Chapter 1
Intrinsic and Extrinsic Observation Mode

This chapter introduces some important epistemology. Without epistemology any inroad into the subject of (un)decidability and (in)determinism may result in confusion and incomprehensibility.

Thereby, and although this book is mainly concerned with physics, we shall not restrict ourselves to the physical universe, but also consider virtual realities and simulations. After all, from a purely algorithmic perspective, is there any difference between physics and a simulacrum thereof?

1.1 Pragmatism by "Fappness"

Throughout this book, the term *"fapp"* is taken as an abbreviation for *"for all practical purposes"* [43]. The term refers to exactly what it says: although a statement may or may not be strictly correct, it is corroborated, or taken, or believed, or conjectured, to be true pragmatically *relative to particular means.* Such means may, for instance, be technological, experimental, formal, or financial.

A typical example is the possibility to undo a typical "irreversible" measurement in quantum mechanics: while it may be possible to reconstruct a wave function after some "measurement," in most cases it is impossible to do so fapp [202, 461]; just as in this great 1870 collection of *Mother Goose's Nursery Rhymes and Nursery Songs* by James William Elliott [199, p. 30]: *"Humpty Dumpty sat on a wall, Humpty Dumpty had a great fall: All the king's horses, and all the king's men, Couldn't put Humpty together again."*

Another example is the fapp irreversibility in classical statistical mechanics, and the fapp validity of the second law of thermodynamics [375]: Although in principle and at the most fundamental, microscopic level of description – that is, by taking the particles individually – reversibility rules, this reversible level of description mostly remains inaccessible fapp. In Maxwell's words [358, p. 279], *"The truth of the second*

K. Svozil, *Physical (A)Causality*, Fundamental Theories of Physics 192,
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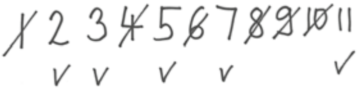


Fig. 1.1 (Wrong) physical proof that all nonzero natural numbers are primes

law is therefore a statistical, not a mathematical, truth, for it depends on the fact that the bodies we deal with consist of millions of molecules, and that we never can get hold of single molecules."

Another, ironic example is the (incorrect) physical "proof" that "all nonzero natural numbers are primes," graphically depicted in Fig. 1.1. This sarcastic anecdote should emphasize the epistemic incompleteness and transitivity of all of our constructions, suspended "in free thought;" and, in particular, the preliminarity of scientific findings.

1.2 Level of Description

At first glance it seems that physics, and the sciences in general, are organized in a layered manner. Every layer, or level of description, has its own phenomenology, terminology, and theory. These layers are interconnected and ordered by methodological reductionism.

Methodological reductionism proposes that earlier and less precise levels of (physical) descriptions can be reduced to, or derived from, more fundamental levels of physical description.

For example, thermodynamics should be grounded in statistical physics. And classical physics should be derivable from quantum physics.

Also, it seems that a situation can only be understood if it is possible to isolate and acknowledge the fundamentals from the complexities of collective motion; and, in particular, to solve a big problem which one cannot solve immediately by dividing it into smaller parts which one can solve, like subroutines in an algorithm.

Already Descartes mentioned this method in his *Discours de la méthode pour bien conduire sa raison et chercher la verité dans les sciences* [165] (English translation: *Discourse on the Method of Rightly Conducting One's Reason and of Seeking Truth*) stating that (in a newer translation [167]) *"[Rule Five:] The whole method consists entirely in the ordering and arranging of the objects on which we must concentrate our mind's eye if we are to discover some truth. We shall be following this method exactly if we first reduce complicated and obscure propositions step by step to simpler ones, and then, starting with the intuition of the simplest ones of all, try to ascend through the same steps to a knowledge of all the rest. ... [Rule Thirteen:] If we perfectly understand a problem we must abstract it from every superfluous conception, reduce it to its simplest terms and, by means of an enumeration, divide it up into the smallest possible parts."*

A typical example for a successful application of Descartes' fifth and thirteenth rule is the method of separation of variables for solving differential equations [204]. For instance, Schrödinger, by his own account [450] with the help of Weyl, obtained the complete solutions of the Schrödinger equation for the hydrogen atom by separating the angular from the radial parts, solving them individually, and finally multiplying the separate solutions.

So it seems that more fundamental microphysical theories should always be preferred over phenomenological ones.

Yet, good arguments exist that this is not always a viable strategy. Anderson, for instance, points out [13] that *"the ability to reduce everything to simple fundamental laws does not imply the ability to start from those laws and reconstruct the universe. . . . The constructionist hypothesis breaks down when confronted with the twin difficulties of scale and complexity. The behaviour of large and complex aggregates of elementary particles, it turns out, is not to be understood in terms of a simple extrapolation of the properties of a few particles. Instead, at each level of complexity entirely new properties appear, and the understanding of the new behaviours requires research which I think is as fundamental in its nature as any other."*

One pointy statement of Maxwell was related to his treatment of gas dynamics, in particular by taking only the mean values of quantities involved, as well as his implicit assumption that the distribution of velocities of gas molecules is continuous [234, p. 422]: *"But I carefully abstain from asking the molecules which enter where they last started from. I only count them and register their mean velocities, avoiding all personal enquiries which would only get me into trouble."*

Pattee argues that a *hierarchy theory* with at least two levels of description might be necessary to represent these conundra [384, p. 117]: *"This is the same conceptual problem that has troubled physicists for so long with respect to irreversibility. How can a dynamical system governed deterministically by time-symmetric equations of motion exhibit irreversible behaviour? And of course there is the same conceptual difficulty in the old problem of free will: How can we be governed by inexorable natural laws and still choose to do whatever we wish? These questions appear paradoxical only in the context of single-level descriptions. If we assume one dynamical law of motion that is time reversible, then there is no way that elaborating more and more complex systems will produce irreversibility under this single dynamical description. I strongly suspect that this simple fact is at the root of the measurement problem in quantum theory, in which the reversible dynamical laws cannot be used to describe the measurement process. This argument is also very closely related to the logician's argument that any description of the truth of a symbolic statement must be in a richer metalanguage (i.e., more alternatives) than the language in which the proposition itself is stated."*

Stöltzner and Thirring [489, 493, 529], in discussing Heisenberg's *Urgleichung*, which today is often referred to as *Theory of Everything* [34], at the top level of a "pyramid of laws," suggest three theses related to a "breakdown" to lower, phenomenologic, levels: *"(i) The laws of any lower level . . . are not completely determined by the laws of the upper level though they do not contradict them. However, what looks like a fundamental fact at some level may seem purely accidental when looked at* *from the upper level. (ii) The laws of a lower level depend more on the circumstances they refer to than on the laws above. However, they may need the latter to resolve some internal ambiguities. (iii) The hierarchy of laws has evolved together with the evolution of the universe. The newly created laws did not exist at the beginning as laws but only as possibilities."* In particular, the last thesis (iii) is in some proximity (but not sameness) to laws emerging from chaos in Chap. 9 (p. 39), as it refers also to spontaneous symmetry breaking.

General reductionism as well as determinism does not necessarily imply predictability. Indeed, by reduction to the halting problem (and also related to the busy beaver function) certain structural consequences and behaviours may become unpredictable (cf. Sect. 6.2 on p. 30). As expressed by Suppes [497, p. 246], *"such simple discrete elementary mechanical devices as Turing machines already have behaviour in general that is unpredictable."*

1.3 Arguments for and Against Measurement

With regards to obtaining knowledge of physical or algorithmic universes, I encourage the reader to contemplate the notion of observation and measurement: what constitutes an observation, and how can we conceptualize measurement?

In general terms measurement and observation can be understood as some kind of information transmission from some "object" to some "observer." Thereby the "observer" obtains knowledge about the "object." The quotation marks stand for the arbitrariness and conventionality of what constitutes an "object" and an "observer." These quotation marks will be omitted henceforth.

Suppose that the observer is some kind of mechanistic or algorithmic agent, and not necessarily equipped with consciousness.

1.3.1 Distinction Between Observer and Object

In order to transmit information any observation needs to draw a *distinction* between the observed object and the observer. Because if there is no distinction, there cannot be any information transfer, no external world, and hardly any common object to speak about among individuals. (I am not saying that such distinction is absolutely necessary, but rather suggestive as a pragmatic approach.)

Thereby, information is transferred back and forth through some hypothetical interface, forming a (Cartesian) cut; see Fig. 1.2 for a graphical depiction. Any such interface may comprise several layers of representation and abstraction. It could be symbolic or describable by information exchange. And yet, any such exchange of symbols and information, in order to take place is some universe, be it virtual or physical, has to ultimately take place as some kind of virtual or physical process.

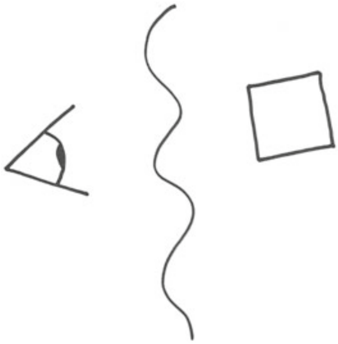


Fig. 1.2 A distinction is made between the observer, represented by a symbolic eye and the object, represented by a symbolic square; The interface or cut between observer and object is drawn by a wavy vertical line

1.3.2 *Conventionality of the Cut Between Observer and Object*

As we shall see, in many situations this view is purely conventional – say, by denoting the region on one side of the interface as "object," and the region on the other side of the interface as "observer."

A priori it is not at all clear what meaning should be given to such a process of "give and take;" in particular, if the exchange and thus the information flow tends to be symmetric. In such cases, the observer-object may best be conceived in a holistic manner; and not subdivided as suggested by the interface. The situation will be discussed in Sect. 1.7 (p. 10) on *nesting* later.

1.3.3 *Relational Encoding*

Another complication regarding the observer-object distinction arises if information of object-observer or object-object systems does not reside in the "local" properties of the individual constituents, but is *relationally* encoded by *correlations* between their joint properties. Indeed there exist states of multi-particle systems which are so densely (or rather, scarcely) coded that the only information which can be extracted from them is in terms of correlations among the particles. Thereby the state contains no information about single-particle properties.

A typical example for this is quantum entanglement: there is no separate existence and apartness of certain entities (such as quanta of light) "tightly bundled together" by entanglement. Indeed, the entire state of multiple quanta could be expressed completely, uniquely and solely in terms of correlations (joint probability distributions) [58, 365], or, by another term, relational properties [588], among observables belonging to the subsystems; irrespective of their relativistic spatio-temporal locations [464].

Consequently, as expressed by Bennett [287], one has *"a complete knowledge of the whole without knowing the state of any one part. That a thing could be in a definite state, even though its parts were not.* [[. . .]] *It's not a complicated idea but it's an idea that nobody would ever think of from the human experience that we all have; and that is that a completely perfectly, orderly whole can have disorderly parts."*

Schrödinger was the first physicist (indeed, the first individual) pointing this out. His German term was *Verschränkung* [452, pp. 827–844]; his English denomination *entanglement* [453]: *"When two systems, of which we know the states by their respective representatives, enter into temporary physical interaction due to known forces between them, and when after a time of mutual influence the systems separate again, then they can no longer be described in the same way as before, viz. by endowing each of them with a representative of its own. I would not call that one but rather the characteristic trait of quantum mechanics, the one that enforces its entire departure from classical lines of thought. By the interaction the two representatives (or ψ-functions) have become entangled."*

Conversely, if in a two-particle entanglement situation a single particle property is observed on one particle, this measurement entails a complete knowledge of the respective property on the other particle – but at the price of a complete destruction of the original entanglement [452, p. 844] a zero sum game of sorts.

It is important to note that Schrödinger already pointed out that there is a trade–off between (maximal) knowledge of relational or conditional properties (German *Konditionalsätze*) on the one hand, and single particle properties on the other hand; one can have one of them, but not both at the same time.

This has far-reaching consequences.

If the observer obtains "knowledge" about, say, a constituent of an entangled pair of particles whilst at the same time being unaware of the other constituent of that pair, this "knowledge" cannot relate to any definite property of the part observed. This is simply so because, from the earlier quotation, its parts are not in a definite state.

This gets even more viral if one takes into account the possibility that *any* measured "property" might not reflect a definite property of the state of that particle prior to measurement. Because there is no "local" criterion guaranteeing that the object observed is not entangled with some other object(s) out there – in principle it could be in a relative, definite state with some other object(s) thousands of light years away.

Worse still, this entanglement may come about a posteriori; that is *after* – in the relativistic sense lying "inside" the future light cone originating from the space-time point of the measurement – a situation often referred to as *delayed choice*.

Surely, classical physics is not affected by such qualms: there, any definite state of a multipartite system can be composed from definite states of the subsystems. Therefore, if the subsystems are in a definite state it makes sense to talk about a definite property thereof. No complications arise from the fact that a classical system could actually serve as a subsystem of a larger physical state.

1.4 Inset: How to Cope with Perplexities

Already at this stage perplexity and frustration might emerge. This is entirely common; and indeed some of the most renown and knowledgeable physicists have suggested – you would not guess it: to look the other way.

For instance, Feynman stated that anybody asking [211, p. 129] *"But how can it be like that?" will be dragged " 'down the drain', into a blind alley from which nobody has yet escaped."*

Two other physicists emphasize in their programmatic paper [228] entitled *"Quantum theory needs no 'Interpretation' "* not to seek any semantic interpretation of the formalism of quantum mechanics.

These are just two of many similar suggestions. Bell [43] called them the *'why bother?'ers*, in allusion to Dirac's suggestion *"not be bothered with them too much"* [175].

Of course, people, in particular scientists, will never stop "making sense" out of the universe. (But of course they definitely have stopped talking about angels and demons [266], or gods [547] as causes for many events.)

Other eminent quantum physicists like Greenberger are proclaiming that *"quantum mechanics is magic."*

So, the insight that others have also struggled with similar issues may not come as great consolation. But it may help to adequately assess the situation.

1.5 Extrinsic Observers

When it comes to the perception of systems – physical and virtual alike – there exist two modes of observations: The first, *extrinsic* mode, peeks at the system without interfering with the system.

In terms of interfaces, there is only a one-way flow from the object toward the observer; nothing is exchanged in the other direction. This situation is depicted in Fig. 1.3.

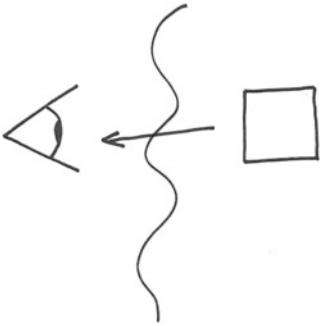


Fig. 1.3 The extrinsic observation mode is characterized by a one-way information flow from the object toward the observer

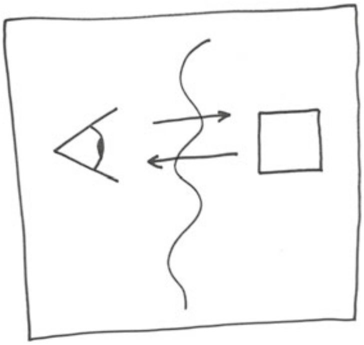


Fig. 1.4 The intrinsic observation mode allowes a two-way information flow between the object and the observer. Both observer and object are embedded in the same system

This mode can, for instance, be imagined as a non-interfering glance at the observed system "from the outside." That is, the observe is so "remote" that the disturbance from the observation is nil (fapp).

This extrinsic mode is often associated with an asymmetric classical situation: a "weighty object" is observed with a "tiny force or probe." Thereby, fapp this weighty object is not changed at all, whereas the behaviour of the tiny probe can be used as a criterion for measurement. For the sake of an example, take an apple falling from a tree; thereby signifying the presence of a huge mass (earth) receiving very little attraction from the apple.

1.6 Intrinsic Observers

The second *intrinsic* observation mode considers embedded observers bound by operational means accessible within the very system these observers inhabit.

One of its features is the two-way flow of information across the interface between observer and object. This is depicted in Fig. 1.4.

This mode is characterized by the limits of such agents, both with respect to operational performance, as well as with regards to the (re)construction of theoretical models of representation serving as "explanations" of the observed phenomenology.

1.7 Nesting

Nesting [30, 31] essentially amounts to wrapping up, or putting everything (the object-cut-observer) into, a bigger (relative to the original object) box and consider that box as the new object. It was put forward by von Neumann and Everett in the context of the measurement problem of quantum mechanics [206] but later became widely known as *Wigner's friend* [571]: Every extrinsic observation mode can be

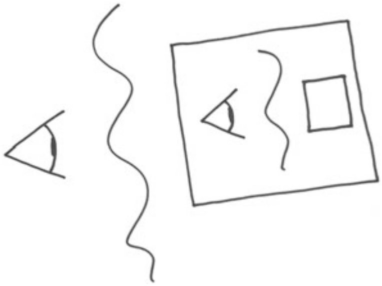


Fig. 1.5 Nesting

transformed into an intrinsic observation mode by “bundling” or “wrapping up” the object with the observer, thereby also including the interface; see Fig. 1.5 for a graphical depiction.

Nesting can be iterated ad infinitum (or rather, ad nauseam), like a Russian doll of arbitrary depth, to put forward the idea that somebody’s observer-cut-object conceptualization can be another agent’s object. This can go on forever; until such time as one is convinced that, from the point of view of nesting, measurement is purely conventional; and suspended in a never-ending sequence of observer-cut-object layers of description.

The thrust of nesting lies in the fact that it demonstrates quite clearly that extrinsic observers are purely fictional and illusory, although they may fapp exist.

Moreover, irreversibility can only fapp emerge if the observer and the object are subject to uniform reversible motion. Strictly speaking, irreversibility is (provable) impossible for uniformly one-to-one evolutions. This (yet not fapp) eliminates the principle possibility for “irreversible measurement” in quantum mechanics. Of course, it is still possible to obtain strict irreversibility through the addition of some many-to-one process, such as nonlinear evolution: for instance, the function $f(x) = x^2$ maps both x and $-x$ into the same value.

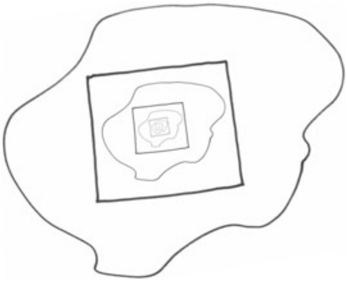
1.8 Reflexive (Self-)nesting

1.8.1 Russian Doll Nesting

A particular, “Russian doll” type nesting is obtained if one attempts to self-represent a structure.

One is reminded of two papers by Popper [416, 417] discussing Russell’s paradox of Tristram Shandy [485]: In volume 1, Chap. 14, Shandy finds that he could publish two volumes of his life every year, covering a time span far shorter than the time it took him to write these volumes. This de-synchronization, Shandy concedes, will rather increase than diminish as he advances; one may thus have serious doubts about whether he will ever complete his autobiography. Hence Shandy will never “catch

Fig. 1.6 Reflexive nesting



up.” In Popper’s own words [417, p. 174], *“Tristram Shandy tries to write a very full story of his own life, spending more time on the description of the details of every event than the time it took him to live through it. Thus his autobiography, instead of approaching a state when it may be called reasonably up to date, must become more and more hopelessly out of date the longer he can work on it, i.e. the longer he lives.”*

For a similar argument Szangolies [526] employs the attempt to create a perfectly faithful map of an island; with the map being part of this very island – resulting in an infinite “Russian doll-type” regress from self-nesting, as depicted in Fig. 1.6. The origin of this map metaphor has been a sign in a shopping mall depicting a map of the mall with a “you are here” arrow [527].

Note that the issue of complete self-representation by any infinite regress only is present in the intrinsic case – the map being located within the bounds of, and being part of, the island. Extrinsically – that is, if the map is located outside of the island it purports to represent – no self-reflexion, and no infinite regress and the associated issue of complete self-description occurs.

Note also that Popper’s and Szangolies’s metaphors are different in that in Popper’s case the situation expands, whereas Szangolies’s example requires higher and higher resolutions as the iteration covers ever tinier regions. In both cases the metaphor breaks down for physical reasons – that is, for finite resolution, size or precision of the physical entities involved.

1.8.2 Droste Effect

Reflexive nesting has been long used in art. It is nowadays called the *Droste effect* after an advertisement for the cocoa powder of a Dutch brand displaying a nurse carrying a serving tray with a box with the same image.

There are earlier examples. Already Giotto (di Bondone) in the 14th century used reflexivity in his Stefaneschi Triptych which on its front side portrays a priest presenting an image of itself (the Stefaneschi Triptych) to a saint.

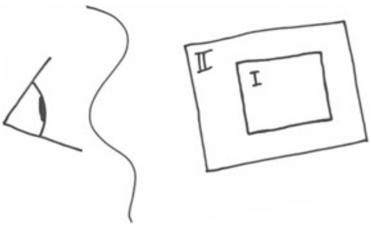


Fig. 1.7 Chaining

The 1956 lithograph "Prentententoonstelling" ("Print Gallery") by Escher depicts a young man standing in an exhibition gallery, viewing a print of some seaport – thereby the print blends or morphs with the viewer's (exterior) surroundings. The presentation of reflexivity is incomplete: instead of an iteration of self-images it contains a circular white patch with Escher's monogram and signature. A "completion" has been suggested [471] by filling this lacking area of the lithograph with reflexive content.

For a more recent installation, see Hofstadter's video camera [283, p. 490] which records a video screen picture of its own recording.

1.9 Chaining

A variant of nesting is *chaining*; that is, the serial composition of successive objects. In this case the cut between observer and object is placed between the "outermost, closest" object and an observer, as depicted in Fig. 1.7.

Chaining has been used by von Neumann [552, 554, Chap. VI] to demonstrate that interface or cut can be shifted arbitrarily.