2

The Syntax and Semantics of Medical Language

2.0 Introduction

When did you last say to someone that you had a headache? Did the listener understand what you meant? If you now reply "yes", how do you know that? Perhaps she usually means by the term "headache" something different than you do. How can we find out whether or not this assumption is true?

When did you last say that someone, for example, a patient or a relative, had jaundice? Did you mean that her skin and the whites of her eyes looked yellow? Do you say "yellow"? What does this term mean? Try to explain it to me and to yourself. After having explained it, consider the following, additional question. Under what light condition did you look at her skin and the whites of her eyes? Try to look at them under another light condition and to describe what you see then.

"Language is the source of misunderstandings", said the fox to the Little Prince. Language is the source of misunderstandings and errors not only because we often don't know whether our listener correctly understands what we say, but also because we ourselves often cannot exactly explain what we really mean by what we say. For example, try to explain to your listener what you mean when you say that you have a 'headache', are 'depressed', or that your patient has 'multiple sclerosis', 'delusions', an 'illness', or a 'disease'. These examples demonstrate that especially in medicine, the language we use often leaves us in the lurch because it is semantically underdeveloped and does not accord with ideal, scientific standards. In the current section, we will try to understand this *fact* in order to find out whether it is possible to ameliorate it by using sophisticated methods of concept formation that are unknown or neglected in medicine. Our discussion divides into the following six sections:

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2.1 Medical Language is an Extended Natural Language

Although medical technology has developed breathtaking techniques and devices in many areas, e.g., in surgery, cardiology, clinical chemistry, immunology, etc., medical language is still light years away from similar achievements. To understand the reasons for this linguistic stunting, we must first distinguish between *natural* languages such as English and German, on the one hand; and *formal* languages, on the other. The former ones emerge and evolve naturally in the communities employing them, whereas the latter ones are artificially constructed for use in disciplines such as mathematics, logic, and computer programming (see Part IX).

Formal languages are characterized by a precise syntax and semantics. By contrast, a natural language has a fairly vague syntax known as its grammar, and lacks any explicit semantics. Its semantics is implicitly determined by a dynamic group decision-making in the process of its use in communities. How people use a term, establishes what it means. Its use varies over time.

To explain, note that every scientific branch has its own scientific language. Examples are the languages of physics, chemistry, theology, and medicine. Unlike the formal languages of mathematics, logic, and computer programming that are artificial systems of signs with precise syntactic and semantic rules, most scientific languages develop as mere expansions of natural language with the admixture of technical terms. Medical language belongs to this intermediate category. It emerges from natural, workaday language by adding terms such as "angina pectoris", "appendicitis", "nerve membrane potential", "immunocytoma", etc. This is the reason why it has no specific syntax and semantics beyond that of natural language. To give an example, consider the term "disease" that denotes the fundamental concept of medicine, i.e., the *concept of disease* underlying nosology and clinical research and practice. Although one would expect it to be a well-defined technical term, it is as yet an undefined phrase. Nobody knows what it means exactly, and apart from a few philosophers of medicine, nobody is interested in its exact meaning. The term languishes without any semantics as if it were an irrelevant or gratuitous one. Its derivatives share with it the same semantic obscurity. For instance, it is unclear what the adjective "diseased" means and what its application domain might be. To which one of the following classes are we allowed to apply it?

> Human beings, organisms, minds, organs, tissues, cells, genes, molecules, animals, plants, societies, buildings, machines, planets.

Although all of us will agree that human beings may be diseased, questions of the following type will give rise to fruitless debates: Can an organism be diseased? Can a human mind be diseased? Can an organ be diseased? Can

there be diseased tissues, cells, genes, molecules, animals, plants, societies, buildings, machines, planets, etc.? These brief notes demonstrate how the inexactitudes and peculiarities of natural language enter into medicine via its syntactically and semantically underdeveloped language. In the next sections, we shall be concerned with some of these peculiarities. However, it may be useful first to consider the general semantics of medical terms.

2.2 What a Medical Term Means

It may seem natural to suppose that the meaning of a word is something that enables it to play the role it plays in human language and communication. For example, nobody is surprised at experiencing that in response to the request "Doctor, please measure my *blood pressure!*" the doctor measures one's *blood pressure* instead of taking an X-ray photograph of the stomach. Otherwise put, the meaning of a word such as "blood pressure" is what transforms it from being an empty sound or inscription, into an effective and useful device in human communication. As plain as this seems, there is as yet no commonly accepted answer to the question "what does 'meaning' mean?". A variety of controversial theories of meaning have been put forward until now each of them having its own advantages and shortcomings. See, for example (Frege, 1892a, 1892b; Quine, 1960; Grice, 1989; Dummett, 1993).

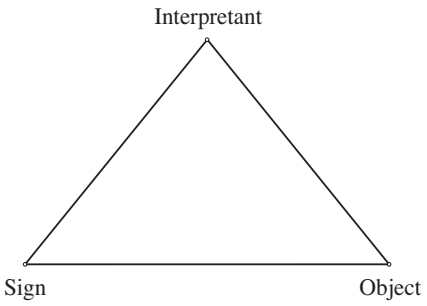

Fig. 5. The semiotic triangle

Traditionally, a term is viewed as a linguistic label that signifies (denotes, designates) an object in the world, be it a concrete or an abstract one. The term is thought to stand in the language as a representer for that object, e.g., "apple" for the fruit *apple*; "belief" for the propositional attitude *belief*; "cirrhosis" for the liver disease *cirrhosis*; "David" for my son *David*; and so on. According to this traditional conception, for the user of a term as its interpretant, the term's meaning comes from this term-to-object correlation. The well-known semiotic triangle reflects this signification idea (Figure 5). It appears at first sight that there is some evidence in favor of this traditional view. For example, from the difference in the veracity of the following two statements, we must conclude that each of the two terms "The Eiffel Tower" and "The World Trade Center" signifies a corresponding object in the world:

1. The Eiffel Tower was destroyed on September 11, 2001, by terrorist attacks;

2. The World Trade Center was destroyed on September 11, 2001, by terrorist attacks.

Nevertheless, the conception of "meaning as signification" is not convincing. The reason is that from the huge ocean of linguistic expressions only individual constants, i.e., proper names, may be considered as signifiers such as, for example, "Albet Einstein", your and my name, "The Eiffel Tower", "The World Trade Center", and others. We shall see below that the remainder of the ocean has nothing to do with signifying and representing any object in the world. For instance, what object in the world does a term such as "love", "schizophrenia", "sin", "electron", or "my death" signify? Such expressions do not derive their meaning from signifying anything in the world out there, but from the way they are related with other expressions within the language itself. We will therefore suggest a suitable, practical frame to guide our discussions in what follows.

The tradition of the modern meaning philosophy started with Gottlob Frege's conception of meaning as a compound of a term's *extension* and *intension* (Frege, 1892a, 1892b; Carnap, 1947). First, the denotation or *extension* of a linguistic expression, relative to a particular language, is the single object or the set of objects to which the expression refers. For example, the extension of the term "Albert Einstein" is, relative to the English language, the famous physicist Albert Einstein, and the extension of the term "has angina pectoris" comprises, relative to the same language, the set of all patients who have angina pectoris. Second, the connotation or *intension* of an expression is, relative to a particular language, the informational content of the expression consisting of the set of all features an object must possess to belong to its extension. For instance, the intension of the term "has angina pectoris" is, relative to the English language, the property of having angina pectoris, i.e., a set of features such as precordial chest pain brought on by stress or exertion, electrocardiographic or scintigraphic signs of myocardial ischemia during pain or exercise, etc. ("Myocardial ischemia" means "reduced blood supply to the heart muscle".) Thus, we may conveniently say that the meaning of a term t relative to a particular language $\mathcal{L}$ is an ordered pair consisting of its extension and intension. That is: the meaning of t relative to language $\mathcal{L} = \langle$extension of t relative to $\mathcal{L}$, intension of t relative to $\mathcal{L}\rangle$.

The extension of a term is also called its referent. The term-to-referent relation is named *reference*. For example, the referent of "has angina pectoris" is, relative to the English language, the set of all patients who have angina pectoris. The intension of a term is also called its *sense*. So, one may say that the meaning of a term relative to a particular language consists of its referent and sense relative to that language. Thus, meaning is language relative.

Note the following two important principles: (i) 'same extension, different intension' is possible; (ii) 'same intension, different extension' is impossible. The first principle means that two terms may be *coextensive* in that they refer to the same object or set of objects, while having different senses nonetheless.

For example, the terms "equilateral triangle" and "equiangular triangle" are coextensive. Both of them refer to one and the same set of triangles. However, they don't have the same sense because a triangle's having three equal sides is a different feature than its having three equal angles. That means that two coextensive terms are not in general interchangeable if they are not *cointensive*, i.e., if they have not the same intension. Consider, for instance, the predicates "is a female" and "has two X chromosomes". They are coextensive because the set of females is exactly the set of those human beings who have two X chromosomes. Suppose now that the following sentence is true:

Hippocrates knows that his patient *Alcestis* is a female.

Surprisingly, this sentence will become false if we replace the term "is a female" with "has two X chromosomes":

Hippocrates knows that his patient *Alcestis* has two X chromosomes.

The reason is that the two terms are not cointensive. They have different senses. Two millennia ago Hippocrates couldn't know anything about his patient's chromosomes. By contrast, 'same intension, different extension' can never occur. Cointensive terms are necessarily also coextensive and may always be substituted for one another.

In closing this section, we will now utilize the terminology above for medical terms. To this end, the following types of medical terms are to be distinguished (readers not acquainted with logic and its terminology should study Part IX first):

1. Individual constants (proper names) such as "the patient Elroy Fox", "Albert Einstein", "Elroy Fox's heart".
2. m-place predicates with $m \geq 1$ such as the unary predicate "has angina pectoris"; the binary predicate "... is lateral from ..."; the ternary predicate "... is located between ... and ..."; and so on. An example may illustrate the latter predicate: "The forefinger is located between the thumb and the middle finger", formalizable by $Pxyz$.
3. n-place function symbols with $n \geq 1$ such as the unary function symbol "the heart rate of" in the following statement: "The heart rate of Elroy Fox is 76", i.e., hr(Elroy Fox) = 76.

Since an n-ary function is an $(n+1)$-ary relation, an n-ary function symbol may be reconstructed as an $(n+1)$-ary predicate. For instance, the unary function symbol 'hr' in group 3 above may be rewritten as a binary predicate of the following form: HR(Elroy Fox, 76). For this reason, function symbols need not always be considered separately and are included as predicates in group 2 above.

We can now inquire into the meaning of such terms. The meaning of a medical term in a particular language consists of its extension and intension relative to this language, i.e., its referent and sense. First, the extension of a

proper name is the individual person or object the name refers to; its intension is the property of being that individual or object. Second, the extension of an n-ary predicate is the set of all objects the predicate applies to; its intension comprises all features an object must have to be a member of that extension. For instance, the unary predicate "has Alzheimer's disease" has all human beings as its extension who suffer from Alzheimer's disease. Its intension is the state of having this disease, that is, a set of defining symptoms and signs such as memory impairment, apraxia, agnosia, etc.

Since meaning is language relative, it does not *reside* in a term itself. One will not be able to uncover it by inspecting or analyzing the printed or spoken word. The meaning of a term manifests itself in the manner of how the users of a language use the term in their communications, including writings. That is, it manifests itself in their linguistic behavior. For instance, if the members of a community currently *employ* in their utterances the term "fever" to talk about the state of elevated body temperature of a patient, then in this community the term "fever" presently means elevated body temperature. Maybe after a few months, years, or decades they will use it in other circumstances, for example, to refer to flying saucers. It will in that case be true to say that in this language community *the meaning of the term "fever" has changed*, i.e., both its extension and intension. But what is it that has changed? It is the behavior of the members of the community in using, and in reacting to, particular utterances that has changed, i.e., the modes of their language use as Ludwig Wittgenstein would say.[6]

Although Wittgenstein's conception of 'meaning as use' may appear to be at variance with the Fregean conception of meaning as 'extension and intension', they are compatible. Fregean meaning is in fact determined by how people use the elements of language.

2.3 Ambiguity

In addition to its language dependence, meaning is also context-dependent. An instance to support this thesis is the ambiguity, or polysemy, of terms. A term is called *ambiguous*, or polysemous, if it has more than one meaning. Such a term is differently used and understood in different contexts. For example, the term "bank" has at least three different meanings: financial institution, the ground near a river, a supply such as a sperm bank. This type of ambiguity cannot be avoided and is harmless. But there is also another type of ambiguity that is not harmless. Although it could in principle be avoided, it is scarcely noticed in medical community. It dominates the language of medicine, especially the clinical sublanguage. We have already referred to it on page 29 as a one-to-many assignment of words to concepts such that one

[6] The idea of *meaning as use* has been developed by Ludwig Wittgenstein in his posthumously published work *Philosophical Investigations* (1953). See below.

and the same word is used as a name for different concepts possessed by different individuals. For example, if the word:

"schizophrenia" names: (a) my concept of schizophrenia,
(b) your concept of schizophrenia, and
(c) the concept of any other person,

whereas the concept of schizophrenia everyone of us possesses is *a private one* different from the others, and there is no public, agreed-upon concept of schizophrenia shared by all of us, then our communication about schizophrenia will suffer from an *inter-user ambiguity* of the term. As a consequence, we shall talk past each other. For this reason, the inter-user ambiguity is semantic-pragmatically malignant. The only cause of this widespread disease of medicine is that most medical terms are not defined, a circumstance that in clinical domains gives rise to misdiagnoses because it prevents the emergence of reliable and useful knowledge. It can easily be remedied by teaching medical students, scientists, and authors how to *define* terms so that in their publications they could clearly define a new term that they introduce. The acquisition of this basic skill is sorely needed in medicine. We shall come back to this issue in Chapter 6 (pp. 93–118).

2.4 Vagueness

Another ubiquitous phenomenon in medicine and its language is *vagueness*. It is something different than ambiguity. Since it is of paramount importance in medicine and medical ethics, and may be regarded a reason to revise the fundaments of medical sciences, practice, and reasoning, it merits particular attention and appropriate evaluation and treatment. We shall touch on only a few aspects of this comprehensive topic in the following three sections:

2.4.1 The Nature of Vagueness
2.4.2 The Sorites Paradox
2.4.3 Varieties of Vagueness

to suggest a solution. For a comprehensive account, see (Graff and Williamson, 2002; Hyde, 2008; Keefe, 2007; Sorensen, 2004; Williamson, 1994).

2.4.1 The Nature of Vagueness

In this book we are concerned, among other things, with the philosophy, methodology, and logic of clinical judgment. Central to clinical judgment in the clinical encounter and the diagnostic-therapeutic process is the question whether or not the health condition of a patient is an instance of a particular symptom, syndrome, disease, allergy, impairment, and the like. The result of such categorization is usually expressed by declarative sentences of the

form "the patient is an X, she is not a Y". For example, "the patient has angina pectoris, she does not have pneumonia". The physician will encounter many hard problems in her decision-making when the labels of the respective categories, i.e., the terms "angina pectoris" and "pneumonia" in the present example, are *vague*. The logical, epistemological, and practical aspects of this issue are briefly examined in what follows. First, the nature of vagueness will be analyzed in these two sections:

- Vagueness described
- Vagueness defined.

To understand our analyses requires acquaintance with logic, especially fuzzy logic, discussed on pages 1065–1120 in Part IX.

Vagueness described

To begin with, we distinguish between clear-cut terms and vague terms. A *clear-cut* term has an extension with sharp, abrupt boundaries. An example is the term "even number". Its potential application domain is the set of integers, with its extension being the set of even numbers $\{\ldots, -4, -2, 0, 2, 4, \ldots\}$. Given any member, e.g., 275 or 276, the term either definitely applies or definitely does not apply to that number. There is no third possibility and no reason for uncertainty whether the number is even or not. The term is not tolerant, so to speak. Otherwise put, the application of the term to a number such as 276 generates a bivalent statement that is either true or false, i.e., the statement "276 is an even number" in the present case. By contrast, an expression is *vague* if it behaves according to the following tolerance principle, TP. See also (Forbes, 1985, 161):

> A term t is tolerant iff an object to which it applies, a t-object, is allowed to be slightly different from what it is to remain still a t-object. (TP)

As defined on page 896, the shorthand "iff" stands for "if and only if" throughout. For example, a *young* man would still be considered young even if he were a few days younger or older than he actually is. In other words, adding a few days to, or subtracting a few days from, his age does not make him abruptly *non-young*. This tolerance of the term "young" brings with it a continuousness of its extension such that it contains borderline cases of which it is not definitely decidable whether or not the expression applies. This indeterminacy and undecidability is not caused by a lack of information about the term or the objects. For instance, the term "young" has borderline cases such as 42-year-old human beings. Although an individual of this age qualifies as a borderline 'young' human being, no empirical, conceptual, or logical analysis will enable us to decide whether she is definitely young or definitely not young. The set of young people as the referent of the term "young" has a

broad grey area, and the people who are 42 years old reside in that area (see Figure 102 on page 1074).

Most medical terms, e.g., "icteric", "angina pectoris", "inflammation", "pneumonia", "Alzheimer's disease", and "schizophrenia" resemble our example "young" and are vague because they are tolerant according to TP above. Before inquiring into the nature and consequences of their vagueness, we will take a look at a short text on *pneumonia* quoted from a clinical textbook to see why vague terms are both unavoidable and desirable in medicine. As a technical term, "vague" is by no means pejorative:

In adolescents and adults the onset is sudden and may come 'out of the blue'; but often the patient has indeed a cold or other respiratory infection and rapidly becomes much more ill, perhaps with an initial rigor but always with a sharp rise in temperature, usually to 101–103 °F. Pleuritic pain usually develops over the affected lobe. The patient may become aware that he is breathing rapidly and certainly feels ill. Initially there may be a dry, painful cough but soon the cough becomes productive of sputum which is characteristically 'rusty' due to its content of altered blood from the foci of red hepatization; quite commonly, however, it is purulent or slightly bloodstained. It is often viscid and difficult to expectorate and this adds to the patient's pain.

In infants the clinical features are less constant and often misleading. Pneumonia in the newborn may present as pyrexia or tachypnoea with hyperthermia or as a feeding problem. In older children, signs of meningeal irritation and complaints of upper abdominal pain commonly dominate the clinical picture, while the initial pyrexia may cause convulsions or vomiting in children aged 1–5 years. Children under 7 years seldom spit (Passmore and Robson, 1975, 18.28).

A closer look at the text above shows that a variety of vague notions are involved in presenting and conveying medical knowledge. First of all, we encounter four types as described in Table 1.

Table 1: Some types of vague or fuzzy terms in medical language

Type of terms:	**Examples:**
1. Vague predicates:	child, adolescent, adult, cold, ill, pneumonia, rigor, viscid, purulent, pyrexia, tachypnoea, hyperthermia, rusty, cyanosis, icterus, red, yellow, pain, headache, malaise, hepatomegalia, tender, polyuria, oliguria, sub-clinical, etc.
2. vague quantifiers:	few, many, most, almost all.
3. vague temporal notions:	acute, chronic, sudden, rapidly, soon.
4. vague frequency notions:	almost always, commonly, usually, often, quite often, very often, seldom, quite seldom, very seldom, etc.

We will here concentrate on vague predicates only. Let us use the first term as an example. It is true that a 1-year-old human being is a child. 2-year-olds,

3-year-olds, and 16-year-olds are also children. However, is someone who is seventeen, eighteen, or nineteen years of age a child? Yes or no? We cannot definitely reply *yes* or *no* because people of these ages are borderline cases of the term "child". We will study this phenomenon below.

Let us distinguish between the extension of a predicate and the complement of its extension. Its extension is given by the set of those objects to which the predicate applies. The complement of its extension is given by those objects to which it does not apply. Those objects of which it is not certain whether or not the predicate applies, constitute its borderline cases called its grey area or *penumbra*. A clear-cut predicate such as "even number" does not have a penumbra. By contrast, it is characteristic of a vague predicate such as "child" to have a more or less broad penumbra, and thus, to lack a sharp dividing line between its extension and the complement of its extension. Its penumbra is due to its tolerance according to the tolerance principle, TP, on page 38 above. That we have difficulty in deciding whether seventeen-, eighteen- or nineteen-year-olds are children, indicates that they reside in the predicate's penumbra. Figure 6 illustrates this circumstance.

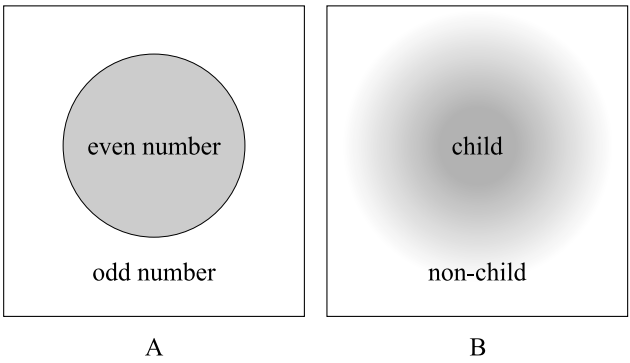

Fig. 6. The difference between clear-cut and vague predicates metaphorically visualized. A: The extension of a clear-cut predicate and its complement are separated from one another by a clear-cut line. B: By contrast, a vague predicate has borderline cases that form a penumbra around the predicate's extension blending it as a fuzzy domain into the complement of its extension

Vagueness defined

A slight formalization may reveal why it is impossible to eliminate, or resist, the semantic tolerance, elasticity, and permissiveness of vague terms like "young", "ill", "icterus", etc. To this end, let us introduce the handy operator "definitely", symbolized by Δ, such that if α is a statement, $\Delta(\alpha)$ says "definitely α". For example, if we are directly standing in front of the Eiffel

Tower in Paris, we may justifiably maintain that Δ(this building is the Eiffel Tower), i.e., "this building is definitely the Eiffel Tower".[7]

We will first define what it means to say that a predicate is vague: A predicate is vague if it denotes a vague class. But what is a vague class?

Definition 1 (Vagueness**).** *A class C is vague iff* $\exists x \neg\Delta(x \in C) \wedge \neg\Delta(x \notin C)$.

That means that a class is vague if and only if it permits borderline cases, that is, if there are some objects which neither definitely belong to it nor definitely do not belong to it. It is these *borderline cases* that form, or reside in, the penumbra of the vague class. For example, the individual Pablo Picasso shows that the class of bald people is vague because:

$$\neg\Delta(\text{Picasso is bald}) \wedge \neg\Delta(\text{Picasso is not bald}).$$

It is indefinite whether Picasso is bald and it is indefinite as well whether he is not bald. Let α be any statement, a sentence of the form:

$$\neg\Delta(\alpha) \wedge \neg\Delta(\neg\alpha)$$

says that we neither know whether α is true nor know whether $\neg\alpha$ is true. This is equivalent to the following statement:

$$\neg\big(\Delta(\alpha) \vee \Delta\neg(\alpha)\big).$$

From this we can conclude that:

$$\neg\Delta(\alpha \vee \neg\alpha).$$

And that means that in the following disjunction contained in it:

$$\alpha \vee \neg\alpha$$

neither α has a truth value nor its negation $\neg\alpha$. But this sentence is exactly the Law or *Principle of Excluded Middle* of classical logic that is extensively discussed in Part IX and will be referred to on several occasions in future chapters. Although the disjunction ought to be definitely true, it is not. Obviously, there is a conflict between vague terms and classical logic. Their tolerant behavior is not covered by classical-logical laws. Otherwise put, classical logic is not reasonably applicable to bald men, young people, icteric patients, and similar things. The only conclusion we can draw from this finding is that classical logic is not the appropriate logic for dealing with vagueness. This fact has already been observed by one of the prominent founders and pioneers of the modern classical logic, Bertrand Russell, as early as 1923 (Russell, 1923).

Due to their penumbra, vague terms generate logical, epistemological, and practical problems which are best demonstrated by the paradoxes of vagueness

[7] The definiteness operator Δ as well as the approach to vagueness using it I owe to Timothy Williamson (2005, 695 ff.).

they give rise to. The prototypical one is the paradox of the heap termed the *Sorites* paradox. This paradox will be sketched below to better understand the nature of, and to ask whether there are any remedies for, vagueness in medicine. For details on the philosophy of Sorites, see (Keefe, 2007).

2.4.2 The Sorites Paradox

A paradox (from the Latin "para" for *beyond*, and the Greek "$\delta o \xi \alpha$" (doxa) for *belief, opinion*) is a correct logical argument that leads from apparently true premises to a false conclusion. The Sorites paradox that will be briefly outlined in this section, emerges from applying classical logic to statements that contain vague terms. It demonstrates how one may classical-logically fall from apparent truth into obvious untruth, an awkward situation we may get in when we unavoidably use in our statements vague terms such as "child", "bald", "heap", "young", "pneumonia", "icterus", "cyanosis", and the like. First consider the following simple example.

Would you say that a one-day-old human being was a child? Yes. Would you say that a two-day-old human being was a child? Yes. Would you say that a three-day-old ...? Yes ..., and so on. But if we continue this question-answering game, you cannot reasonably maintain, for example, that a 36,500-day-old human being was a child. So, where would you draw the line? That is, how would you precisely define the term "child" by fixing a definite age? You will not be able to do so.

One can try to get rid of this annoying and seemingly unsolvable dilemma by a legal decision to entitle a citizen "mature" when she becomes 18 years old, and by issuing the edict "A mature person is not a child any more". This possibility of legal intervention in the semantics of vague terms demonstrates that with regard to a vague term two types of borderline cases must be distinguished: *spurious* and *genuine* ones. Obviously, the borderline cases of the predicate "child" are spurious ones. They disappear by a legal settlement of the issue and transforming the vague term "child" into a clear-cut one. However, not all problematic terms can be defined by legal authorities without engendering absurdities. There are genuine borderline cases that are clearly not legal issues. For instance, would you say that a man with one hair on his head was a bald man? Yes. Would you say that a man with two hairs on his head was a bald man? Yes ..., and so on. But again, if we continue our question-answering game, you cannot reasonably maintain, for example, that a man with 200,000 hairs on his head was a bald man. So, where would you draw the line for baldness?

There is no doubt that drawing any sharp demarcation line in the following fashion to resolve the bald-man dilemma would be absurd: "A man with less than x hairs on his head is bald" where one may substitute for x any favorite number, e.g., 5273 or any other one. The dilemma is known as the bald man or *falakros* puzzle, from the Greek term $\phi \alpha \lambda \kappa \rho o \varsigma$ (falakros) for "bald"; and belongs to a group of related, ancient puzzles attributed to

the logician Eubulides of Megara, a contemporary of Aristotle (Kneale and Kneale, 1968, 114). All of them have the same logical structure. They provoke paradoxical arguments known as little-by-little arguments, and are subsumed under the umbrella label *Sorites* paradox. The term "sorites" derives from the Greek $\sigma\omega\rho\varepsilon\iota\tau\eta\varsigma$ (soreites) meaning "in heaps". Stated semiformally, the paradox emerges from an argument of the following type with a *basis step* and an *induction step* being its premises (readers not acquainted with logic are requested to study Part IX first):

Basis step:	A single grain of sand does not make a heap;
Induction step:	Adding one grain of sand to something that is not a heap, does not turn it into a heap.
Therefore:	100,000 grains of sand do not make a heap.[8]

This is a valid deductive argument by mathematical induction (for the notion of mathematical induction, see footnote 211 on page 1057). It leads from apparently true premises to a false conclusion nonetheless. To understand and analyze the problem, let us rewrite the argument in a somewhat more precise fashion. Henceforth, the phrase "therefore" will be symbolized by a straight line between the premises and their consequence:

1. 1 grain of sand does not make a heap;
2. If n grains of sand do not make a heap, then $n + 1$ grains of sand do not make a heap;

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3. 100,000 grains of sand do not make a heap.

The first premise, *the basis step*, of the argument is true. Its second premise, *the induction step*, is seemingly true. The deduction is correct. But the conclusion is false. Where lies the problem? To elucidate the issue without complicated proofs, the argument can be reformulated by splitting up the premise used in the induction step as follows:

1. 1 grain of sand does not make a heap;
2. If 1 grain of sand does not make a heap, then 2 grains of sand do not make a heap;
3. If 2 grains of sand do not make a heap, then 3 grains of sand do not make a heap;

⋮

n. If 99,999 grains of sand do not make a heap, then 100,000 grains of sand do not make a heap;

100,000 grains of sand do not make a heap.

[8] An alternative formulation is the following, reverse argument by gradual decrease: 100,000 grains of sand constitute a heap. Removing a single grain of sand from a heap results in a heap. Hence, null grains of sand constitute a heap.

Each one of the premises is based on the understanding that heaphood does not depend on a single grain of sand. All of them, taken separately, are true. The reasoning step from premises to the conclusion indicated by the phrase "therefore" is based on the Chain Rule of deduction presented in Table 38 on page 965. So, it is correct. Nevertheless, the conclusion is false. Why?

Since according to Metatheorem 1 on page 970 the deduction rules of classical logic are considered to be sound and truth preserving, whereas the conclusion of the argument above is obviously false, the question arises where this falsehood comes from. Vagueness philosophers concerned with the paradox are still puzzled about its genesis. However, most of their explanations are not convincing. The least plausible one is the so-called epistemicism that holds the view that vagueness is a kind of ignorance. It says, in essence, that the paradox reflects our ignorance of the location of the 'real borderline' between what is a heap and what is not a heap. That is, there really exists a non-heap which by adding a single grain of sand turns into a heap, but we do not know which one it is (Keefe and Smith, 1999; Sorensen, 2004; Williamson, 1994, 2005).

But this view is mistaken. A closer look at the induction premises 2 through n shows that by the Chain Rule they imply the following claim: "If 1 grain of sand does not make a heap, then 100,000 grains of sand do not make a heap". This, however, is an obvious untruth. The untruth is hidden in the whole of the *premises* of the argument. Thus, the Sorites paradox is in fact no paradox, but a logically sound argument with false premises. Their falsehood is caused, and concealed, by little-by-little steps that according to the above-mentioned tolerance principle, TP, *all vague terms* allow. This is the well-known, catastrophic *slippery slope*.

The predicate "heap" is such a vague term. This is unveiled by the operator Δ introduced on page 40. It shows that with respect to many different collections of sand grains, the term gives rise to a statement of the form $\neg\Delta$(this collection of sand grains is a heap) $\wedge$ $\neg\Delta$(this collection of sand grains is not a heap). That is, $\neg\Delta(\alpha) \wedge \neg\Delta(\neg\alpha)$ if α is a shorthand for the sentence "this collection of sand grains is a heap". A finding of the form $\neg\Delta(\alpha) \wedge \neg\Delta(\neg\alpha)$ exactly characterizes the penumbra of a vague predicate. Every predicate that generates a penumbra is vague and denotes a class without sharp boundaries.

In Section 34.1 on page 1067, we distinguish between classical or crisp sets, on the one hand; and fuzzy sets, on the other. In contrast to a crisp set such as "the set of even numbers", a fuzzy set does not have sharp boundaries. The solution to the Sorites paradox is this: A vague predicate refers to a fuzzy set and not to a crisp set. In other words, the extension of a vague predicate is a fuzzy set. Therefore, a vague or fuzzy predicate such as "is bald" or "is a heap" is not two-valued. Thus, it is not the case that such a predicate either applies to an object or not. A man is not simply either bald or not bald, but bald to a particular extent and not bald to another extent. Likewise, a collection of sand grains is not simply either a heap or not a heap, but a heap to a particular extent and not a heap to another extent. In fuzzy logic, the

Sorites paradox cannot arise because arguments such as above are simply not possible. Moreover, the Principle of Excluded Middle cannot be violated for this law is not valid in fuzzy logic at all. See Section 34.2.5 on page 1084.

2.4.3 Varieties of Vagueness

So far we have not touched the question of where to locate vagueness. We must take a cursory glance at this issue because we shall need some clarity about it in later chapters. Is vagueness something merely linguistic? Is it something epistemic? Does it concern the semantic relation of reference? Or is it something ontic, i.e., inherent in the things themselves? We will briefly discuss the above questions in the following four sections:

- Linguistic vagueness
- Epistemic vagueness
- Semantic vagueness
- Ontic vagueness.

Linguistic vagueness

If vagueness were merely a linguistic property of expressions, it could always be removed by making precise the respective terms. The definition of the vague term "child" by the precise concept of maturity on page 42 was such an example. But whenever the attempt to make an expression percise generates absurdity or impracticality, as is the case with terms such as "bald", then non-linguistic vagueness outside language is involved. For instance, try to introduce a precise concept of baldness by, say, defining that a person with less than 5273 hairs on her head was bald. In contrast to the vague notion of baldness, this new, precise concept is both bizarre and impractical. Baldness is too complex a property to be captured by a simple numerical term. A more adequate method is required, e.g., by reconstructing the fuzzy set of bald people by means of its membership function. We shall come back to this issue in Section 22.3 on page 767.

Epistemic vagueness

What is usually viewed as epistemic vagueness, is nothing different than epistemic uncertainty, i.e., uncertain knowledge. For example, we don't know yet whether myocardial infarction is a genetic disease or not. Any assertion on the genetic origin of the patient Elroy Fox's myocardial infarction will therefore be something uncertain, something hypothetical and conjectural, i.e., it will have an indeterminate truth value. This kind of truth-value indeterminacy of statements is obviously due to a lack of information and would be removed if a sufficient amount of information were available. Therefore, it is not advisable to refer to it as vagueness. The vagueness we have been talking

about in previous sections concerns conceptual vagueness such as the features *heap, bald, tall, red, icteric,* and the like, but not propositional aspects and qualities mirrored as epistemic uncertainty. Conceptual vagueness does indeed cause epistemic uncertainty, but such an uncertainty per se is not vagueness. For further details on this issue, see Section 17.4.1 on page 619.

Semantic vagueness

As far as linguistic expressions, pictures, or perceptions represent something, for example, picture x representing person y, such a binary representational relation may be expressed by "$Repr(x, y)$" to say that x *represents* y. An instance of the relation *Repr* may of course be vague if x does not represent y isomorphically. For there may be a better representation that displays more details of y than x does. Thus, a representation as a semantic relation of reference may be more or less vague. It is a *vague relation*.

Ontic vagueness

This neologism stands for *'vagueness in reality'*. The adjective "ontic" means "concerning the being". It originates from the Greek term *ον* (on) that derives from the present participle of the Greek verb *εἶναι* (einai) for "to be".

Ontic vagueness is the prototypical vagueness and the source of all other types of genuine vagueness. It concerns the vagueness of individual objects, classes, relations, and states of affairs in 'the world out there'. Are there such vague entities? And what does their vagueness look like?

Concisely, we cannot know how things are 'in themselves' irrespective of whether or how they are perceived, recognized, or represented. As we shall see in Chapter 27 on page 875, the world looks different depending on what glasses we put on. We may therefore be tempted to take the position that "we shall never know whether there is vagueness in the world out there and whether objects or states of affairs can be vague". To assert or to deny vagueness in the world, will remain an ontological postulate in any case. From a practical perspective, however, it appears reasonable to prefer the affirmative. That means that it is more reasonable than not to suppose that there are vague individual objects, vague sets, including relations, and vague states of affairs. To give three corresponding examples, (i) a frog is a vague animal, i.e., an object with indeterminate spatio-temporal boundaries, because it is impossible to determine when it emerges from a tadpole. There is no abrupt end of being a tadpole and no abrupt start of being a frog. The transition is continuous. Similarly, (ii) the class of bald human beings has no sharp boundaries. It has a penumbral region of genuine borderline cases that imperceptibly vanishes into the set of non-bald people. Finally, (iii) there are also vague states of affairs. For a state of affairs amounts to the belonging of an object to a class. For example, the state of affairs that *Picasso is bald* entails Picasso's membership in the class of bald people. If the class an object belongs to is a vague set,

such as *the class of bald people,* and the object resides in its penumbra, the state of affairs turns out to be something indefinite. That means, according to the terminology we have introduced on page 40, $\neg\Delta$(Picasso is bald) $\wedge$ $\neg\Delta$(Picasso is not bald). That Picasso is not definitely bald and not definitely not bald, is an ontically indefinite, i.e., *vague,* state of affairs.

When we apply these considerations to medicine, we shall easily discern that many medical objects and subjects, e.g., cells, tissues, organs, organisms, persons, patients, symptoms, diseases, individual disease states of patients, and recovery processes are ontically vague to the effect that their vagueness is principally not eliminable. We shall come back to this issue in Chapter 23 on page 773. Fuzzy set theory is a conceptualization and precise theory of ontic vagueness (see Section 34.1 on page 1067).

2.5 Clarity and Precision

"Clarity" is the antonym of vagueness. For instance, "living thing" and "ill" are vague terms, whereas "brother" and "Aspirin" are clear. Precision, however, is something more than mere clarity. A term is precise if it is a clear-cut one due to its numerical nature. A numerical term measures a property such as age, or weight, or intelligence by assigning numbers to it (see Section 5.1.4 on page 82). For example, the term "17 years old" in the statement "Amy is 17 years old" is a numerical, and thus a *precise,* term.

Usually, precision is viewed as an ideal in science. Vagueness is frowned upon, especially in natural sciences. It is generally recommended to make precise or sharpen vague terms. To implement this recommendation radically, however, would mean to give up the tolerance principle TP mentioned on page 38 and to eliminate vague terms from the language of medicine. The idea is based on a misunderstanding and is neither beneficial nor practicable for following reasons:

First, it is not reasonable to sharpen or make precise every vague term because this would severely change natural languages and thereby damage their expressive power. To vaguely say that a patient is *icteric* is much more informative than to precisely say that the light reflected by her skin has a wavelength of 570 nanometers. Second, it would become almost impossible to learn and to employ precise terms in everyday life. For instance, before asserting anything about the color of an object, we would have to measure the wavelength of the light it reflects. Third, medicine is concerned with highly complex systems and issues such as the human organism, suffering persons, and their treatment. By increasing the precision of their analysis, the relevance of the information obtained is not necessarily increased. This has been well expressed by the inventor of fuzzy logic, Lotfi A. Zadeh, whose *Principle of Incompatibility* reminds us to prefer relevance to precision: "Stated informally, the essence of this principle is that as the complexity of a system increases, our ability to make precise and yet significant statements about its

behavior diminishes until a threshold is reached beyond which precision and significance (or relevance) become almost mutually exclusive characteristics" (Zadeh, 1973, 28). We shall come back to this issue on page 631.

2.6 Semantic Nihilism

Our philosophizing on medical language aims at practical goals. One of these goals is to explore whether and how medical language is tied to the real world of suffering human beings and their affairs. We must pay attention to this problem again and again in order to reduce and neutralize the influence that unworldly scientific ambitions and speculations exert on medical knowledge and action by deforming medical language and its semantics. To assess the importance of the issue, we may ask ourselves whether there are any methods of scientific concept formation on which the introduction of terms such as, for example, "schizophrenia", "membrane channels", or "autoimmunity" is based. To this problem area belongs first of all the inquiry into the nature of the meaning of medical terms, i.e., into the medical word-to-world relationship:

Does a medical term *refer* to something in the world? Does it have a *meaning?* The immediate answer to this question will in general be 'yes' because, it will be argued, "otherwise our medical theorizing and practicing would be in vain". We have tacitly shared this traditional view until now and have supposed above that medical terms indeed have a meaning, e.g., the terms "heart" and "angina pectoris". For instance, everybody knows that the term "heart" refers to the central organ of the circulatory system beating in one's chest. It would therefore be strange if someone tried to deny that "heart" refers to, and *means*, just that central organ. However, it is exactly this denial that is the claim of Ludwig Wittgenstein's later philosophy. Words don't mean anything, he says. They refer to nothing. They are only used as a ball is used in a ball game. The use of a word – as a ball is used in a ball game – is its meaning and vice versa. In the present section, we will take a brief look at this disturbing semantic nihilism that was developed by Ludwig Wittgenstein in his *Philosophical Investigations* (Wittgenstein, 1953).

Our aim here is to present Wittgenstein's alternative view that has significant consequences for our understanding of medical semantics and for the analysis and evaluation of medical knowledge and action. Our discussion is based on, and will draw and benefit from, Saul Kripke's interpretation of Wittgenstein's view (Kripke, 1982).

Ludwig Wittgenstein (1889–1951) was a Vienna-born philosopher who taught philosophy at the University of Cambridge from 1939 to 1947. He is viewed as the most influential analytic philosopher of the twentieth century. His work is commonly divided into an early period, culminating in his epoch-making booklet *Tractatus Logico-Philosophicus* (first published in 1921), and a later period from 1929 until his death, culminating in his eminent, posthumously published *Philosophical Investigations* (1953). Both periods are dom-

inated by a concern with the nature of language and the impact it has on mathematics, logic, philosophy, and psychology. In the early work, *Tractatus*, language is treated in a syntactic, semantic, and logical way abstracting from the language user. In the later, pragmatic period, however, the language users, their linguistic activities, and their *form of life* are considered to be the determinants of almost everything. (For the concepts of syntax, semantics, and pragmatics, see Section 30.1.4 on page 923 in Part IX.)

Between his earlier and later writings lies the dramatic change of his philosophy around 1929. His theory of language presented in the later period is practically the repudiation of *Tractatus*. We shall here touch on only one aspect of his new philosophy, i.e., his pragmatic view of semantics expressed by the slogan that *use exhausts meaning*. He begins this philosophy with a criticism of the traditional conception of meaning according to which "Every word has a meaning. This meaning is correlated with the word. It is the object for which the word stands" (Wittgenstein, 1953, section 1).

Usually we believe in this age-old doctrine. We believe, for example, that the word "angina pectoris" stands for a malady consisting of a group of symptoms such as precordial chest pain radiating to the left shoulder and upper arm. Accordingly, we also believe that grasping an expression, or meaning something by an expression such as "angina pectoris", is a mental state or act. Wittgenstein, however, says that there is no such mental state or act. There is no such 'meaning something' by an expression. A word does not stand for something that might be its meaning. To understand a word is not to know what it means, but to know how to use it.

How does Wittgenstein substantiate this radical view? His reasoning is based on the notion of *following a rule* that we will briefly sketch in order to evaluate his insight and his alternative proposal. To this end, we will understand by the term "linguistic rule", or "rule" for short, a standard method or procedure prescribing how a particular term is to be used. Examples are the definition of a term, grammatical rules, and algorithms.[9] Since the consistent application of a term such as "angina pectoris" may be construed as following a rule, i.e., following its definition, we may choose any term such as, for instance, "angina pectoris", "democracy", "minus", or "plus" to study

[9] An *algorithm* for a well-defined class P of problems is an unambiguous, finite and effective sequence of instructions for solving any specified instance of P. Examples are the rules of basic arithmetical operations (addition, subtraction, multiplication, division). An algorithm belongs to the category of *procedural knowledge* (see pages 17 and 471). Its execution is thus a finite procedure that terminates at some point and produces the correct answer. The term "algorithm" derives from the following, italicized surname of the medieval Iranian mathematician Abu Abdullah Mohammed ibn Musa *al-Khwarizmi* (around 800–845). He is viewed as 'the father of algebra'. In contrast to an algorithm, a *heuristics* doesn't terminate for some instances of P. That is, it has not been proved correct for all instances of P either because the procedure is not effective, or the class P is not well-defined. For the terms "heuristics" and "heuristic", see footnote 135 on page 715.

Wittgenstein's argument. For the sake of convenience and transparency, however, we will use the latter term as a simple example.

Suppose you have examined a patient, and on the basis of your final diagnosis you have administered her a particular drug. The maximum dose per day one is allowed to take of this drug, is 120 milligrams. The first portion that you gave her about midday was 80 mg. You advise her to take a second portion in the evening. The tablets you prescribe for her are 40 mg each. How many tablets is she allowed to take in the evening? One tablet or two or more? You are computing the total amount for current day in case she takes a single tablet in the evening: 80 + 40 = ? You perform the computation and straightforwardly obtain "120", the maximum admissible dose. However, your patient is a well-known skeptic and claims that your calculation was wrong. "80 + 40 = 150", she says, "so I must not take the whole tablet in the evening". It is true that you have computed only finitely many sums in the past. Let us suppose that you have never performed a computation such as '80 + 40'. The largest number involved in your exercises may have been 40 (or any other number you like provided you adapt the example accordingly). Nevertheless, you are absolutely sure that your answer "120" for "80 + 40 = ?" is the only right one, and that you must give it if you want to accord with what you have meant by the sign '+' in the past. Therefore, you defend your current computation and try to convince your patient that she has made a mistake. "I have always *meant* the function 'sum' when I have used '+' in the past", you say. "And 80 + 40 is 120".

Your patient stresses that she is not questioning the accuracy of your computation. Nor are your cognitive power and your memory of your computations in the past under dispute. However, you are asked to prove that you have *meant* by "+" the function "sum" in the past and not another function, say "qusum", that may be symbolized by "$\oplus$" and defined as follows:

$$x \oplus y = \begin{cases} x + y & \text{if } x, y \leq 40 \\ \\ 150 & \text{otherwise.} \end{cases} \tag{7}$$

Your patient urges you to demonstrate in the details of your past applications of "+" a *fact* in support of your claim that you have meant the function "sum" rather than "qusum" as in (7) above. It will not be difficult for you to discern that there exists no such fact constitutive of your *having meant* "sum" rather than "qusum" by "+" because all of your past applications of "+" are in complete accord with *qusum*. So, you ought seriously consider the question what rule you have followed until now, the rule for *sum* or the one for *qusum?* Since this question is undecidable, nothing can justify your belief that the answer "120" to the query "80 + 40 = ?" is the right one. You are allowed to do otherwise: Do what you like! There is no such behavior as *following a rule*.

We could of course add to the rule *qusum* a large number of different, other rules all of which would share the past history of your sum rule for "+" in

the same fashion as *qusum* does (see Figure 7). Since your past computation behavior has been finite, and as such, is compatible with all of these distinct rules, the nagging question you will face is this: Which one of these distinct rules did you follow in the past when performing a computation, for example, "80 + 39 = ?". Be it as it may, you could now go in the same or another direction according to how you choose to act. Thus, there is always a large, practically infinite number of divergent and incompatible ways to perform a computation such as "80 + 40 = ?". Therefore, your claim that you mean the *sum* rule by "+" needs to be acknowledged by the community depending on your observable responses to additional problems indicating how you *use* "+". The supposed mental fact constituting your meaning *sum* rather than *qusum* by "+" has thus been replaced with a social fact. Otherwise put, to obey a rule, be it a rule of science or a rule of a game such as chess, is a practice, a custom, an *institution* (Wittgenstein, 1953, sections 199 and 202).

From what has been said above it should be clear that this conclusion does not only concern you or the expression "+". It applies to all users of medical language and all terms.

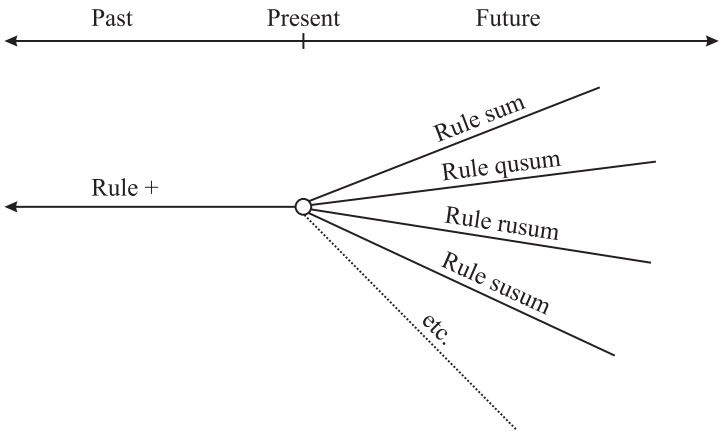

Fig. 7. The compatibility with our *past* behavior of a variety of "possible" and "impossible" rules each of which we may choose to apply in the future

2.7 Summary

Medical language is an expansion of natural, everyday language by adding technical terms. It lacks specific syntax and semantics. Most of its terms are either undefined or not satisfactorily defined. This deficiency is disadvantageous both in medical research and practice and may be responsible for many misdiagnoses. In addition, medical terms are ambiguous and vague. We have shed some light on the nature of vagueness and have distinguished between spurious and genuine vagueness. In contrast to spurious vagueness, genuine

vagueness cannot be eliminated. Moreover, it is a desirable property because the precision of scientific investigations decreases the relevance of their results. The best method of dealing with vagueness is fuzzy logic discussed in Chapter 34 on pages 1065–1120. We shall see in later chapters that its application may also advance medical semantics by improving methods of concept formation in medicine. We have determined the meaning of a medical term to be its extension and intension. A different view has been held by the late Ludwig Wittgenstein who has rejected all theories of meaning to suggest his semantic nihilism instead according to which a term has no meaning per se. Its meaning is the manner of its use by members of a community. We shall try to utilize this pragmatic view in our philosophy of medicine in the next chapters.

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