
|              /        /    /                       |
|             /       SR__EM                         |
|            /       /                               |
|   AM --> CM_______/           ??? (1925)           |
|            \      \                                |
|             \  E   \     E                         |
|              \/     QM__/   ¿¿interpretation??     |
|               \         \                          |
|                M         M                         |
|                                                    |
+----------------------------------------------------+
|  Fig. 20: The interpretation of quantum mechanics  |
|  was, and still is, an open question.  Not only    |
|  was there no unification in sight in terms of     |
|  mathematical equations, between QM and the rest   |
|  of physics, indicated by "???" above, the lack of |
|  interpretation of what the equations *meant* was  |
|  in some ways even more of a problem.              |
|                                                    |
+====================================================+
```

The momentous difference between classical and quantum physics is that it is no longer obvious whether there even is an objective world out there. More precisely, of whether an objective description of the world is something that is not observer dependent. Currently there are numerous different interpretations of quantum mechanics, some of them based on intersubjective agreements of measurements, without requiring, or even allowing, an objective background world.

I am hesitant to even begin selecting some pointers to the literature, among the hundreds of books that have been written on this topic. Fortunately, for the purpose of my narrative in this and the next two entries, I can strongly recommend the book "Waves in an impossible sea" by Matt Strassler which came out just one week after I started this Log. It gives the clearest description I have seen of the roles of fields and waves and many of the seeming paradoxes of quantum field theory (the topic of entry #012), on a surprisingly clear non-technical level.

An unhappy family

In entry #009, Figs. 13 and 15, I presented a comparison between three happy families: the Newtonian classical mechanics view of physics around 1700, the Maxwellian picture, still the best one around in 1900, and the Einsteinian picture arrived at in 1915. They all looked alike.

Following Tolstoy's observations at the start of his novel Anna Karenina, “All happy families are alike; each unhappy family is unhappy in its own way”, the unhappy family, shown in Fig. 21, definitely looks very different from anything seen before.

```
+=====================================================+
|                                   \  BROKEN FAMILY |
|                UG______GR___       \    PORTRAIT   |
|               /       /    /?       `--------------|
|              /       /    /  ?                     |
|             /       SR__EM____?                    |
|            /       /           ?                   |
|   AM --> CM_______/             ??? (1925)         |
|            \      \            ?                   |
|             \  E   \     E ?  ?   ¿¿inter-         |
|              \/     QM__/   ??      pre-           |
|               \         \   ?       ta-            |
|                M         M ?        tion??         |
|                                                    |
+-----------------------------------------------------+
|  Fig. 21: as Fig. 20, but highlighting the lack    |
|  of clarity between the two different worlds, the  |
|  world of very large velocities, in need of the    |
|  theory of special relativity, and the world of    |
|  the quantum, at very small distances, in need of  |
|  the theory of quantum mechanics.                  |
|  A broken family portrait.                         |
|                                                    |
|  Note the three Es and three Ms in the figure, for |
|  the CM, SR and QM realms at left-bottom, mid-top, |
|  and bottom top, respectively.  While the bottom   |
|  E and M signify the classical limit, the other    |
|  two are incompatible with each other, even though |
|  both reduce to the bottom left one under close to |
|  classical conditions.                             |
|                                                    |
+=====================================================+
```

To make another comparison with entry #009, the genealogy figures, Figs. 16 and 17, now get enriched with quantum mechanics, to produce Figs. 22 and 23.

```
+====================================================+
|                                        \ GENEALOGY |
|              UG___________              `----------|
|             /             \                        |
|            /               GR                      |
|   AM --> CM               /  \                     |
|            \    E      _SR_   ???  (1925)          |
|             \  / \_  _/    \ /                     |
|              XF   _EM_      ???                    |
|                \ /    \_  _/                       |
|                 M       QM  (1925)  ¿¿reality??    |
|                                                    |
+----------------------------------------------------+
|  Fig. 22: The state of physics in 1925, with full  |
|  detail of the discoveries and unifications.       |
|  This figure is similar to Fig. 16, but with QM    |
|  now added, together with the various question     |
|  marks QM produced                                 |
|                                                    |
+====================================================+
```

```
+====================================================+
|               __     ____________      \ GENEALOGY |
|          __  |UG|___|__________  |      `----------|
|         |  | /  |   |         \  |                 |
|         |  _/|   \  |         _GR|_                |
|   AM -->|CM_ |    | |       _/   | \               |
|         |  |\|   E| |    _SR_    |  ???            |
|         |__| \  / \_|  _/    \__ | /               |
|              |XF  |_|EM_        ???   (1925)       |
|              |  \ / |___\______/_|                 |
|              |   M|     ???___/____________        |
|              |____|    |  \  /             |       |
|                        |   QM  ¿¿reality?? |       |
|                        |___________________|       |
|                                                    |
+----------------------------------------------------+
|  Fig. 23: The state of physics in 1925, with full  |
|  detail of the discoveries and unifications.       |
|  This figure is similar to Fig. 17, but with one   |
|  extra box around the discovery of QM, with no     |
|  connection to any of the other boxes.             |
|  To make a tally, we see the same 4 unifications   |
|  as in Fig. 17: CM, EM, SR, GR, and the same 3     |
|  discoveries of theories of forces: UG, E, M.      |
|                                                    |
|  The new kid of the block is the first discovery   |
|  of an important new element that is *not* a new   |
|  force *and* not a unification of *anything*       |
|  previously seen or suspected, but rather an       |
|  altogether unexpected interloper.  Yet QM gives   |
|  a more accurate description of reality than any   |
|  earlier classical theory did.  But what kind of   |
|  reality??                                         |
|                                                    |
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```

Early warning signals

The way I presented my very short summary of the advent of quantum mechanics has left out many important details. Yes, the full paradoxical nature of quantum mechanics was totally unexpected. Even so, during the 25 years running up to 1925 it already became increasingly clear that *something* was going on that was likely to shake the foundations of physics.

It started in 1900, when Max Planck coined the word "quantum". He did so to give a name to an observation that he had made. He noticed that the behavior of some forms of radiation could be explained by an ad hoc postulate that this radiation could only be emitted in the form of discrete energy packages, which he called quanta. He realized that, using this strange and unnatural postulate, things fell into place that otherwise didn't make any sense. But at first he had no idea how revolutionary the consequences of that first step would become.

Before 1925 at least a dozen scientists made significant contributions to the framework of what would become full fledged quantum mechanics in 1925, including Einstein, Bohr and de Broglie. And when finally quantum mechanics got off the ground, there were another dozen scientists who made significant contributions, right in the first two or three years. Most prominent were Heisenberg and Schrödinger, each of which found a rather different approach to what would turn out to be the same underlying theory. But many others, like Born, Dirac and Pauli, made essential contributions as well.

A shift towards collaborative efforts

In that sense, the discovery of quantum mechanics as a theory was rather unlike the discoveries by Newton, Maxwell and Einstein. In each of those three cases, too, several other physicists had made very important breakthroughs that provided essential building blocks for the final discoveries. But still, there was this magical moment when one person managed to put everything together, showing that everything "clicked", as in finding the places for the last pieces of a puzzle.

Quantum mechanics was different, and indeed during the next hundred years after the discovery of quantum mechanics, there never was a particular insight of a single person that started a whole new approach to theory building in fundamental physics.

Finally one more aspect that I have left out: I have not mentioned in my history of physics the very important role of thermodynamics and statistical mechanics, developed in the nineteenth century, which gave physicists experience in working with calculations involving probabilities. Such a discussion would deserve at least one more entry in this log.

What we have seen so far

Looking back to the beginning of this FEST Log, three months ago, the first five entries, #001 through #005, have centered on a very brief initial exploration of the nature of experience. Since the FEST program aims at establishing a science of mind, experience is an obvious place to start. I suggested some possible directions for setting up an initial and very simple theory of experience. In addition, I also provided some sketches for experimentation.

My aim was to show early on how to get the "ratchet of science" started: developing new experiments to test the latest theory, followed by developing new theories more in line with the results from the latest experiments, and so on. I described the "ratchet" in entries #001, #003, and #006. And in order to make initial contact with recent literature, I found it helpful to mention two philosophers, Husserl in entry #004, and Nishida in entry #005, both of whom did their work in the early twentieth century.

However, already in entry #002, I argued that it makes sense to turn to the treasure troves of prescientific studies of the mind, that have been preserved in oral and written form, in various contemplative traditions in many cultures. Following the example of astronomy, the foundations of which were laid by a millennium of Babylonian observations, I named a number of still living traditions that might give us inspiration as well as specific sets of observations.

The biggest problem in receiving inspiration for setting up theories and interpreting observations from ancient traditions is sectarianism. Imagine that scientists in different fields of physics would not talk to each other, and only or mostly discuss their specific field among themselves. That would be a similar situation as what prescientific engineers were limited to, keeping their knowledge within their own circles.

What we might learn from physics for a science of mind

Following our short initial exploration of the nature of experience, from entry #006 onward we started to analyze the structure of theories of physics, in order to have at least one example of an evolving set of theories, all empirically based. Hopefully, this can give us some inspiration for setting up a tentative theory structure, based on observations gleaned from contemplative traditions.

To make this a bit more formal, starting with entry #008, I introduced a new working hypothesis:

WH 3: the shifts in perspectives between viewing objects as matter, experience, or appearance, might have analogies in the shifts of perspectives between subsequent theories in physics.

One reason I think this might work to some extent, is that all contemplative traditions I am familiar with have a nested set of instructions for view and practice, from simple and practical for lay persons, to more and more refined forms within monasteries or other communities focused entirely or mostly on contemplation. If we translate view into theory, and practice into experiment and observation, the parallels with physics, as we have seen in our set of diagrams so far, is striking.

In order to go to the Moon, classical mechanics is good enough. But in order to find our way in a city, when we use GPS, we are using software that is based on general relativity, since the accuracy required goes well beyond that of Newton's theory of universal gravity. To study the outlines of a living cell, and the ways cells are packed together, again classical mechanics can do a good job. But to model the details of small-scale processes within cells, sooner or later we have to take quantum mechanics into account. In fact, all of chemistry is based on quantum mechanics on the atomic level.

The similarity of nested structures of theories in physics and in contemplation, which became more and more clear to me, was my main motivation for delving into the nested structure of theories of physics, as they evolved over time. Before long we will start making specific comparisons between some contemplative traditions and their nested views and the structure of their physics counterparts. Let us see how far we can get, in making at least some initial progress in setting up a candidate for a foundation of theory building for a science of mind.

With that goal, we will visit the history of physics of the last century, from 1925 till now, in the next two entries. Following that, we will take a break and sum up what we have learned, thereby concluding Part 1 of this FEST log. My aim is to bundle together a dozen or so entries in each Part, together with a postscript summarizing the structure and contents of that particular Part.

Quantum Field Theory

Entry #011
July 02, 2024

From properties to observables

In our previous entry, we have seen how in 1925 the worldview incorporated in physics was forever altered. Gone were any remaining notions of the world as a kind of mechanism, largely independent of human beings trying to make sense of it. Instead of determinism, probability appeared at the core of the new formalism of quantum mechanics.

In classical mechanics, before 1925, physics dealt with objects that had observable properties that could be measured, through observations with various kinds of apparatus. Once observed, if carefully done, those properties would no longer change. Whatever was observable, once observed, was known. At least, that was the understanding, but that turned out to be wrong, when investigated carefully, at atomic and subatomic scales.

Afterwards, in quantum mechanics, the understanding changed completely. Objects still had characteristics, but they were no longer called properties. Rather, they were given a new name, "observables", something that could be found as an outcome for any act of observation, but most of those outcomes would not be reproducible. There was nothing fixed beforehand that could be observed in its totality. Rather, there was a potential for making observations with different outcomes, each of which were in principle "observable". The only thing left that could be certain were the probabilities for certain outcomes to take place.

Quick unification of matrix mechanics and wave mechanics

The mathematical equations for determining the probabilities were discovered soon after 1925, but the interpretation of what was going on during a measurement, if anything, was completely unclear, as indicated in Fig. 20, reproduced here from entry #010, below.

```
+=====================================================+
|                                                     |
|                UG______GR___                        |
|               /       /    /                        |
|              /       /    /                         |
|             /       SR__EM                          |
|            /       /                                |
|   AM --> CM_______/            ??? (1925)           |
|            \      \                                 |
|             \  E   \     E                          |
|              \/     QM__/   ¿¿interpretation??      |
|               \         \                           |
|                M         M                          |
|                                                     |
+-----------------------------------------------------+
|  Fig. 20: The interpretation of quantum mechanics   |
|  was, and still is, an open question.  Not only     |
|  was there no unification in sight in terms of      |
|  mathematical equations, between QM and the rest    |
|  of physics, indicated by  "???" above, the lack    |
|  interpretation of what the equations *meant* was   |
|  in some ways even more of a problem.               |
|                                                     |
|  AM: Aristotelian Mechanics (300 BC)                |
|  CM: Newton's Classical Mechanics (1687)            |
|  UG: Newton's law of universal gravitation (1687)   |
|  E: Electricity                                     |
|  M: Magnetism                                       |
|  EM: Electromagnetism (1865)                        |
|  SR: Special Relativity (1905)                      |
|  GR: General Relativity (1915)                      |
|  QM: Quantum Mechanics (1925)                       |
|                                                     |
+=====================================================+
```

At first, the only successful equations describing quantum mechanical effects were of two types, Heisenberg's discovery of what would soon be called matrix mechanics, and Schrödinger's wave equation. Soon those were shown to be compatible, as two different ways of viewing the same thing. However, both were developed as variations of classical mechanics, and as such were incompatible with special relativity, let alone with general relativity.

This is the beauty of physics: when two rather different approaches appear to lead to the same new results, physicists discard both of the two "normal" ways to deal with rivalry. They refuse to fight it out, to see which one is "really true". They also refuse to fall back on any type of friendly "compromise": you do your thing, I do mine. Rather they fight together, struggling to see *how come* that two seemingly very different approaches can lead to the same result.

Interestingly, this practical approach is similar to that used by computer scientists when they debug a computer program -- but with a minus sign. A nagging bug, no matter how small or infrequent, can be a golden opportunity to learn something new about the structure of the program. And a nagging correspondence similarly is a golden opportunity to learn something new.

Slow unification of quantum mechanics and special relativity

In fig. 20, the "???"indicate an incompatibility gap, separating special relativity, SR, and electromagnetism, EM, in the upper half and the non-relativistic treatments of electricity, E, and magnetism, M, in the lower half. Initially there was rapid progress toward unification across that gap. It would take only three years until at least a partial solution would be found, by Dirac, in 1928. He was able to write an equation describing a relativistic generalization of Schrödinger's wave equation. The result was the configuration shown in Fig. 24.

```
+=====================================================+
|                                                     |
|                  UG______GR___                      |
|                 /       /    /                      |
|                /       /    /                       |
|               /       SR__EM                        |
|              /       /      \                       |
|       AM --> CM_______/      _\__QFT (1928)         |
|              \       \     _/                       |
|               \  E    \  _/                         |
|                \/      QM                           |
|                 \                                   |
|                  M                                  |
|                                                     |
+-----------------------------------------------------+
|  Fig. 24: Dirac's initial form of unification of    |
|  quantum mechanics and electromagnetism, in the     |
|  form of a quantum field theory (QFT).              |
|                                                     |
+=====================================================+
```

Dirac's equations formed the first example of what is called a Quantum Field Theory, QFT, the name used for theories that unify quantum mechanics, QM, with the relativistic electromagnetic field, which is at the core of electromagnetism, EM. While various predictions were confirmed by experiment, there were still some serious questions about the validity of the mathematical structure of Dirac's equations, and that of subsequent versions of quantum field theories, as indicated in Fig. 25. It would take until 1950 to resolve these difficulties. Only then was a real unification of quantum mechanics and electromagnetism achieved, under the name of QED, quantum electrodynamics.

```
+====================================================+
|                                                    |
|              UG______GR______________              |
|             /       /    /           \             |
|            /       SR__EM             ??? (1928)   |
|   AM --> CM_______/      \__QFT??____/             |
|            \      \     _/                         |
|             \  E   QM__/                           |
|              \/                                    |
|               \                                    |
|                M                                   |
|                                                    |
+----------------------------------------------------+
|  Fig. 25: The state of physics in 1928.  Apart     |
|  from the lingering problems concerning the        |
|  interpretation of quantum mechanics, there was    |
|  a significant question as to the validity of the  |
|  mathematical structure of QFTs, indicated by the  |
|  double question marks.  Even more problematic was |
|  the complete lack of agreement as to how to even  |
|  begin unifying QFT and GT, general relativity,    |
|  a problem that is still with us today.  This is   |
|  indicated by the triple question marks.           |
|                                                    |
|  QFT: Quantum Field Theory                         |
|                                                    |
+====================================================+
```

<u>New kids of the block: weak and strong interactions</u>

The existence of gravity, by whatever name, has been obvious from time immemorial. Things fall down and don't flow up, unless emerged in some buoyant medium. In entry #008 we saw a brief history of how electricity and magnetism entered the mainstream of physics around 1800, as two additional forces acting at a distance, beyond the force of gravity, depicted in Fig. 4. The forces were seen to be carried by fields, and the electric and magnetic fields were unified into a single electromagnetic field by Maxell in 1865.

For quite a while that seemed to be it. In 1915 Einstein's theory of general relativity and Maxwell's theory of electromagnetism were completely compatible, and in that sense were unified in the classical sense. Even the shocking advent of quantum mechanics ten years later did not change the inventory of force fields.

However, in 1933 a completely unexpected new "interaction" was discovered. Not sure about its character, as a force or a field or something else, and because it seemed intrinsically quite weak, it was called the "weak interaction", WI, as shown in Fig. 26.

```
+=====================================================+
|                                                     |
|              UG_______GR______________              |
|             /        /    /           \             |
|            /       SR__EM              ???          |
|   AM --> CM_______/      \__QFT??____/              |
|                   \      _/     \                   |
|                    QM__/        XI: WI (1933) ??    |
|                                                     |
+-----------------------------------------------------+
|  Fig. 26: For well over a century gravity,          |
|  electricity and magnetism were known as the only   |
|  fundamental forces.  Maxwell and Einstein had      |
|  unified and improved their descriptions, which     |
|  had produced important side effects, such as a     |
|  much deeper understanding of the nature of space   |
|  and time.  Quantum mechanics had appeared "out     |
|  of nowhere", yet the list of basic interactions    |
|  remained the same: gravity and electromagnetism    |
|  -- until 1933, when the "weak interaction" was     |
|  discovered.                                        |
|                                                     |
|  XI: Extra Interactions, besides gravity and        |
|      electromagnetism                               |
|  WI: Weak Interaction                               |
|                                                     |
+=====================================================+
```

In addition, only two years later, yet another one was discovered, stronger than the weak interaction, and dubbed "the strong nuclear interaction", or "strong interaction" for short, SI, as shown in Fig. 27.

```
+====================================================+
|                                                    |
|              UG______GR______________              |
|             /       /    /            \            |
|            /       SR__EM              ???         |
|   AM --> CM_______/      \__QFT??____/             |
|                   \      _/     \    _             |
|                    QM__/         \  / WI (1933) ?? |
|                                   XI               |
|                                     \_SI (1935) ?? |
|                                                    |
+----------------------------------------------------+
|  Fig. 27: Almost at the same time the number of    |
|  known fundamental interactions doubled, from two  |
|  to four, with the discovery of the weak and the   |
|  strong interactions.                              |
|                                                    |
|  SI: Strong Interaction                            |
|                                                    |
+====================================================+
```

Unlike gravity and electromagnetism, the weak and the strong interactions have an extremely short range. They play important roles at a distance comparable to the size of a proton or neutron, but beyond that they drop off exponentially in strength as a function of distance. In comparison, electromagnetism and gravity both drop off as the inverse square of the distance. As a result, we can draw sparks from the hairs of a cat and we can play with magnets, but we need rather advanced specialized equipment to detect and study effects of the weak and strong interactions.

It would take forty years before the nature of the weak and the strong interactions was understood on a fundamental level. Rather than following the twists and turns of various theories and speculations, we will come back to these interactions in our next entry, #012.

QED: the first successful renormalization of a QFT

The next major milestone, after the formulation of the first theories of quantum mechanics in 1925, was the renormalization of at least one quantum field theory, QFT. The bottom line of what is called "renormalization" is the invention of mathematical techniques to avoid spurious singularities, or infinities, that prevent us from making specific predictions from the first generation of quantum field theories. Physicists had extracted some results from QFTs, starting with Dirac's equations in 1928, but until 1950 these attempts had been rather haphazard and not systematic in any way.

Things changed within a short period of a few years, centered on 1950. Quantum electrodynamics, QED for short, was established as the unification of quantum mechanics, special relativity and electromagnetism, into one consistent quantum field theory. Until then, it had not been clear to what degree QFT could give reliable predictions for the outcome of experiments. Soon, however, calculations in QED became some of the most accurate ones in all of physics. Currently, experiments and calculations agree to an accuracy of one in one hundred million.

As was the case for the discovery of quantum mechanics around 1925, where there were several main players involved, the situation was no different around 1950. The most flamboyant and original of them was Richard Feynman, one of the three who shared the Nobel Prize for the discovery of QED, while a fourth physicist, Freeman Dyson, was the one who showed how the theories of the other three could be translated into each other. Feynman gave a wonderful series of lectures on QED for a popular audience, 35 years later, which were published as "QED: The Strange Theory of Light and Matter."

```
+====================================================+
|                                                    |
|              UG___GR_____________                  |
|             /    /    /          \                 |
|            /    SR__EM            ??? (1950)       |
|   AM --> CM____/      \     QED__/                 |
|                \       \   /                       |
|                 QM______QFT                        |
|                            \    _                  |
|                             \  / WI ??             |
|                              XI                    |
|                                \_SI ??             |
|                                                    |
+----------------------------------------------------+
|  Fig. 28: Around 1950, as a result of the effort   |
|  of various physicists, QED was established as the |
|  first successful quantum field theory that could  |
|  avoid the mathematical singularities that plagued |
|  earlier versions of quantum field theories.       |
|                                                    |
|  QED: Quantum Electrodynamics                      |
|                                                    |
+====================================================+
```

Another look at history: the genealogy of QED

In the two previous entries, #009 and #010, I have sketched a pictorial genealogy of general relativity and of quantum mechanics, in Figs. 16 and 17, and in Figs. 22 and 23, respectively. In both entries I showed in each picture the historical order of the discoveries leading to further discoveries, when reading from left to right. The equivalent genealogical diagram is given below in Fig. 29. As before, special relativity, SR, here *follows* electromagnetism, EM, in historical order, even though we now consider EM a relativistic theory *based* on SR, according to Fig. 28.

```
+====================================================+
|                                        \ GENEALOGY |
|              UG___________              `----------|
|             /             \                        |
|            /               GR_________             |
|   AM --> CM               /           ???          |
|            \    E      _SR   ___QED__/   (1950)    |
|             \  / \_  _/   \ /                      |
|              XF   _EM_    QFT   _                  |
|                \ /    \_  / \  / WI ??             |
|                 M       QM   XI                    |
|                                \_SI ??             |
|                                                    |
+----------------------------------------------------+
|  Fig. 29: The genealogy of QED, the theory of      |
|  quantum electrodynamics, as the next step after   |
|  the genealogy of QM, quantum mechanics, depicted  |
|  in Figs. 22 and 23 in the previous entry.         |
|                                                    |
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A quick preview of the next quarter century

In the first quarter century of quantum mechanics, it only took three years till the first quantum field theory, QFT, was introduced by Dirac. But from then on progress slowed down, and it would take more than two decades until QED, quantum electrodynamics, would become the first reliable QFT.

In our next entry, covering the second quarter since the discovery of quantum mechanics, we will see that the reverse would happen. For the first twenty years there was no real prospect that either the weak or the strong force could possibly be modeled as a QFT. It seemed that QED might turn out to be the only lucky exception where QFTs might be of use in physics. The rest was shrouded in mystery.

But then, in only a few years, from 1971 to 1975, just about everything fell into place, as we will see in the next log entry, our fifth and final entry of our picture book of progress in physics series.

<u>A comparison of natural science and contemplation</u>

We have seen in entry #002 how science of matter could take off relatively quickly during the 17th century, given the presence of millennia of previous written knowledge that provided foundations for further progress. In our attempt to start a science of mind, the natural thing to do would be to similarly use written knowledge, ideally with commentaries from individuals who are part of still living traditions based on that knowledge. The combination of both could then provide educated guesses for potentially useful working hypotheses -- stepping stones toward a scientific investigation of the human mind, using our mind as a laboratory, as we discussed in entry #004.

The big stumbling block in this rather obvious approach is that contemplative traditions with a written history do not resemble each other very much, at least at first sight. There are monotheistic contemplative traditions such as Judaism, Christianity and Islam, between which comparisons are relatively easier, given that they share the same roots. But comparing any of them with Daoism, say, will be a far greater challenge.

We saw at the beginning of this entry how matrix mechanics and wave mechanics seemed utterly different and incompatible at first. But within a year they were seen not only to be compatible, but physicists had already started to develop a kind of dictionary to translate between those two theories. And using that approach, they could show explicitly that the results for actual experiments, where applicable, were the same.

It is my hope and expectation that similar developments will appear in a science of mind, once a community with a critical mass has grown around the idea of applying the scientific method to the area traditionally known as contemplation, as I have started to outline in a few preliminary contours in entry #003. We will pick up that thread again in far more detail in Part 2 of our series of log entries, to begin with in entry #014. But for now, we can already point to an important hint that the first half century of quantum mechanics may offer us.

<u>Another hint for a science of mind</u>

At the start of our picture book of physics theories, in entry #008, I listed a number of hints toward the end that might become handy later on in our search for a science of mind. The main hint that we can glean from the current entry is that theories do not have to be internally consistent, let alone logically complete. As long as a new theory gives more accurate results than the previous best theory, by hook or by crook, the new theory is given pride of place. In that sense science is fully pragmatic and sometimes surprisingly opportunistic.

To wit: Dirac's theory was hailed as a breakthrough, because in some areas of application it was clearly successful, even though it failed in others. Two decades later QED was a major breakthrough because its predictions were far more accurate than any other theory in the first quarter century of quantum mechanics. Even so, it was still glaringly clear that at some higher energies its validity would break down. In short, in science you can't argue with success in applications, no matter how elegant or attractive less successful theories may seem to be.

Perhaps the main inspiration of all this for a science of mind is that very different views, the equivalent of different theories in physics, may not be as incompatible as they may look at first sight. For contemplative traditions, the ultimate validity in terms of experiential depth of insight for a practitioner may not have an obvious relationship to the outer forms of the belief systems, used to introduce the practice.

The Standard Model of Particle Physics

Entry #012
July 10, 2024

Physics, act 3: material reality as quantum fields

Toward the end of entry #009, I introduced 1925 as the year that ended "classical physics", act 1 in the play of physics as the science of matter. That act started with the publication of Newton's Principia in 1687. During the subsequent 238 years, the accepted scientific worldview was that the material cosmos could be viewed as a mechanism. Not only that; any future state of the cosmos could in principle be derived from knowledge of the current state.

The opening of act 2 took place in 1925 with the discovery of quantum mechanics, which triggered a worldview in which matter did not behave at all like clockwork type deterministic mechanics. Instead, on atomic and subatomic scales, the best description was that matter and energy consisted of discrete packages, quanta, which were neither actual nor potential in terms of their properties, but some mysterious mix of both.

It is hard to overstate the shock that physicists experienced in 1925, when they were forced to accept the fact that their best model of material reality was now based on a kind of probabilistic mix of "real" and "possible" in ways not foreseen by anybody. I mentioned in entry #010 that physicists knew, already in 1925, that they had entered a whole new area. What is more, it was an intermediate period, a kind of "Middle Ages" of an unusual type, where the people living in that period had already realized that it was a "middle" age.

I consider 1975 as marking the opening of yet another act of physics. Whereas the opening of act 2 ushered in a new period of bewilderment, 1975 marked the start of a much happier period. The enormous relief that came at the opening of act 3 stemmed from the fact that at last a new form of unification was possible: that of the standard model of particle physics. Almost overnight, a way was found to describe material reality as based on a set of related quantum fields, to be discussed below.

To put this in context, we can add a prescientific act 0, which opened with Aristotle's mechanics around 300 BC, an act that would last 2,000 years. It featured a split unification, one half of which described temporal motion in the Earthly realm, the other half eternal motion in the Heavens above the orbit of the Moon. After act 1, starting with Newton's unification of motion everywhere, and act 2, turning any notion of existence and motion upside down, act 3 resembled that of Aristotle: material reality was unified as governed by quantum fields, while spacetime remained the stage for gravity in its classic field form.

Material reality vs. reality of space and time

In quantum field theory, QFT, each elementary particle has its own field. There is an electron field, and each electron, as well as its antiparticle, the positron, can be viewed as a local excitation of the electron field. The electron field is present everywhere in the Universe. An approximate picture is to view that field as a kind of spacetime-filling ocean, with each electron a localized wave in that ocean. Similarly, each photon is an excitation of the electromagnetic field, also filling the whole Universe in space and time.

The interactions between electrons, as well as other electrically charged particles, and photons are described in QED, quantum electrodynamics. The best reference I know for getting a feel of what this all means, without using any mathematics, is the book "Waves in an impossible sea" by Matt Strassler which I already referenced in entry #010.

After 1975, any elementary particle that we know of, as well its corresponding quantum field, forms part of the unification scheme of the standard model. The only exception is the gravitational field. The classical, pre-quantum description of that field is given by general relativity, GR, and we simply don't know what the quantum equivalent of GR is. One thing we *do* know about the gravitational field is that there is a medium in which the waves that can occur in that field propagate. It is the nothingness of empty spacetime. And when spacetime gets disturbed, its waves carry immaterial energy and momentum.

In contrast, for any of the quantum fields, each one corresponding to a particular elementary particle, we have no idea of what its medium "is". What is more, we don't even know whether it "exists", and what is more, we don't even know whether "existence" is an appropriate term.

If that sounds familiar, it should: we encountered the electromagnetic "aether" already in entry #007, as the proposal by Maxwell to describe what the classical medium could be for his classical theory of electromagnetism. In entry #009 we saw that roughly half a century later Einstein's special relativity ruled out any three-dimensional form of "aether" medium. And in entry #011 the QED formalism gave us the mathematical medium of the QFT of electromagnetism, a new kind of four-dimensional spacetime-based "aether" with no clear physical interpretation except for it being the (non-existent?) carrier for photons.

After this prelude, we are ready to catch the meaning of the title of this section: "Material reality vs. reality of space and time". The first part refers to quantum field theories describing the dynamics of elementary particles. The second part describes gravity, operating in the dynamic medium of spacetime.

Disclaimer: what I have tried to summarize in simple terms is the established view in 2024. Before too long deeper insight might arise that will describe space and time as side effects of a more fundamental theory than general relativity, and in that case the distinction between "material" and "immaterial" may disappear in the next unification. Philosophically speaking, that would be yet another sublation (in the original "Aufhebung") in Hegelian terms.

Mining the history of physics, towards a science of mind

This entry is the fifth and last of our "picture book" series, starting with entry #008, in which I have tried to summarize theory formation in physics, from Galileo to the present. My intent was to map some of the twists and turns, disappointments and surprises, that have characterized the progress of natural science in all of its disciplines. Physics was a convenient place to start, being the oldest discipline, and the first to reach quantitative and accurate reproducible results.

The motivation for me to map fundamental progress in the most basic natural science, was to have at least one concrete example of how a branch of science has grown over time. In entry #006 we started on a trek to search for candidate theories, to go with the two experiments discussed in entry #005. Rather than coming up with ad hoc theories of what a theory of mind studying mind using only mind might look like, the most conservative approach I could think of was to try to find clues from the evolution of theories of matter, using material instruments, aided by the use of mathematics and thought experiments.

The narrative that unfolded in these five entries and the use of these kinds of diagrams are new, to the best of my knowledge. They form an example of what I have witnessed often during my work in interdisciplinary studies. While looking to find a path through the jungle of a whole new terrain, one can fall back on inspecting various beaten paths in more familiar areas. In my experience, one can often discover new clues in the historical processes that led to older paths being constructed.

Down to details

Picture time! After the more than 1400 words used so far in this entry, let's see whether a picture here can be worth more than a thousand words.

The first rays of light and hope after the 1925 shock of the discovery of the mystery of quantum mechanics, were symbolized in entry #011 in Fig. 28, reproduced below. Around 1950 at least one of the known forces, electromagnetism, could be "quantized" to produce QED, quantum electrodynamics, as a relativistic quantum field theory, QFT. But the euphoria upon being able to make amazingly accurate calculations and predictions for electromagnetic interactions between charged particles and photons didn't last long. During the next twenty years, till 1970, neither the strong nor the weak interactions could be treated in the same way as QED, as a QFT.

```
+=====================================================+
|                                                     |
|              UG___GR_____________                   |
|             /    /    /          \                  |
|            /    SR__EM            ??? (1950)        |
|   AM --> CM____/      \      QED__/                 |
|               \        \    /                       |
|                QM______QFT                          |
|                          \     _                    |
|                           \  / WI ??                |
|                            XI                       |
|                              \_SI ??                |
|                                                     |
+-----------------------------------------------------+
|  Fig. 28: Around 1950, QED was established as the   |
|  first successful quantum field theory in that it   |
|  provided very accurate calculations of processes   |
|  involving electromagnetic interactions between     |
|  elementary particles.  However, the connection of  |
|  QED with the other three forces, gravitation and   |
|  the strong and weak interactions, remained an      |
|  enigma until the early seventies.                  |
|                                                     |
|  AM: Aristotelian Mechanics (300 BC)                |
|  CM: Newton's Classical Mechanics (1687)            |
|  UG: Newton's law of universal gravitation (1687)   |
|  EM: Electromagnetism (1865)                        |
|  SR: Special Relativity (1905)                      |
|  GR: General Relativity (1915)                      |
|  QM: Quantum Mechanics  (1925)                      |
|  QED: Quantum Electrodynamics (1950)                |
|  QFT: Quantum Field Theory                          |
|  XI: Extra Interactions, besides gravity and        |
|      electromagnetism                               |
|  WI: Weak Interaction                               |
|  SI: Strong Interaction                             |
|                                                     |
+=====================================================+
```

In my attempt to propose a historical division in periods, always a haphazard enterprise, I proposed 1975 as the start of act 3, the discovery of the standard model of particle physics. During a short period spanning only a few years in the early seventies, the standard model was developed and tested as a model that unified all three non-gravitational forces into a single theory. The only field that could not be quantized yet, and therefore not be unified either, was the classical theory of general relativity. This is indicated in Fig. 30 with the three question marks.

```
+====================================================+
|                                                    |
|             UG___GR_________________               |
|            /    /    /               \             |
|           /    SR__EM                 ??? (1975)   |
|   AM --> CM____/      \      __QED    /             |
|               \        \   /      \  /             |
|                QM______QFT___WI__SM                |
|                           \_     /                 |
|                             \_SI                   |
|                                                    |
+----------------------------------------------------+
|  Fig. 30: By 1975, the Standard Model of particle  |
|  physics was completed in its basic form through   |
|  the unification of the three non-gravitational    |
|  forces, those of electromagnetism and of the      |
|  strong and weak interactions.  The main puzzle    |
|  remaining was their relationship with general     |
|  relativity, GR, still a classical field theory,   |
|  for which no consistent quantum field has been    |
|  developed.                                        |
|                                                    |
|  SM: Standard Model                                |
|                                                    |
+====================================================+
```

Full Disclosure

In Fig. 30 I have glossed over a detail that is not important for the current level of exposition. For completeness, I could have replaced SI, for the strong interactions, with QCD, quantum chromodynamics as the field theoretical name for SI. This would be following the same convention in which I replaced EM, for classical electromagnetism, with QED, for its field theoretical counterpart. The result is Fig. 31.

```
+===================================================+
|                                                   |
|              UG___GR________________              |
|             /    /    /             \             |
|            /    SR__EM               ??? (1975)   |
|   AM --> CM____/      \     __QED    /            |
|                \       \   /     \  /             |
|                 QM______QFT___WI__SM              |
|                            \     /                |
|                             \_QCD                 |
|                                                   |
+---------------------------------------------------+
| Fig. 31:  This figure is the same as Fig. 30, but |
| SI, for the strong interaction, replaced by QCD   |
|                                                   |
| QCD: Quantum Chromodynamics                       |
| SM: Standard Model                                |
|                                                   |
+===================================================+
```

However, to be fully consistent I should also replace WI, for the weak interactions, with its field theoretical counterpart. The problem here is that while QCD corresponds to SI, there is no single QFT that corresponds to WI. Rather, the standard model is formed by a unification of QCD with another theory, modeling the electroweak interactions, EWI, that itself is a unification into one QFT, of EM and WI, the forces of electromagnetism and the weak interactions. I have depicted that situation in Fig. 32, for completeness, but in subsequent figures I will simplify things back to the style of Fig. 31.

```
+===================================================+
|                                                   |
|              UG___GR_________________             |
|             /    /    /               \           |
|            /    SR__EM         _       \          |
|   AM --> CM____/      \     QED \      ??? (1975) |
|                \       \   /     EW    /          |
|                 QM______QFT__WI_/  \_SM           |
|                            \       /              |
|                             \___QCD               |
|                                                   |
+---------------------------------------------------+
| Fig. 32:  This figure is the same as Fig. 31, but |
| with WI, the weak interaction, and QED, quantum   |
| electrodynamics, unified into a single quantum    |
| field theory for the electroweak interactions     |
|                                                   |
| EWI: Electroweak Interaction                      |
| QCD: Quantum Chromodynamics                       |
| SM: Standard Model                                |
|                                                   |
+===================================================+
```

Mapping the structure of atoms

Having sketched the theoretical background for the opening of act 3 of physics, followed by presenting a single picture, Fig. 32, it is time to ask "what does this buy me?" The answer is: for the first time in human history we not only know *that* matter around us consists of atoms, we also have arrived at a quantitatively accurate detailed picture of *what* is hiding inside atoms.

As often is the case, a terribly boring way of teaching what humanity has learned so far would be to provide a laundry list of the contents of atoms. This list would then have to be learned by heart by bored students at some time in their schooldays. Instead, let's take a quick walk through history, in order to see how this list was designed in steps, based on new discoveries at each step.

We can start our journey by traveling back in time to the beginning of the previous century. In 1904 the British physicist J.J. Thomson, the discoverer of the electron, proposed a model for the contents of the atom, while wondering what to do with his electrons. It was called the "plum pudding model" of the atom in the popular press (Google tells me that plum pudding is an English dessert similar to a blueberry muffin). In that model the negatively charged electrons were embedded in an amorphous distribution of positive charge, surrounding the electrons like raisins in a plum pudding (or blueberries in a muffin).

Then, in 1911, Ernest Rutherford introduced a model that looked more like the solar system: it had a heavy nucleus in the center, with electrons orbiting around it. The motivation was the fact that electrons, when aimed with high speed at atoms, would occasionally scatter or even recoil at large angles from their original direction of motion, suggesting the presence of small heavy objects in the center of atoms.

Soon afterwards, in 1913, Niels Bohr proposed a model that featured some quantization aspects, in contrast to the previous two models that were purely classical. He posited that electrons circle the atomic nucleus, as in Rutherford's model, but only on specific orbits, like standing waves in a string, thereby introducing a discrete element in the model. Several other physicists proposed variations on this idea, in what later would be called the "old quantum theory", using "semi-quantum" approximations before 1925.

All of these models became obsolete in 1925 in one stroke, or more accurately, in two parallel strokes. That year saw the advent of two initially competing models, Heisenberg's matrix mechanics and Schrödinger's wave mechanics, that were quickly recognized as being equivalent, as we saw in entry #010.

Immediately during and after 1925 the nature of the "electron cloud", filling the atom around the nucleus, was elucidated in detail. It took much longer to determine the nature of the nucleus itself. In 1932 neutrons were discovered, and it was realized that an atomic nucleus is built up of a tightly packed mix of positively charged protons and electrically neutral neutrons, hence the name. Using the term tightly here is not an exaggeration: the size of a nucleus inside an atom can be compared to that of a flea inside a cathedral, spanning roughly one hundred thousandth of the atom.

Soon afterwards, two new forces were discovered, both playing important roles inside atomic nuclei, simply called weak and strong interactions, respectively, in their order of discoveries, as we saw in entry #011. Their bland names indicated the surprise at their discovery and the initial uncertainty as to what they were. The uncertainty would last till 1970, and it was only when the standard model was completed that their roles in atomic nuclei were fully elucidated.

In short, and very much oversimplifying, since 1975 we know that protons and neutrons are each "blobs" of a mix of quarks and gluons. Here quarks are components of protons and neutrons. Quarks are much lighter than protons and neutrons, and gluons are massless: like photons, quanta of the electromagnetic field, gluons can be viewed as quanta of the strong interaction. Most of the mass of protons and neutrons is formed by the energy of relativistic motions of the quarks and gluons, confined inside the protons and neutrons. Its composition resembles a modern version of plum pudding or blueberry muffins, used 70 years earlier by Thomson, but on a scale one hundred thousand times smaller, and with inner turmoil moving close to the speed of light.

Not yet mapping the structure of the cosmos

Having sung the praises of the standard model, let me hasten to mention that act 3, like act 2, is still part of a kind of "middle ages" of physics, carrying in it the seeds of (a) very different period(s) to come. At the danger of pushing the analogy too far, perhaps act 3 can be seen as a renaissance, literally a rebirth, following the middle ages of act 2. As we saw above, 1975 brought a new stability in our understanding of the structure of atoms, from a-tomos, non-divisible and otherwise nondescript things, to a neat inventory of its components. Or with a longer view back, a rebirth of the prescientific model of atoms in four or five forms, in Greece, India, and China.

Whatever future theories will propose for the nature of material reality, the picture of atomic structure drawn using the standard model is here to stay. Any future theory that may replace quantum field theory as a more accurate description of matter of smaller and smaller scales, whatever its structure may be, has to agree with the same experiments that the standard model had to agree with -- just as general relativity had to agree with Newtonian gravity in the limit of weak forces and low speeds.

That said, physicists are certain that the standard model is only a way station on route to a much more filled-out future theory of material reality. For one thing, while doing an amazing job explaining the state of affairs inside the microcosmos of the atom, it utterly fails to give an equally rosy picture for the macrocosmos of the Universe.

In a nutshell: we astrophysicists don't know what we're talking about. More precisely, given that our task is to study the Universe, it is a sobering thought that we only know the nature of 1/20th of the inventory of the Universe. Of the remaining 95%, we have no idea what it is -- or equivalently, we have too many ideas, none of which we can be sure of with any measure.

Ordinary matter, made out of atoms, makes up only 5% of the content of the Universe. Another 25% of the matter in the Universe is invisible. It is there, and can be detected by its gravitational pull on visible matter, but we simply don't know what it is made of. It could be yet unknown types of elementary particles, it could be some type of black holes, it could be many other things sprinkled through the virtual universe of imagination that astrophysicists entertain.

What is even worse: we have no idea what the remaining more than 2/3 of the mass of the universe is made of. This "mass", being equivalent to energy, can be made of something more resembling energy, perhaps the energy inherent in the structure of the vacuum of our Universe. With that in mind, the 25% that is missing is called "dark matter", in that it does not seem to interact with electromagnetic radiation, and the rest that is missing, the bulk of the content of the cosmos, is called "dark energy", since it is not condensed in or around clusters of galaxies, the way "dark matter" is. The fact that it is spread out almost evenly hints at it moving at very high speed, meaning that its energy of motion is far higher that the equivalent rest mass it has, if any.

Apart from its inability to explain the contents of the Universe, there is much more that is still "missing" in the standard model. Shifting our view from space to time, to the start of our Universe in the Big Bang, the standard model has nothing to say about the Planck time, as it is called, a time at which the energy density of the Universe was so large that the force of gravity was as strong as that of the forces displayed in the standard model. The Planck time is very short: 5x10^-44 seconds or in the ballpark of a quadrillionth of a quadrillionth of a quadrillionth of a second.

To sum up: we astrophysicists don't know what we are talking about and we don't know where we're coming from. Such an exciting time to be an astrophysicist, given that we do have reason to believe that we are getting closer to the answers to both questions! "Any day now" would be an exaggeration, but "possibly in a decade (or two)" may not be unreasonable as a guess.

Anatomy of the standard model

Above I used the metaphor of mining the history of physics, in search of clues for theory formation, to apply those to our burgeoning science of mind. I will now switch to another metaphor: let's make an attempt to uncover the anatomy of the standard model. Which historical theories "fit into" later more expanded theories, how do they fit, and what does "fit" mean?

Let us return to Fig. 31, including QCD, quantum chromodynamics, in a slightly expanded version, which is given in Fig. 33. Here classical electricity and magnetism are added as E and M before they were unified into electromagnetism by Maxwell. To be precise, in entry #011, Fig. 29 showed the genealogy of EM, with EM taking the place where Maxwell had put it, whereas the current place of EM, after Einstein's discovery of relativity, can be spotted in Figs. 28, 31, and 33 in this entry.

```
+====================================================+
|                                                    |
|            UG___GR___________________              |
|           /    /      /              \             |
|          /    SR_    /                \            |
|         /    /   \_EM                  \           |
| AM -> CM____/        \                  ??? (1975) |
|         \   \         \                /           |
|          \   \         \     __QED    /            |
|           \   QM____    \   /     \  /             |
|            \        \____QFT___WI__SM              |
|             \               \     /                |
|              \  E            \_QCD                 |
|               \/                                   |
|                \                                   |
|                 M                                  |
|                                                    |
+----------------------------------------------------+
|  Fig. 33: A slightly expanded version of Fig. 31, |
|  with electricity, E, and magnetism, M added.      |
|  Note that electromagnetism, EM, is not where it   |
|  was placed when Maxwell initially unified the     |
|  two in the single field of electromagnetism,      |
|  to the right of classical E and M.  Instead,      |
|  it appears higher up, to the right of special     |
|  relativity, as a relativistic theory, in which    |
|  space and time appear as spacetime, the solution |
|  given by Einstein to the problems with Maxwell's |
|  classical version, which led him onto the trail   |
|  of relativity.                                    |
|                                                    |
+====================================================+
```

Now that we are up-to-date as to our best theories of the nature of matter, in terms of the smallest constituents we know and the interactions between them, let us step back and make some anatomical snapshots as to which parts of the theory "fit into" other parts. "Fitting in" is used here in the sense that Newton's theories "fit into" the wider theory of Einstein's general relativity by giving the same results in the limit of weak gravitational theory. Another way to express this is to say that Einstein's theory is "bigger" or "more accurate" than Newton's theory.

The simplest form of "fitting into" is a straightforward nesting of a series of theories, like that of Russian dolls. From Fig. 33, we can read off an example, in the way that classical mechanics, CM fits into special relativity, SR, which in turn fits into general relativity, GR. Using the symbol "<" for "fitting into", we have CM < SR < GR. Another example is CM < QM < QFT, with QM for quantum mechanics, and QFT for quantum field theory.

The latter two are examples of what mathematicians call a total ordering. More frequently, we are confronted with what is called a partial ordering. Fig. 33 shows the following four fitting relationships: CM < SR, CM < QM, CM < QFT, but there is no fitting relationship between the two middle players, SR and QM.

Each of the pictures we have used up to now, starting in the first Picture book entry, #008, shows fitting relationships, deepening when we move further to the right. One potentially confusing aspect of these figures is that moving to the right can also indicate "with examples of" instead of "fits into". Whenever moving to the right branches into more than one path, we are dealing with examples. For QFT, quantum field theories, three examples are given in Fig. 33, that of quantum electrodynamics, QED, and WI and QCD for the weak and strong interactions.

```
+====================================================+
|                                                    |
|       _______                                      |
|      |     UG|__GR___________________              |
|      |    /  | /      /              \             |
|      |   /   |SR_    /                \            |
|      |  /    /   \_EM                  \           |
| AM ->|CM____/|       \                  ???        |
|      |  \   \|        \                /           |
|      |   \   \         \     __QED    /            |
|      |    \  |QM____    \   /     \  /             |
|      |     \ |      \____QFT___WI__SM              |
|      |      \|____          \     /                |
|      |       \  E |          \_QCD                 |
|      |        \/  |                                |
|      |         \  |                                |
|      |          M |                                |
|      |____________|                                |
|           1800                                     |
+----------------------------------------------------+
|  Fig. 34: the part of Fig. 31 known in 1800,       |
|  that is, the classical sector in Fig. 33.         |
|  The boxed part of the various theories contains   |
|  classical theories of Newton, classical mechanics |
|  CM and universal gravity, UG, as well as the      |
|  theories of electricity, E, and magnetism M, as   |
|  they were separately developed by many scientists |
|  up to Faraday.                                    |
|                                                    |
+====================================================+
```

Fig. 34 shows the first anatomical picture, in the form of what was known a bit more than a century after Newton. A detailed study of electricity, E, and magnetism, M, had begun and the various theories of increasing accuracy of detail all neatly fit into the classical paradigm established by Newton.

```
+====================================================+
|                                                    |
|               __________                           |
|            UG|__GR______|____________              |
|           /  | /      / |            \             |
|          /   |SR_    /  |             \            |
|         /    /   \_EM   |              \           |
| AM -> CM____/|_______\__|               ???        |
|         \   \   1915  \                /           |
|          \   \         \     __QED    /            |
|           \   QM____    \   /     \  /             |
|            \        \____QFT___WI__SM              |
|             \               \     /                |
|              \  E            \_QCD                 |
|               \/                                   |
|                \                                   |
|                 M                                  |
|                                                    |
+----------------------------------------------------+
|  Fig. 35: the part added to Fig. 34 known in 1915, |
|  that is, the relativistic sector of Fig. 33.      |
|  Special relativity, SR, is featured here as an    |
|  extension of classical mechanics, SM, while GR,   |
|  general relativity, and EM, electromagnetism,     |
|  are in turn extensions of SM: GR approached SR    |
|  under weak gravitational fields; EM approaches    |
|  SR under weak electromagnetic fields.             |
|  As a reminder, in these pictures, reading from    |
|  left to right, a theory further to the right      |
|  includes a theory to its left as an approximate   |
|  form, while a theory to the right indicates an    |
|  extension of the theory to its left.              |
|  Moving from left to right, if a theory generates  |
|  more than one line, it means that that theory can |
|  be considered as a limiting case of more than one |
|  theory to its right.                              |
|  If two or more lines from the left converge on a  |
|  single theory to the right, it means that that    |
|  theory forms a unification of the theories to its |
|  left.                                             |
|                                                    |
+====================================================+
```

Fig. 35 shows the anatomy of physics theories a bit more than a century later. Newton's classical theories are seen to fit into the extensions provided by Einstein, including Einstein's further extension of Maxwell's theory of electromagnetism.

```
+====================================================+
|                                                    |
|            UG___GR___________________              |
|       ____/____/_      /              \            |
|      |   /    SR_|    /                \           |
|      |  /    /   \_EM                   \          |
| AM ->|CM____/    |   \                  ???       |
|      |  \   \     |    \                /          |
|      |   \   \    |     \      __QED    /          |
|      |    \   QM_|__     \   /     \  /            |
|      |_____\_____|  \____QFT___WI__SM              |
|        1925 \              \     /                 |
|              \  E           \_QCD                  |
|               \/                                   |
|                \                                   |
|                 M                                  |
|                                                    |
+----------------------------------------------------+
|  Fig. 36: the fundamental part added to Fig. 34 in |
|  1925.  Instead of one extension of CM, there now  |
|  appear two independent ways to augment CM, going  |
|  relativistic with special relativity, SR, and     |
|  going quantum with quantum mechanics, QM, with at |
|  that time no known connection between the two.    |
|  It was a time of bewilderment.                    |
|                                                    |
+====================================================+
```

Fig. 36 shows the state of anatomy in 1925, after the arrival of the shock of the discovery of quantum mechanics. It seemed that the parts of the body of physics no longer fit together! Following road signs pointing from classical mechanics to wider views would lead you to different hills, each with a sign pointing to the other hill reading "you can't get there from here".

```
+====================================================+
|                                                    |
|            UG___GR___________________              |
|           /    /      /              \             |
|          /    SR_    /                \            |
|         /    /   \_EM                  \           |
| AM -> CM____/ _______\_______________   ???        |
|         \   \|        \              | /           |
|          \   \         \     __QED   |/            |
|           \  |QM____    \   /     \  /             |
|            \ |      \____QFT___WI__SM|             |
|             \|______        \     /  |             |
|              \  E   |        \_QCD   |             |
|               \/    |________________|             |
|                \           1975                    |
|                 M                                  |
|                                                    |
+----------------------------------------------------+
|  Fig. 37: the end of bewilderment, which happened  |
|  to arrive almost exactly half a century later.    |
|  By 1975 SR and QM were fully unified, including   |
|  not only QED, quantum electrodynamics, as a       |
|  quantum field theory, QFT, extension of EM, but   |
|  also similar QFT extensions of both weak and      |
|  strong interactions, WI and SI respectively.      |
|                                                    |
+====================================================+
```

Fig. 37 shows the next picture Rip van Winkle would have seen, had he slept for 50 years instead of 20. All would be well after the quantum field theory revolution had taken place. There was not even a need to change the hill signs: the two hills turned out to be different sides of the same hill.

```
+====================================================+
|                                      ______        |
|            UG___GR__________________|      |       |
|           /    /      /             |\     |  F    |
|          /    SR_    /              | \    |  U    |
|         /    /   \_EM               |  \   |  T    |
| AM -> CM____/        \              |   ???|  U    |
|         \   \         \             |  /   |  R    |
|          \   \         \     __QED  | /    |  E    |
|           \   QM____    \   /     \ |/_____|       |
|            \        \____QFT___WI__SM              |
|             \               \     /                |
|              \  E            \_QCD                 |
|               \/                                   |
|                \                                   |
|                 M                                  |
|                                                    |
+----------------------------------------------------+
|  Fig. 38: having found a solution to the specific  |
|  bewilderment mentioned in the caption to Fig. 36, |
|  there is still a major Bewilderment left in terms |
|  of the incompatibility of our best theory of the  |
|  field of gravity, general relativity, GR, and our |
|  unified theory of all other fields, the standard  |
|  model, SM.  Stay tuned!                           |
|                                                    |
+====================================================+
```

Fig. 38 points to a future time when the spacetime based gravitational field and all other material fields will have been unified in an as yet unknown way. We currently have no idea what it will look like, nor do we know how long Rip van Winkle would need to sleep, were he to start his next nap today.

Wrapping up

This anatomy lesson, while lacking the elegance of Rembrandt's painting with that name, I am planning to use in subsequent entries as comparison material. Specifically, I will introduce and explore hypotheses concerning relationships between matter, experience and appearance, beyond what I described initially in entries #003, #004 and #005.

These hypotheses I will develop using the working hypotheses, introduced in entries #003 and #008:

WH 1: there are primitive elements underlying experience

WH 2: appearances are primitives for any form of experience

WH 3: the shifts in perspectives between viewing objects as matter, experience, or appearance, might have analogies in the shifts of perspectives between subsequent theories in physics.

In particular, we will encounter situations that might be analogous to Fig. 34, where the boxed part could correspond to what Husserl called the natural attitude, as we saw in entry #004. Fig. 35 could offer a simple model for what might happen when we zoom in on specific aspects of the natural attitude, say E and M in Fig. 35. Such inspection can hold clues as to the existence of a whole new sector beyond the natural attitude, necessary to show how elements like E and M can be unified into EM in ways for which there is no room in the boxed part of Fig. 34.

I will use Fig. 36 as inspiration for a comparison between the way Galileo introduced mathematics as a kind of "transcendental" probing of material processes and Husserl introduced his epoché to probe what he called the nature of the "transcendental" subject. In that figure, the boxed part shows candidates for two different extensions of the same initial attitude that at first sight seem blatantly incompatible, only to be unified later through a wider perspective.

The boxed part in Fig. 37 can serve as inspiration, if nothing else, for persistence in dealing with unexpected discoveries that lead to dead ends for many decades. Such discoveries might suddenly offer equally unexpected and truly marvellous solutions to problems one didn't yet know were lying in wait.

To wit: quantum mechanics upset the apple cart of classical mechanics. But fifty years later, in just a few years, quantum field theories provided a coherent quantitatively accurate picture for material reality -- down to quarks and gluons, now seen as internal parts of protons and neutrons, which themselves are parts of the atomic nucleus, which in turn is the central part of each atom. What a marvelous solution, so far beyond anything that a mechanical model could have provided!

Finally, Fig. 38 reminds us that a final near-miraculous solution to one persistent problem can highlight the next, even more persistent problem, and in doing so, can provide new clues for that next-in-line problem.

Note that in all this I make no claim, in fact not even a hypothesis, that any of the figures mentioned above have any direct relationship with the various possible analogies I just mentioned. Rather, what inspires me is the fact that in natural science very often mathematical models developed for one application have found quite different applications in seemingly totally unrelated areas. The most conservative guess for what will happen in a science of mind would be that such a pattern of discoveries will continue, and at least we should keep an open eye for such a possibility.

FEST Log, Part 1: Summary and Outlook

Entry #013
July 26, 2024

A new program

I started this FEST log on leap day, five months ago, with entry #000, a maniFESTo for the FEST program.

The name FEST can be read in two different ways, as Fully Engaged Science and Technology, as well as Fully Empirical Science and Technology. Here the words "science" and "technology" apply to science of matter, using technologies based on matter, as well as science of mind, using technologies based on mind. Both forms of science can use the very effective methodology developed for natural science, each in their own domain.

Rather than a project, FEST is a program, one that aims at initiating a full extension of natural science. To the best of my knowledge this has not yet been attempted in a fully consistent way. From the start my intention has been to be as conservative as I possibly can, while following the established core principles of science. I have tried to learn from the history of science about the ways research has often meandered, but typically in the end found novel ways to obtain deeper ways of understanding -- of matter in the past few centuries, and perhaps of mind as well in the near future: an obvious opportunity, and worth a try.

While neuroscience has made enormous progress, with benefits for pure science as well as for medical applications, it is a hybrid discipline, driven mostly by deep investigations of the material properties of the brain, and the nervous system in general. While the ultimate aim is to understand the nature of mind and consciousness, we are still far removed from that goal. A science of mind can act as a complementary approach.

Leaving the mind/body question open for now

Whether a mind is a complex form of emergent properties arising from a brain, or whether consciousness in whatever form can be seen as more fundamental than matter, or whether the two are complementary aspects of reality, or whether their relation is of a type we cannot even guess, science in its current state cannot tell us. All we can do is keep an open mind, designing working hypotheses without believing or disbelieving in them, deepening our knowledge of the phenomena, matter phenomena and mind phenomena, while more pieces of the puzzle fall into place. This is the way science works.

A science of mind should avoid any premature choice among the four options listed above, since in any case, reality is likely to be far more interesting than anything we can imagine it to be, as the history of science has shown us over and over again. Therefore I would bet on the fourth possibility, based on the way most really novel results could not have been guessed, simply because too little was known yet about the types of possible outcomes.

The fact that by far most scientists take it for granted that matter is the sole basis of reality is a very interesting sociological or ethnographic fact in itself, worth more research than has been given to it yet. However, opinions as to what is real don't carry any weight. We have seen a large fraction of physicists being fully convinced that the natural world is structured like a clockwork mechanism following Newton's laws, while trying to convince others around them to accept it on their authority. Overinterpreting one's success is all too human.

The classical mechanics era lasted for two and a half centuries until quantum mechanics replaced its picture of matter with a far more interesting and far more fluid notion: matter at its core is based on a playful mixture of actual and potential elements. Nobody could have guessed. But when theory and experiment came into agreement, as judged by a self-governing community of peers, scientists accepted the new picture, even without understanding what it all meant. That is the incredible strength of the scientific method, and of the integrity of scientists following that method. They are willing to junk what had been established wisdom for centuries, in the light of new evidence. We may wish that more human endeavors would work that way.

An open kitchen

While considering writing one or more books about FEST, I decided to take a different route, inspired by the model of an open kitchen, where you can see exactly what is happening while a meal is being prepared. This gave me two advantages.

First, it did not allow me to erase my original tracks, given that each entry of my log would be put in stone upon publication, two or three times a month. It instilled in me a discipline of carefulness and honesty, while building up FEST as a new program. Whenever I feel forced to change my mind, either based on new experimental or theoretical evidence, or simply because I learned to see things in a deeper way, I will point it out, referring back to earlier log entries, but without modifying those, apart from adding a footnote with a pointer to later entries.

Second, it allowed me to share my insights immediately, rather than waiting for years until a book manuscript is accepted, reviewed, going into print, and reviewed in the literature. In short, this log is like a series of preprints of the type used in natural science before articles go into print, in order to allow early peer review.

To make it easier to browse through older parts in the FEST Log, I have decided to bundle the first 14 entries, #000 through #013, into one document, "FEST Log, Part 1". The original entries will remain where they are now in the Log, so can still be found there, when jumping from a later entry to a particular place in the Log.

Structure of the first half of Part 1

By starting the FEST program, my aim has been two-fold. First, to provide a somewhat worked-out example of what a science of mind could be like, something I have now started to explore in this current FEST log. Second, to provide a seed for a community, structured in a scientific way, as self-governing and peer-based. In entry #001 I have outlined what I see as the basic elements of any form of science, independent of the target of research, be it forms of matter or mind.

Following entry #001, which lists an abstract summary, entry #002 provides a concrete historical view of how natural science got consolidated in the 17th century. Entries #003 through #005 very briefly touch upon some examples of types of experiments using our mind as a lab. I have singled out two, given by the

German philosopher Edmund Husserl and the Japanese philosopher Kitaro Nishida.

After giving an initial taste of experimenting with our minds using our minds, I address the task of developing theories to guide further experimentation, starting in entry #006. At any step along the way of developing a science of mind, I have tried to be as conservative as I could possibly be, by taking off from natural science as the only example we have, when defining science as I have done in entry #001. It is tempting to come up with wild and unproven radical ideas as to what the structure and processes are of our minds. My choice, rather, is to take the simplest extrapolation of approaches that have already been taken. Only if they really don't work, I could be convinced to try something different. This is my understanding of how science works.

For that purpose I started in entry #006 to provide examples of the conservative ways in which natural scientists have found themselves paradoxically forced to develop ever more radical theories, in the light of convincing experiments. In doing so, I have chosen to give a historical overview of theory formation and evolution in physics, the most elementary field of natural science. Entries #006 and #007 set up the stage by sketching the trajectories from Newton through Maxwell to Einstein, spanning a period of two and a half centuries, while pointing out potential lessons to be learned for starting up a theory of mind.

Structure of the second half of Part 1

Not satisfied that the sketches given so far could find enough traction to guide actual theory formation in a science of mind, I was looking for more concrete and precise ways to analyze theory formation in physics. Starting with entry #008, following a time-honored tradition in physics, I designed a new type of diagram in order to keep track of what happened when and how. It was my attempt to trace the twists and turns of the reactions of theoretical physicists whenever radically new experiments told them to overhaul their ideas.

To the best of my knowledge these diagrams present a novel way to trace problems and solutions in the historical processes of diversification and unification in physics. It took me five entries, from #008 through #012, to reach the present. Starting from the prescientific mechanics of Aristotle, via the first truly scientific theory of Newton, to reach our current best theory of the structure and processes characterizing matter, as incorporated in the standard model of particle physics.

Follow-up

The current entry, #013, forms the last entry of Part 1 of the FEST Log entries. As mentioned above, the original Log will continue to grow, leaving all the previous entries in place.

My current plans are to provide at least two more Parts. Where Part 1 is almost entirely preparatory in spirit, I want to let it all come alive in Part 2. Returning to the very sketchy treatment of two types of experiments in entries #003 through #005, I will provide more context as well as more guidelines for actual experimentation. Alongside, I will explore ways of theory formation to make sense of various outcomes of those experiments, following the inspiration that the second half of Part 1 can provide. Specifically, I will introduce several new diagrams as candidates for a science of mind, along the lines of what I presented in my "Picture book" of physics theories, starting in entry #008.

Outlook

Finally, starting in Part 2, I will address the one aspect mentioned in entry #001 that I have not yet touched upon in describing the essential ingredients of science: the formation of a self-governing community of peers. I have postponed bringing that point up in order to give a sufficiently detailed description of what kind of seed it is that might possibly sprout a full-blown community around it. Let me end this entry with one more characterization of what FEST is, in addition to how I described it at the start of the current entry.

FEST is a program, aimed at starting a community that in turn can suggest and carry out many projects in an interdisciplinary way. As with any interdisciplinary project, it actually requires more discipline from the side of the participants compared to disciplinary projects, within any one of the usual academic disciplines. Because there are few established conventions in any new interdisciplinary field, there are neither training wheels nor guard rails for those setting up or joining such a new discipline. Hence the extra discipline called for when opening a new field of research.

The main challenges for FEST will be to encourage the development of the formation of a science of mind, and at the same time to discourage premature leaps of speculation -- forms of speculation that cannot be tested with an agreed-upon methodology based on intersubjective peer review. In this I will try to follow the very successful example of natural science.