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# Alice's Adventures in Scienceland

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Lewis Carroll based much of his nonsense humour and curious themes in *Alice's Adventures in Wonderland* and *Through the Looking-Glass* on his expertise in logic and mathematics. Years after the books were written, Alice, under the guidance of new authors, is experiencing new adventures in different regions of Scienceland, from Quantumland to Computerland. Situations, characters and concepts from Carroll's books on Alice are often reused in different scientific fields to illustrate scientific phenomena. Alice has become an archetype placeholder name for experimentalists in physics and cryptology. Carroll's books on Alice have been adopted by the scientific community and it seems that, although it is characteristic for science to keep changing, Alice's adventures in Scienceland are here to stay.

**Keywords:** Alice, Lewis Carroll, logic, mathematics, physics, science

## Introduction

The books of Charles Dodgson (pen name Lewis Carroll) on Alice – *Alice's Adventures in Wonderland* and *Through the Looking-Glass* – are two of those curious books that remain popular long after they were written and are read by an audience much wider than the readership they were written for. Published in 1865 and 1871 respectively, these Victorian books still trigger our imagination and address modern readers, children and grown-ups alike. However, and this is usually the case with books that outgrow the space and time in which they were written, it is difficult to assign them to a particular genre. According to numerous studies published on this topic (Gardner 1998), Carroll's books on Alice can be considered as (children's) fantasies as well as fairy tales, literary nonsense books, satires, (mathematical) allegories or even educational books on logic. Over the decades, not only have children, adult readers, literary scholars and philosophers taken to Alice, but she has also become adored by the scientific community which has adopted her world full of scientific allegories and symbols, and the implications of logical problems and argumentations. As a result, Alice has a parallel life in Scienceland, which can perhaps be interpreted as a continuation of her life in Wonderland, which Carroll, or better to say Dodgson,[1] a mathematician, logician and Oxford scholar, already designed to contain elements inspired by his expertise in logic and mathematics. Thus, to understand the complex Wonderland, it is necessary to understand Dodgson's attitude towards contemporary science and be acquainted with his work in mathematics and logic, which has already been extensively studied. For a long time, Dodgson was known as a conservative mathematician, ignorant of the advanced mathematics of his time (Becker Lennon 1945, Gridgeman 1970/2008, Beale 1973). However, more recent studies of Pycior (1984) and Abeles (2009) show that Dodgson's rejection of the new mathematical theories, such as non-Euclidean geometries and symbolical algebra "was well informed, but based on a conservative view of mathematics" (Pycior 1984: 150). However, some of his advanced mathematical discoveries have only been recognised in the last decades, for example his work on determinants and mathematics of voting (Abeles 2008, Moktefi 2008, Wilson 2008). Dodgson was often involved in interdisciplinary problems, as his interests in literature, logic and mathematics often intertwined, and made some contributions to probabilities and cryptology (Abeles 2005, Moktefi 2008, Wilson 2008, Seneta 2012). Regarding logic, Dodgson was less committed to tradition and considered symbolic logic superior to traditional formal logic (Moktefi 2008). He was a pioneer of the diagrammatic method of drawing conclusions from propositions and of the expression of classical logic in terms of symbols (Carroll 1887, 1897).

Recognising the status of Wonderland as Scienceland as related to Dodgson being a mathematician and logician, we first analyse Carroll's original Wonderland and its elements inspired by Dodgson's expertise in logic and mathematics, which is subtly incorporated into Alice's curious adventures (section 1: "Carroll's Alice in Dodgson's world of science"). The section includes an analysis of often-overlooked

[1] Expert literature mostly refers to Carroll's works for a general audience, e.g. his literary works and books on logic, and to Dodgson's work in the field of mathematics, life in Oxford, etc. Depending on the context, we will use both names (Carroll and Dodgson) in the present article.

influences of Dodgson's knowledge and interests in science and logic, and helps us understand why Carroll's books on Alice have become so attractive to scientists. We are interested in how Alice or her doubles, Wonderland, and the scenes, characters and concepts from Carroll's books on Alice pour into the current world of science. We analyse the presence of elements from Carroll's books on Alice in current scientific theories and in books on current science, be they expert books (including the philosophy of science) or books popularising science or fiction, including elements from the world of science, e.g. science fiction. The selection of the presented literature is based on Gardner's annotations (1998), the COBISS database (Co-operative Online Bibliographic System and Service), the database of *The Carrollian* (The Lewis Carroll Journal), an extensive web search, and this author's interest in the philosophy of science and fiction related to science. The findings are presented and analysed in section 2: "Alice's further adventures in Scienceland".

## 1. Carroll's Alice in Dodgson's world of science

### *A) The world of nonsense, the world of logic*

*Alice's Adventures in Wonderland* and *Through the Looking-Glass* are often considered two of the best examples of the literary nonsense genre (Lecercle 1994: 1; Schwab 1996: 49–102). Nonsense in the two books is mostly based on logical syllogisms, logical inversions and semantic games. The books contain instances of Carroll's work on symbolic logic later presented in his publications (Carroll 1887, 1897). The examples in his books on logic often contain the same wittiness that we know from the books on Alice, for example the following pair of propositions (conclusion to be found by the reader) (Carroll 1897: 101):

> No portrait of a lady, that makes her simpler or scowl, is satisfactory;
> No photograph of a lady ever fails to make her simpler or scowl.

Dodgson found his game of logic an endless source of amusement (Carroll 1887: [v]); he was very "keen to introduce young people to the delights of symbolic logic" (Wilson 2008: 183) and could not quite understand why children were not amused by it (Gardner 1998). However, his inclusion of logical games in the *Alice* books was much more successful: leaving the pedagogical tone behind, the books can be read as humorous and witty nonsense. Most of this humour and nonsense are there thanks to Carroll's exercises in logic. His characters often use syllogisms containing correct argumentations, but false premises, or wrong argumentation with not so easily discovered logical fallacies – in all cases, the conclusions are absurd and humorous.

In *Alice's Adventures in Wonderland*, Alice, having eaten the left-hand bit of a mushroom and having had her neck enormously extended, meets the Pigeon, who beats her violently with its wings and calls her a serpent (Carroll 2003: 50–51; emphasis in the original):

> "Serpent!" screamed the Pigeon. […]
> "But I'm *not* a serpent, I tell you!" said Alice. "I'm a – I'm a –" […]
> "I - I'm a little girl," said Alice, rather doubtfully […].
> "I've seen a good many little girls in my time, but never *one* with such a neck as that! No, no! You're a serpent; and there's no use denying it. I suppose you'll be telling me next that you never tasted an egg!"
> "I *have* tasted eggs, certainly," said Alice who was a very truthful child; "but little girls eat eggs quite as much as serpents do, you know."
> "I don't believe it," said the Pigeon; "but if they do, why then they're a kind of serpent, that's all I can say."

The Pigeon's logic could fit the following form:

Anyone eating eggs is a serpent.
Little girls eat eggs.
―――――――――――――――
Little girls are serpents.

The argumentation is correct; however, the first premise is, obviously, false. As one of the premises is false, the argument is not sound.

We could also describe the Pigeon's logic as having correct premises, but invalid argumentation:

Serpents eat eggs.
Little girls eat eggs.
―――――――――――――――
Little girls are serpents.

Although the reader immediately identifies flaws in the Pigeon's argumentation, the Pigeon's way of forming premises is often (erroneously) used in everyday dialogues, for example:

Stars are bright objects in the sky.
I saw a bright object in the sky.
―――――――――――――――
It is a star.

Later, Alice has a similar logical conversation with the Cheshire Cat who assures her that they are both mad. To prove its own madness, the Cat explains (Carroll 2003: 61–62):

> "To begin with," said the Cat, "a dog's not mad. You grant that?"
> "I suppose so," said Alice.
> "Well, then," the Cat went on, "you see a dog growls when it's angry, and wags its tail

when it's pleased. Now I growl when I'm pleased, and wag my tail when I'm angry. Therefore I'm mad."

A reader can see that the Cat is talking nonsense. We could describe the Cat's logic in the following way:

Dogs are not mad.
Cats behave in the opposite manner to dogs.
―――――――――――――――――
Cats are mad.

The Cat's argumentation is not valid, as the conclusion (Not Q) is based on a denied antecedent (P):

If P (dog) then Q (not mad). Not P (not dog). Then not Q (mad).

A valid logical deduction would be:

If P (dog) then Q (not mad). P (dog). Then Q (not mad).

Although it is wrong, we often use this logic in our everyday discussions, for example:

When it rains, the roads are wet.
It is not raining.
―――――――――――――――――
The roads are not wet.

Again, Carroll is not following the rules of correct reasoning. He uses invalid argumentation, which is often (erroneously) used in our everyday conversations and considered correct, to create witty, nonsense dialogue.

Another logical question arises later in the story, when Carroll confronts the mathematical and semantic implications of taking away from and adding to nothing. At the mad tea party, the March Hare invites Alice to take some more tea (Carroll 2003: 70; emphasis in the original):

"Take some more tea," the March Hare said to Alice, very earnestly.
"I've had nothing yet," Alice replied in an offended tone: "so I can't take more."
"You mean you can't take *less*," said the Hatter: "it's very easy to take *more* than nothing."

From the mathematical point of view, one does not need to start with anything in order to add to it, and Alice can certainly take more tea if she starts with no tea. But from the semantic point of view this is problematic, as taking more carries the semantic implication that she has already had some (Piette 2009).

A similar ambiguity of natural languages occurs when the White King interprets the word "like" literally, not considering the change of its meaning in a particular context (Carroll 2003: 207):

> "There's nothing like eating hay when you're faint," he remarked to her, as he munched away.
> "I should think throwing cold water over you would be better," Alice suggested: "—or some sal-volatile."
> "I didn't say there was nothing *better*," the King replied. "I said there was nothing *like* it." Which Alice did not venture to deny.

In a similar way, Carroll treats some other peculiar logical problems, which were later comprehensively discussed and analysed by modern logicians. For example, Carroll often uses the treatment of a "null class" (a set with no members) as though it were an existing thing in order to provide a rich source for logical nonsense and humour. As Gardner summarises (1998: 182):

> The March Hare offers Alice some nonexistent wine; Alice wonders where the flame of a candle is when the candle is not burning; the map in *The Hunting of the Snark* is "a perfect and absolute blank"; the King of Hearts thinks it unusual to write letters to nobody, and the White King compliments Alice on having keen enough eyesight to see nobody at a great distance down the road.

In Dodgson's time, there was a fierce debate among mathematicians over negative numbers and zero (for example, whether it makes any sense to divide a number by zero) in which Dodgson took part. Mathematical satire was also popular among Victorian mathematicians, with different views expressed on the discussed mathematical problems, including satire of the mathematical concept of nothing, for example in a humorous essay written by the influential conservative mathematician William Frend. Carroll's humorous treatment of a "null class" in the books on Alice is thus influenced by the Victorian tradition of mathematical humour and his attitude towards progressive mathematics of his time (Pycior 1984).

A great play with semantics, assisted by the logician's point of view, can be seen in "Jabberwocky", which "few would dispute […] is the greatest of all nonsense poems in English" (Gardner 1998: 192). "Jabberwocky" is based on Carroll's position that words (names) are not something a priori connected with things; we just find tagging useful, and this is a matter of agreement (Carroll 1897: 166):

> I maintain that any writer of a book is fully authorised in attaching any meaning he likes to any word or phrase he intends to use. If I find an author saying, at the beginning of his book, "Let it be understood that by the word 'black' I shall always mean 'white' and by the word 'white' I shall always mean 'black'", I meekly accept his ruling, however injudicious I may think it.

In *Through the Looking-Glass*, Alice meets two logicians of a kind who drag her into a sophisticated, although at first glance nonsensical, logical discourse. The first one is Humpty Dumpty (Carroll 2003: 197):

> "I don't know what you mean by 'glory'," Alice said.
> Humpty Dumpty smiled contemptuously. "Of course you don't – till I tell you. I meant 'there's a nice knock-down argument for you!'"
> "But 'glory' doesn't mean 'a nice knock-down argument'," Alice objected.
> "When *I* use a word," Humpty Dumpty said, in rather a scornful tone, "it means just what I choose it to mean – neither more nor less."

Humpty seems to be defining words as he pleases, without a priori instructions on how to understand them. As Gardner writes, "If we wish to communicate accurately we are under a kind of moral obligation to avoid Humpty's practice of giving private meanings to commonly used words" (1998: 270). "In one sense words are our masters, or communication would be impossible. In another we are the masters; otherwise there could be no poetry" (Holmes 1959: 137). To understand science, it is important to remember that the words used in science are jabberwocky words, that they have no meaning outside the meaning scientists have given them in a given context, but this is a meaning that everyone working in the field has agreed upon and they have to stick to if they are to communicate efficiently. However, in poetry, jabberwocky is allowed and welcomed; poets are free to create new words and new meanings.

The second logician that Alice meets is the White Knight, often recognised by Carrollian scholars as a caricature of Carroll himself (Gardner 1998: 296). The White Knight decides to sing Alice a song (Carroll 2003: 225; emphases in the original):

> "Everybody that hears me sing it – either it brings the *tears* into their eyes, or else –"
> "Or else what?" said Alice, for the Knight had made a sudden pause.
> "Or else it doesn't, you know. The name of the song is called '*Haddocks' Eyes*'."
> "Oh, that's the name of the song, is it?" Alice said, trying to feel interested.
> "No, you don't understand," the Knight said, looking a little vexed. "That's what the name is *called*. The name really is '*The Aged Aged Man*'."
> "Then I ought to have said 'That's what the *song* is called'?" Alice corrected herself.
> "No, you oughtn't: that's quite another thing! The *song* is called '*Ways And Means*': but that's only what it's called, you know!"
> "Well, what *is* the song then?" said Alice, who was by this time completely bewildered.
> "I was coming to that," the Knight said. "The song really is 'A-*sitting On A Gate*': and the tune's my own invention."

As Gardner writes: "to a student of logic and semantics all this is perfectly sensible. […] Carroll is distinguishing here among things, the name of things, and the names of names of things" (1998: 306). However, Holmes thinks that Carroll is pulling our leg when he has the White Knight say that the song is "A-sitting On A Gate", as it cannot be the song itself, but another name: "To be consistent, the White Knight, when he had said that the song *is*…, could only have burst into the song itself. Whether consistent or not, the White Knight is Lewis Carroll's cherished gift to logicians" (Holmes 1959: 139; emphasis in the original).

Although sensible to a student of logic, to a reader (and Alice) the White Knight's explanations seem bewildering, nonsensical and funny. The White Knight's dialogue with Alice can be seen as a caricature of Carroll's conversation with non-logicians which includes the use of logical differentiation between different levels of naming, metalanguage and, at the beginning of the quoted dialogue, also an example of the law of excluded middle (if A is not true, then its negation is true), the third of the three classic laws of thought.

### *B) The world of strange events, the world of mathematics*

While the logic games, tricks and fallacies in Carroll's books on Alice are difficult to miss by a reader with at least some understanding of logic, more knowledge of the history of mathematics is required to recognise Carroll's books on Alice as mathematical allegories.

In her paper, Helena Pycior shows that the background of Carroll's books on Alice was formed by "the eighteenth and nineteenth century tradition of popular mathematics and mathematical humour" (1984: 158). Carroll's books on Alice embody his "misgivings about symbolical algebra, the major British contribution to mathematics of the first half of the nineteenth century" (149). Symbolic algebra departed from universal arithmetic (where algebraic symbols stand for specific numbers rooted in a physical quantity) and allowed any operations involving negative and impossible solutions, provided they follow an internal logic. Unlike literary scholars before her (Becker Lennon 1945; Gridgeman 1970/2008; Beale 1973), Pycior argues that Dodgson was not ignorant of symbolical algebra and that his "rejection and ridicule of symbolical algebra was well informed, but based on a conservative view of mathematics" (1984: 150).

While symbolical algebra found no place in Dodgson's teaching, it occupied his mind and imagination. As reported by his fellow student, "Alice was incubated" at their joint mathematical reading party by Professor Price[2] (Pycior 1984: 163):

> […] it was with visions of lines multiplied by lines, quantities less than nothing, and symbolical algebra dancing in his head that Dodgson first set about constructing an other-world (the underground) in which meaninglessness and arbitrariness prevailed.

One of the mathematical problems that inspired humorous passages in his *Alice* books is the problem of negative numbers. Carroll approaches it "through the

[2] Bartholomew Price (1818 – 1898), an English mathematician and an Oxford lecturer, was one of Lewis Carroll's teachers at the university.

definitions of the negatives as 'quantities less than nothing' and 'quantities obtained by taking greater from lesser'" (Pycior 1984: 164) and emphasises their absurdity in the presented context. In *Alice's Adventures in Wonderland*, the Mad Hatter explains to Alice that you can take more (tea) if you had nothing, but you cannot take less, while the Mock Turtle, who "lessened" its lessons (Carroll 2003: 91) each day and started with ten hours of work, refuses to deal with Alice's question how he managed his twelfth day. In *Through the Looking-Glass*, the "Red Queen asks Alice to subtract nine from eight" and Alice, who apparently "acquired some mathematical subtlety […], objects to what she now sees as impossible subtraction" (Pycior 1984: 164).

According to Pycior, Carroll's books on Alice also refer "to a breakdown of mathematics as a science of absolute truths" (1984: 165). When, subjected to the vagaries of her experiences, Alice questions her own identity, she first turns to mathematics, but mathematics fails: "Alice multiplies in a nondecimal base and finds that the multiplication leads nowhere in particular" (ibid.). Pycior argues that Carroll's "choice of a varying nondecimal base is designed […] to indicate the arbitrariness of mathematics. […] Alice finds that mathematics is no mainstay of truth and certainty, and cannot save her from the madness of the underground world" (166). From this perspective, Pycoir argues, the meaninglessness and arbitrariness of symbolical algebra can provide a key to the meaninglessness and arbitrariness of Wonderland (165–166).

It is possible, Pycior argues, that symbolical algebra did not inspire just particular scenes in Carroll's books on Alice, but his nonsense style in general, as (1984: 166):

> [T]he parallels between Carroll's nonsense writings and symbolical algebra are striking: both stressed form or structure over meaning, using words (or other symbols) with multiple possible interpretations.

Pycior links her thesis of "an integral relationship between [… Dodgson's] algebraic views and the *Alices*" to earlier analyses of Carroll's books on Alice, which interpreted them in a similar way, but, "lacking knowledge of the history of English Algebra (readily available only in the last decade)" (1984: 168), did not connect it to symbolical algebra. For example, once we acknowledge Carroll's algebraic views, Rackin's (1966) analysis of meaninglessness as the leading theme of *Alice's Adventures in Wonderland*, argues Pycior, can be more comprehensively explained (Pycior 1984: 168):

> The *Alices* deal with the search for meaning in a meaningless world – a world in which even mathematics no longer signifies. The loss of meaningful mathematics is tantamount to the loss of human certainty.

Thus, Pycior concludes: "The *Alices* were, at least partly, expressions of Dodgson's anxiety over the loss of certainty implicit in mathematicians' acceptance of symbolic algebra" (1984: 170).

More recently, another study connected Carroll's books on Alice with his attitude towards contemporary mathematics (Bayley 2009; see also Bayley 2010). However, while Pycior strives to support her thesis with an extensive study of the context in which Carroll's books on Alice were written and looks for links with earlier analyses to support her interpretation of Carroll's books, Bayley's arguments lack this support. Like Pycior, Bayley reads *Alice's Adventures in Wonderland* in the context of the 19th century which was a turbulent time for mathematics. Considering this context, Bayley (2009) claims that:

> it becomes clear that Dodgson, a stubbornly conservative mathematician, used some of the missing scenes [scenes that were not included in the original story that the author told Alice Liddell and her two sisters during their boat trip] to satirise these radical new ideas.

Dodgson, who highly valued the rigorous reasoning of Euclid's *Elements* (Bayley 2009):

> took his mathematics to his fiction. Using a technique familiar from Euclid's proofs, reduction ad absurdum, he picked apart the 'semi logic' of the new abstract mathematics, mocking its weakness by taking these premises to their logical conclusions, with mad results. The outcome is *Alice's Adventures in Wonderland*.

Based on these assumptions, Bayley interprets some of the scenes from *Alice's Adventures in Wonderland* as mathematical allegories. For example, she believes that the scene with the Caterpillar, "who shows Alice a mushroom that can restore her to her proper size" (Bayley 2009), is actually about the absurdity of symbolical algebra. When Alice's height fluctuates (ibid.):

> Alice, bound by conventional arithmetic where a quantity such as size should be constant, complains this is very confusing. 'It isn't,' replies the Caterpillar and warns Alice to keep her temper. To intellectuals in Dodgson's time, the word 'temper' retained its original sense of 'the proportion in which qualities are mingled'. So the Caterpillar could well be telling Alice to keep her body in proportion – no matter what her size. […] To survive in Wonderland, Alice must act like an Euclidean geometer, keeping her ratios constant, even if her size changes.

In the next chapter "Pig and Pepper", Alice meets the Duchess with a baby, who, when given to Alice, turns into a pig. "The target of this scene," claims Bayley, "is projective geometry, which examines the properties of figures that stay the same even when the figure is projected onto another surface" (ibid.). Dodgson transmits one of its rules that conditions variations of geometric figures – the so-called principle of continuity – to the world of real objects (ibid.):

> What works for a triangle should also work for a baby; if not, something is wrong with the principle, QED. So Dodgson turns a baby into a pig through the principle of continuity. Importantly, the baby retains most of its original features, as any object going through a continuous transformation must.

After leaving the Duchess's house, Alice wanders into the mad tea party, which, as Bailey claims, explores Hamilton's work on quaternions. Quaternions belong to a number system based on four terms. There is one term for each dimension of space, while Hamilton connects the extra term, the extra-spatial unit that he had to add to get the three-dimensional rotation, with the concept of time. At the mad tea party, Alice meets three characters: the Hatter, the March Hare and the Dormouse. "The character Time, who has fallen out with the Hatter, is absent, and out of pique he won't let the Hatter move the clock past six" (Bayley 2009). Without Time, the characters are stuck at the tea table: "Their movement around the table is reminiscent of Hamilton's early attempts to calculate motion, which was limited to rotations in a plane before he added time to the mix" (ibid.). Furthermore, the Hatter's nonsensical riddle "Why is a raven like a writing desk?" may reflect the fact that in the realm of pure time (a philosophical term connected with the role of time in new algebra by Hamilton), cause and effect are no longer linked. Alice's attempt to solve the riddle reflects another aspect of quaternions, namely that their multiplication is non-commutative (a x b is not the same as b x a) (Carroll 2003: 65–66):

> "Then you should say what you mean," the March Hare went on.
> "I do," Alice hastily replied; "at least – at least I mean what I say – that's the same thing, you know."
> "Not the same thing a bit!" said the Hatter. "You might just as well say that 'I see what I eat' is the same thing as 'I eat what I see'!"
> "You might just as well say," added the March Hare, "that 'I like what I get' is the same thing as 'I get what I like'!"
> "You might just as well say," added the Dormouse, who seemed to be talking in his sleep, "that 'I breathe when I sleep' is the same thing as 'I sleep when I breathe'!"

Whether connected with ridicule of Hamilton's work or not, the inspiration for this humorous dialogue can be linked to Dodgson's expertise in mathematics. It confronts the world of mathematics with the world of semantics – the commutativeness of terms/phrases in some contexts and their non-commutativeness in others.

If *Alice's Adventures in Wonderland* was not a mathematical parody, if it did not contain scenes in which Dodgson pokes fun at contemporary mathematics, the tale would still be charming but short on characteristic nonsense, claims Bayley (2009):

> Dodgson was most witty when he was poking fun at something, and only then when the subject matter got him truly riled. […] [W]ithout Dodgson's fierce satire aimed at his colleagues, *Alice's Adventures in Wonderland* would never have become famous, and Lewis Carroll would not be remembered as the unrivalled master of nonsense fiction.

Besides Pycior's and Bayley's comprehensive studies on the influences that Dodgson's attitude to mathematics had on Carroll's books on Alice, some mathematical problems incorporated in the *Alice* books have attracted the attention of other literary scholars and mathematicians. For example, Alice's multiplying, discussed by Pycior (1984) and Gardner (1998), had already been analysed by Taylor (1952) and later by Salins (2000). In *Alice's Adventures in Wonderland*, Alice, not feeling like herself, tests her knowledge: "I'll try if I know all the things I used to know. Let me see: four times five is twelve, and four times six is thirteen, and four times seven is – oh dear! I shall never get to twenty at that rate!" (Carroll 2003: 21). As Taylor and Salins explain, Alice is multiplying in different non-decimal bases, which increase by three, for example 4 x 5 = 12 in base 18, 4 x 6 = 13 in base 21, etc.[3] Thus (Salins 2000: 54–55):

> Alice will never get to 20 (or two-zero) because the base in increasing by three while the product is only increasing by one. Thus the number of available symbols used in the ones column will never be exhausted. In other words, we shall always have one-something and never get two-zero. […] So, Alice needs to head towards -3 to get to twenty (in base -6). Going from five to six to seven and so on won't get her there.

So if we decrease the factors besides four by one and the base by three, we start with 4x5=12 in base 18 and we can end with 4x-3=20 in base -6. As Salins writes, "It appears that Carroll wasn't just making up nonsense"; what appears as nonsense to the uninformed reader is actually a very subtle "ingenious mathematics problem that has twists and turns any way it is approached" (2000: 55).

Carroll, occupied by the new mathematics of his time, no doubt included some of the mathematical twists in *Alice's Adventures in Wonderland*, while new mathematics influenced his writing style and inspired some of the presented scenes. Mathematics could not have been the only source for Carroll's complex "missing scenes" (Bayley 2009) and some of Bayley's interpretations seem to some extent unpersuasive. However, Dodgson's interest in mathematical problems and preoccupation with the advanced mathematics of his time co-create the Wonderland as we know it. Without Wonderland being Scienceland, it would lose much of its charm. But Dodgson managed to create a unique place many scientists have really taken to. Thus, decades after her first adventures in Wonderland, Alice still continues her adventures in Scienceland.

[3] The progression of increasing bases will follow in this manner: $4x7=14_{24}$; $4x8=15_{27}$; $4x9=16_{30}$; $4x10=17_{33}$; $4x11=18_{36}$; $4x12=19_{39}$; $4x13=1A_{42}$, etc.

## 2. Alice's further adventures in Scienceland

### *A) Alice in Quantumland*

Carroll's books on Alice inspired many authors to write their own sequels, adaptations and allusions. In some, Alice (or sometimes her equivalent) continues her adventures in other parts of Scienceland. This has been most directly done by Robert Gilmore who places his Alice in Quantumland. Her travels are used to present the odd world of quantum mechanics (Gilmore 1995: vi):

> The Quantumland in which Alice travels is rather like a theme park in which Alice is sometimes an observer, while sometimes she behaves as a sort of particle with varying electric charge. This Quantumland shows the essential features of the quantum world: the world that we all inhabit.

The quantum theoretical description of the world may seem at first sight to be nonsense and possibly also at the second, third, and twenty-fifth sight, writes the author. However, this nonsense is not provided by parodies, (disallowed) transitions or logical fallacies, but simply by describing the characteristics and the laws of our world on the smallest scale, from the point of view of the classical observer – Alice.

Gilmore borrowed Carroll's Alice, with her wonderment, lust for adventure, wittiness and courage. In his illustrations, Alice is depicted similarly to John Tenniel's famous ones, which shaped the image of Alice among readers worldwide. Gilmore also reused some of Carroll's themes to deliver the message about the strangeness of the quantum world. These themes forced Gilmore to be more playful and less directly educational.

At the beginning of the story, Gilmore's Alice, like Carroll's in *Through the Looking-Glass*, finds herself at the train station and then takes the train to explore the new land. Both Alices are driven into a disagreement with their strange travel companions due to their lack of understanding of the properties and laws of the new, strange lands. Carroll's Alice is asked to show her ticket, which she doesn't have, and consequently gets entangled in a dialogue full of double meanings and logical games. Gilmore's Alice ends up on the train where all compartments seem to be full; however, as she later realises, they are only full for the electrons, because no more than two can occupy each compartment, while Alice (who, although much bigger than the electrons, is not a fermion[4]) can enter any of the compartments.

Throughout the book, Gilmore plays with Carroll's asymmetric relations. In *Through the Looking-Glass*, Carroll often plays with mirror-reflections of

[4] According to the Pauli exclusion principle, only one fermion can occupy a particular quantum state at any given time, thus no more than two electrons with opposite spins can go into each compartment.

the described objects: "If we extend the mirror-reflection theme to include the reversal of any asymmetric relation, we hit upon a note that dominates the entire story" (Gardner 1998: 181). Gardner connects Carroll's notion of inversion with contemporary science, dealing with matter and anti-matter, with particles and anti-particles. In *Alice in Quantumland*, this inversion is incorporated into quantum scenery and explained from the quantum mechanical point of view.[5] When Alice is walking in a park together with her companion the Quantum Mechanic (Gilmore's illustration of the scene resembles Tenniel's illustrations of the garden of live flowers from *Through the Looking-Glass*), she sees another little girl, who looks like Alice in photo-film negatives. They collide and afterwards Alice finds herself walking alone down the reverse-girl's path, while the reverse-girl walks, still backward, along Alice's original path, now accompanied by the negative of the Quantum Mechanic. When Alice looks around, she discovers that her surroundings have also changed – everything seems to be reversed. It is later explained to Alice (Gilmore 1995: 100–101):

> What happened to you would have appeared to the rest of the world as an unusually high-energy photon giving up its energy to create an Alice and anti-Alice. The anti-Alice would travel along until it collided with an Alice and the two mutually annihilated one another, converting their energy back to photons. […] How it would appear to you is quite different […]. For you the annihilation would come before the creation of course. […] if you move *backward* in time you naturally expect the creation to come after destruction from your point of view. […]. As far as your companion was concerned you and the anti-Alice were both utterly destroyed […]. Naturally, the Quantum Mechanic knows about antiparticle annihilation, so he will know that you have simply gone back in time.

In this explanation, the notion of inversion is connected with the reversed time arrow. In Carroll's books on Alice, both of these topics occur, but are not clearly connected. For example, in *Through the Looking-Glass*, the White Queen explains the advantages of living backward in time and the looking-glass cake is first handed around and then sliced.

While discussing virtual particles, Alice and her companion, the State Agent, touch upon another famous theme from Carroll's books on Alice – the "null class". Alice's and the State Agent's dialogue starts very similarly to the dialogue between Alice and the White King in *Through the Looking-Glass* (Carroll 2003: 205):

[5] Tweedledum and Tweedledee, probably two of the most famous characters from *Through the Looking-Glass*, are mirror reflections of each other. Gilmore utilises their likeness when describing two volunteers in a quantum experiment. The volunteers' depiction resembles Tweedledum and Tweedledee. However, we can see that they are not mirror images of each other; they are, as Gilmore writes "not actually identical to one another, since only particles are completely identical, but they were certainly much alike" (1955: 171).

> “I see nobody on the road,” said Alice.
> “I only wish I had such eyes,” the King remarked in a fretful tone. “To be able to see Nobody!”

In *Alice in Quantumland*, Alice, after observing virtual particles through the virtual reality helmet, remarks that she has (Gilmore 1995: 104):

> “[…] seen nothing like it before.”
> “You may well have done so,” returned the Agent. “What you have just seen is like Nothing anywhere else. Though I am a little surprised that you have managed to see Nothing before you came here.”
> “I am sure that I wouldn’t say that,” replied Alice indignantly. “I may not have travelled very much, but I have still seen something, I would have you know.”
> “I have no doubt that you have,” said the State Agent. “I am sure that you came from a very desirable location, but it is relatively easy to see Something, you know. It is much more difficult to see Nothing. I do not know how you could have done it without the aid of my virtual reality helmet.”
> “Just a minute,” interrupted Alice, who had begun to suspect that they were talking at cross-purposes. “Would you tell me please what you mean by Nothing?”
> “Why, yes, certainly. I mean Nothing: the complete absence of any real particles whatever. You know: the Vacuum, the Void, the oblivion of all things, whatever you like to call it.”

Unlike in Carroll’s *Alice* books, Gilmore’s Alice and her companion realise they are talking at cross-purposes. Since Gilmore’s intention is to present the strangeness of Quantumland and reveal the mechanisms behind it, they are also able to resolve their misunderstanding and find appropriate explanations.

Gilmore also reuses the scene with the Cheshire Cat. When Carroll’s Alice meets the Cat she asks it which way she ought to go from where she is (Carroll 2003: 61):

> “That depends a good deal on where you want to get to,” said the Cat.
> “I don’t much care where–” said Alice.
> “Then it doesn’t matter which way you go,” said the Cat.

Gilmore reuses the scene to explain the quantum phenomenon of superposition. This time it is Schrödinger’s Cat[6] (a character from the famous *Gedankenexperiment*) that Alice meets and asks for direction (Gilmore 1995: 49):

> “Oh Cat,” she began rather timidly. “Would you tell me please which way I ought to go from here?”
> “That depends a good deal on where you want to get to,” said the Cat.
> “I am not really sure where…” began Alice.

[6] Erwin Schrödinger (1887 – 1961) was an Austrian physicist and Nobel Prize winner, famous for his achievements in quantum physics. His thought experiment involving a cat refers to the problem of applying quantum mechanics to everyday life objects.

> "Then it doesn't matter which way you go," interrupted the Cat.
> "But I have to decide between these two paths," said Alice.
> "Now that is where you are wrong," mused the Cat. "You do not have to decide, you can take all the paths. Surely you have learned that by now. Speaking for myself, I often do about nine different things at the same time. Cats can prowl around all over the place when they are not observed. Talking of observations," he said hurriedly, "I think that I am about to be obs…" At that point the Cat vanished abruptly.

The scene with the Cat is probably the most quoted passage from Gilmore's book (e.g. Malin 2004: 75–76), mostly due to its witty intertextuality, which offers a perfect canvas for the presentation of one of the most important quantum phenomena.

Later, Gilmore also reuses Alice's and the Red Queen's race from *Through the Looking-Glass* (Carroll 2003: 151–152):

> Alice never could quite make out, in thinking it over afterwards, how it was that they began: all she remembers is that they were running hand in hand, and the Queen went so fast that it was all she could do to keep up with her: and still the Queen kept crying "Faster!" but Alice felt she could not go faster, though she had no breathe to say so. The most curious part of the thing was that the trees and the other things round them never changed their places at all: however fast they went, they never seemed to pass anything. "I wonder if all the things move along with us?" thought poor puzzled Alice. And the Queen seemed to guess her thoughts, for she cried, "Faster! Don't try to talk!"

As the Queen later explains to Alice, in her land "it takes all the running *you* can do, to keep in the same place" (Carroll 2003: 153; emphasis in the original). It is a curious explanation that itself needs a kind of interpretation to be understood, or hence stays uninterpreted as witty nonsense.

The running scene in Gilmore's *Alice in Quantumland* is almost identical: however, this time Alice is running with a heavy virtual photon to get into the nucleus of an atom (Gilmore 1995: 122):

> She could never quite make out, in thinking it over afterwards, how it was that they began: All she could remember was that they were running side by side and the photon was continuously crying 'faster', and Alice felt that she could not go faster, though she had no breath left to say so. […] [T]he most curious part of experience once they were inside the atom was that the things around them never changed in position.

As the photon explains to Alice, they are there all the time, but to have their position sufficiently determined, their momentum has to be sufficiently uncertain, hence the fast running. When their momentum is great enough, they get localised in the nucleus. Though almost identical to Carroll's running scene, Gilmore's scene has a single, scientific explanation: Heisenberg's uncertainty principle (the more precisely the position of a particle is determined, the less precisely its momentum can be known). Thus, it can be interpreted in a single way, while Carroll's original scene belongs to a world of wonder in which the reader is welcome to find different meanings for the strange occurrences.

Although Gilmore's Alice resembles Carroll's Alice, Gilmore's book is mainly educational – it is non-fiction based on famous fiction; consequently, Quantumland, though strange, is determined by contemporary scientific knowledge.

### *B) Wonderland as Quantumland*

Gilmore's *Alice in Quantumland* is not the only entanglement between *Alice's Adventures in Wonderland* and quantum mechanics. In his book *Uncle Albert and the Quantum Quest*, Russell Stannard (1994) sends his main character, a girl named Gedanken, into Wonderland to find answers to the most important quantum questions (e.g. what is matter, what is light?).

Gedanken's uncle, Albert, is able to "think so hard that he could produce a bubble. […] When he thought mega-hard, he was even able to beam Gedanken into the bubble!" (Stannard 1994: 3). For Gedanken to explore what everything is made of, they have to make her very small. Being a fan of *Alice's Adventures in Wonderland*, Uncle Albert beams Gedanken into Wonderland. When inside the bubble, Gedanken falls for a very long time, only to find herself in a room with a table and a bottle on it. "The bottle was labelled […]. It said: DRINK ME" (6). Gedanken considers her Uncle's decision to send her to Wonderland extremely old-fashioned, as "nobody reads this fuddy-duddy stuff these days" (33). However, thanks to the liquid she becomes small enough to see into atoms, and figures out what they are made of. In Wonderland, she meets the Queen who is now interested in science, while the White Rabbit has been made the Queen's Chief Scientist. Together, Gedanken and the Rabbit carry out some experiments to help them understand the nature of elementary quantum systems (e.g. electrons, photons), which are both particles and waves. Later, they are also accompanied by the Cheshire Cat, who seems to already know some of the experimental results and helps them set up the experiments. The Cheshire Cat is itself a bit quantum (Stannard 1994: 71):

> "Jump from one place to another with nothing between, you mean?" replied the Cat. "Easy. That's the way things are down here. I learned the trick from the electrons and quarks." It winked slyly.

Stannard's Cheshire Cat seems to be influenced not only by Carroll's, but also by Gilmore's Schrödinger's Cat. It seems that Uncle Albert (or Stannard) has not only read *Alice's Adventures in Wonderland*, but also *Alice in Quantumland*, as both novels influence the context of his mind bubble.

Stannard includes elements from Carroll's book as the context for Uncle Albert's daydreaming, entangling them with completely new adventures. All that remains from *Alice in Wonderland* is some of the scenes and the main characters (except for Alice, who is replaced by Gedanken). Stannard's text is full of allusions: not only does he reuse elements from Carroll's texts, but he also includes some facts from Carroll's life (e.g. Gedanken going on a boating weekend with her uncle, who has no children but enjoys the company of his niece) and of course elements from the history of quantum physics, with Uncle Albert as Albert Einstein, who, at the end of the story, has dinner with Niels (Bohr), Werner (Heisenberg), Max (Born), Eric (Schrödinger) and others. During dinner they reveal their main views on (the philosophy of) quantum mechanics. In Stannard's imagination, the history and theory of quantum mechanics entangle with Carroll's *Alice's Adventures in Wonderland* as well as his own fiction about Gedanken and her Uncle. In Uncle Albert's imagination, *Alice's Adventures in Wonderland* is intertwined with his knowledge on quantum mechanics and Gedanken's new reality. However, both Stannard and Uncle Albert seem to be good popularisers of quantum mechanics as well as of *Alice's Adventures in Wonderland*.

### *C) Alice as Lauren and Wonderland as Computerland*

Another young adult novel, which does not directly reuse the character of Alice, but still alludes to her adventures in Wonderland while presenting the computer science part of Scienceland, is *Lauren Ipsum* written by Carlos Bueno (2011). The main character, Lauren Ipsum[7] or Laurie, is lost and the only way home leads through a strange land of creatures, places and events based on ideas from computer science. As a witty little girl who hates school lessons but is nonetheless driven by her lust for knowledge and adventure, Laurie resembles Alice.[8] During her adventure she is faced with different concepts from computer science, but not in a classic pedagogical way. Instead of being directly described or explained, computer science problems and their solutions are integral to the scenes that unfurl. Most of the problems are logic problems, treated similarly to the way they are presented in Carroll's books on Alice. *Lauren Ipsum* is an educational book, but can also be read as fiction; it is full of witty humour, strange characters and science (in disguise).

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[7] *Lorem ipsum* is a filler text commonly used in publishing and graphic design to demonstrate the graphic elements of a document. It is typically a section from Cicero's 45 BC philosophical work *De finibus bonorum et malorum* [*On the ends of good and evil*] with words altered, added, and removed to turn it into nonsensical Latin.

[8] Bueno's book also shares some of Carroll's other characters. For example, in the chapter "What the Tortoise says to Laurie", Laurie meets the Tortoise and Achilles, characters first used by Zeno and later by Carroll in his well-known text on logic "What the Tortoise Said to Achilles" (1895).

### *D) Scenes, characters and concepts from Carroll's books on Alice pour into Scienceland*

Although many retellings and sequels to Carroll's books on Alice were set in a kind of Scienceland, not all allusions have been designed in this form. Often, scientists, philosophers of science and popularisers of science reuse just a particular scene, character or concept.

**i) Scenes from Carroll's books on Alice transmitted into science**

Among the scenes from Carroll's books on Alice, the one most often reused in the scientific context is Alice's and the Red Queen's race from *Through the Looking-Glass*. We have already discussed the scene when analysing Gilmore's *Alice in Quantumland* in which it serves to explain Heisenberg's uncertainty principle.

In evolutionary biology, the scene was the inspiration for the Red Queen hypothesis, which proposes that organisms must constantly adapt and evolve just to maintain their position in a constantly changing environment, full of other evolving organisms. The hypothesis is used to explain the law of extinction: all groups for which data exist become extinct at a constant rate, which is caused by co-evolution between competing species (Van Valen 1973), and the evolution of sex, the advantage of sexual reproduction at the level of individuals (Bell 1982).

As an illustration, the race has also been included in science fiction texts. In his short story "The Red Queen's Race", Isaac Asimov (1949) uses Carroll's scene to illustrate the predestination paradox. In Vernon Vinge's science fiction novel *Rainbows End* (2006), the scene is used to illustrate the struggle between much wanted advancement in technology and protection against newly evolved weapons.

Although Carroll was a mathematician and logician, the examples we have found in our research indicate that the scenes from his books on Alice have most often been reused within the context of modern physics. Revolutionary physics theories that emerged in the 20$^{th}$ century, such as quantum mechanics and relativity, were experimentally confirmed and implemented in technology, thus crucially affecting our everyday life. As a consequence of this success, the lay public became interested in modern physics and physics became the scientific field most often presented in popular science books. However, many concepts from modern physics seemed very counterintuitive and writers found it difficult to explain "the new world" to their readers. The strange world of Carroll's *Alice* books offered a perfect source of metaphors to explain modern science. Beside Alice's and the Red Queen's race, physicists reused, for example, the mad tea party scene from *Alice's Adventures in Wonderland* to illustrate the nature of time in the theory of relativity, particularly "that portion of De Sitter's model of the cosmos in which time stands eternally still" (Gardner 1998: 99). The scene with Alice in the sheep's shop where Alice finds it difficult to look straight at the objects on sale has been transmitted to the field of quantum mechanics to illustrate the impossible task of pinning down the precise location of an electron in its path around the nucleus of an atom (Gardner 1998: 253).

**ii) Characters from Carroll's books on Alice transmitted into Scienceland**

Not all characters from Carroll's books on Alice are equally suitable for use in science. Their curious nature has to offer a basis for connections with the "strange" scientific concepts they are meant to explain, while at the same time they have to be famous enough to be familiar to (most of) the target audience. The Cheshire Cat seems perfect for this role. Therefore, it is not surprising that the world of science is full of diverse transpositions of the Cheshire Cat character, of its iconic mischievous grin that sometimes stays visible when the body of the Cat disappears and of his witty answers to Alice.

In Gilmore's *Alice in Quantumland*, this famous Cat is used to explain quantum superposition, along with other quantum phenomena, for example the physical separation of a particle and its properties. When researchers separated a beam of neutrons from their magnetic moment (Denkmayr et al. 2014; Morgan 2014), they found "the Cat in one place, and its grin in another" (Aharonov et al. 2013: 1).

In physiology, the Cheshire Cat effect describes a binocular rivalry in which motion in the field of one eye triggers "suppression of the other visual field as a whole or in parts" (Duensing and Miller 1979: 269). To get a three-dimensional image of the world around us, our visual cortex fuses the views from each of our eyes. The Cheshire Cat effect occurs when one eye is fixated on a stationary object, while the other looks at a moving object. As our brain, very sensitive to changes in motion, focuses on the moving object, parts of the stationary object disappear. When the stationary object is another person, the eyes and the mouth seem to be the last to disappear – hence the name the Cheshire Cat effect (Duensing and Miller 1979, Exploratorium Science Snacks 2015).

The Cheshire Cat has also been used to describe the fading of catalytic RNAs, which dims their complex three-dimensional ribonucleotide structure to leave in view only the "smile" of sharp mineral parts (Maichael 1993).

In another biological context, the Cheshire Cat is used to describe an escape strategy of *Emiliania huxleyi*, a class of ocean algae, in response to viral infection. When *Emiliania huxleyi* does not enter the haploid phase of its lifecycle, it enables the "separation of meiosis from sexual fusion in time" and thus (Frada et al. 2008: 15944):

> […] genes of dominant diploid clones are passed on to the next generation in a virus-free environment. These 'Cheshire Cat' ecological dynamics release host evolution from pathogen pressure and thus can be seen as an opposite force to a classic 'Red Queen' coevolutionary arms race.

Frada et al. (2008: 15946) write:

> In keeping with the RQ metaphor taken from Lewis Carroll, we liken this theory to the strategy used by the Cheshire Cat in *Alice's Adventures in Wonderland* of making its body invisible to make the sentence 'off with his head' pronounced by the Queen of Hearts impossible to execute.

In *The Annotated Alice*, Gardner, a mathematician, writes that (1998: 91):

> The phrase 'grin without a cat' is not a bad description of pure mathematics. Although mathematical theorems often can be usefully applied to the structure of the external world, the theorems themselves are abstractions built on assumptions that belong to another realm remote from human passions.

Arthur Stanley Eddington, who includes some elements from Carroll's *Alice* books in most of his works on science, uses the phrase "grin without a cat" in his essay "The Constants of Nature" to illustrate the difference between a mathematician's and physicist's understanding of scientific concepts, such as the radius of curvature (1956: 1080):

> To the pure geometer the radius of curvature is an incidental characteristic – like the grin of the Cheshire Cat. To the physicist it is an indispensable characteristic. It would be going too far to say that to the physicist the cat is merely incidental to the grin. Physics is concerned with interrelatedness such as the interrelatedness of cats and grins. In this case the 'cat without a grin' and the 'grin without a cat' are equally set aside as purely mathematical phantasies.

John G. Kemeny's book *A Philosopher Looks at Science* (1959), a classic in the field of the philosophy of science, starts every chapter with a quote from one of the *Alice* books. In his book, Kemeny examines philosophical questions that arise in connection with science. His treatment falls into three principal sections, dealing with the presuppositions of science, the nature of the scientific method, and some philosophical problems raised by modern science. The quotes from Carroll's *Alice* books describe – more or less directly and successfully – each chapter's main problems. Although Carroll's books are not mentioned or discussed later in the text, the possibility to start each of the chapters with such a quote shows the diverse ways Carroll's *Alice* books can be connected with current science. The Cheshire Cat chapter is the only one mentioned by Gardner in *The Annotated Alice*. Kemeny uses the Cat's answer to Alice to express the eternal cleavage between science and ethics: "science cannot tell us where to go, but after this decision is made on other grounds, it can tell us the best way to get there" (Gardner 1998: 89).

**iii) Concepts from Carroll's books on Alice transmitted into Scienceland**

After the publication of *Through the Looking-Glass*, Carroll's famous nonsense poem "Jabberwocky" started a life of its own, being analysed by literary scholars, frequently imitated, and integrated into different contexts. The word "Jabberwocky" outgrew its role as the title of a (famous) nonsense poem and became a concept, a signifier for "meaningless speech or writing" ("Jabberwocky", no date). In this role, for example, Jabberwocky appears in Eddington's *The Nature of the Physical World* (1929: 260–261):

> The spectacle is so fascinating that we have perhaps forgotten that there was a time when we wanted to be told what an electron is. The question was never answered. No familiar conceptions can be woven round the electron; it belongs to the waiting-list. […] Something unknown is doing we don't know what – that is what our theory amounts to. [However, we bring this unknown phenomenon in order by scattering some numbers freely in the description.] By admitting a few numbers even Jabberwocky may become scientific.

As Eddington often takes his examples and metaphors from Carroll's books on Alice, we assume that in his text Jabberwocky is not just a word for "meaningless speech", but it keeps the connection with the original context. According to Gardner, "Jabberwocky" was "a favourite of the British astronomer Arthur Stanley Eddington and is alluded to several times in his writings" (1998: 192). Beside the quoted passage from *The Nature of the Physical World* (1929), Gardner points out that in *New Pathways in Science* Eddington likens "the abstract syntactical structure of the poem to that modern branch of mathematics known as group theory" (1998: 192).

Several science-fiction writers incorporated Jabberwocky into their works as a particular nonsense poem and not a signifier for any nonsense text. In his short story "Mimsy were the Borogoves" (a verse from Carroll's "Jabberwocky"), Lewis Padgett (1943) describes "Jabberwocky" as a poem written by super-humans and sent to the past in order to help save their super-culture. In some respects, Carroll's "Jabberwocky" really is a poem ahead of its time, a poem that keeps addressing new readers who keep finding fresh meanings in its nonsense. Douglas Adams, one of the most famous science-fiction writers of the 20$^{th}$ century, was also inspired by "Jabberwocky". The Vogon Captain's lovelorn ode from *Hitchhiker's Guide to the Galaxy* (1979) is "in its deranged and glorious musicality, a clear homage to Carroll's Jabberwocky poem" (McFarlane 2001).

The specific character of "Jabberwocky" is also analysed in Douglas Hofstadter's *Gödel, Escher, Bach: An Eternal Golden Braid* (1999) described by publishers as "A metaphorical fugue on minds and machines in the spirit of Lewis

Carroll" in an additional subtitle. In the book, which interweaves various narratives (non-fiction chapters alternate with dialogues between imaginary characters), the main two characters, Achilles and the Tortoise, are taken from Carroll's "What the Tortoise Said to Achilles" (1895). One of the chapters in Hofstadter's book is dedicated to an analysis of different translations of "Jabberwocky", comparing the English original with translations into German and French. Thus, Hofstadter provides an insight into different symbolical networks. As he writes, the translations of "Jabberwocky" demonstrate "the problem of trying to find "the same node" in two different networks" (Hofstadter 1999: 372). In "Jabberwocky", "many 'words' do not carry ordinary meaning, but act purely as exciters of nearby symbols. However, what is nearby in one language may be remote in another" (370). With his analysis, the reader gains an insight into entanglements between different words and into different dimensions of their meanings. The words are not determined just by what they are meant to mean, but also by how they sound, how they feel, what they are connected to and where they come from. Hofstadter concludes (1999: 373):

> Yet, even in this pathologically difficult case of translation, there seems to be some rough equivalence obtainable. Why is this so, if there really is no isomorphism between the brains of the people who will read the different versions? The answer is that there is a kind of rough isomorphism, partly global, partly local, between the brains of all the readers of these three poems.

Though full of indirect allusions to Carroll's works, the chapter on translations of "Jabberwocky" is Hofstadter's most direct allusion to a particular element from Carroll's books on Alice. However, in a sense, the whole spirit of Hofstadter's book is Carrollian. As Hofstadter writes, Carrollian dialogue, the dialogue between Achilles and the Tortoise in "What the Tortoise Said to Achilles", "with its wit subtracted out, still leaves a deep philosophical problem: *Do words and thoughts follow formal rules, or do they not?* That problem is the problem of that [*Gödel, Escher, Bach*] book" (1999: 46; emphasis in the original).

### *E) Alice's independent life in science*

Current scientific theories and literature containing elements from and inspired by contemporary scientific theories are full of Alice and her lust for knowledge, of the Cheshire Cat and its mysterious grin, of the Red Queen and her race. Consequently, Alice has become a part of the scientific world itself. She emerged in the scientific everyday quite independently, without direct connection with the original context of Carroll's books.

For example, today more or less all experiments in the fields of cryptography and physics are carried out by Alice and Bob (a character that has no connection with Carroll). When scientists (or any others discussing science) want to describe a specific experiment (either in written or oral form), they use placeholder names for the experimentalists. In cryptography and physics, the experimentalists are usually labelled A and B (e.g. in diagrams) and named Alice and Bob. Thus, technical topics can be explained in a more understandable way, while every reader can intuitively figure out that the experiment is not carried out by a particular Alice or Bob, that they themselves could do the same thing as Bob or Alice. The names were first used by Ron Rivest, Adi Shamir and Len Adleman (1978) in "their seminal public-key cryptosystem paper" (NetworkWorld 2005). Rivest "came up with Alice and Bob to be able to use 'A' and 'B' for notation, and […] by having one male and one female, the pronouns 'he' and 'she' could be used in descriptions" (ibid.). However, he says that Alice possibly came to mind because he is a fan of *Alice's Adventures in Wonderland*, but he never expected "the names to take on lives of their own" (ibid.). In the following years, Alice and Bob became archetypes, while names for the other placeholders keep changing from experiment to experiment. It is barely known among scientists that Rivest's choice for the placeholder A is connected with him being a fan of Carroll's *Alice.* However, when, on diagrams presenting particular experiments, Alice and Bob are presented by some illustrations/pictures of well-known characters, Alice is almost exclusively presented as Carroll's Alice. Carroll's Alice is so widely known and popular among physicists, who, as we have seen, most frequently of all the scientists use elements from Carroll's *Alice* books to illustrate scientific phenomena, that there is no question which Alice it is that carries out the experiments.

## 3. Conclusion

Carroll's books on Alice are deeply interwoven with his enthusiasm for logic, mathematics and science in general. Without his exercises in logic, his nonsense style inspired by symbolical algebra, mathematical allegories and treatment of meta-scientific problems, Carroll's books on Alice would lose much of their charm, which, we would argue, is the reason for their "curiouser" persistent popularity and presence in Scienceland.

Alice and Wonderland have a genuine place in the world of science and, as far as we know, there is no other fictional work with so many and so diverse reincarnations in Scienceland. While Alice continues her adventures in Gilmore's Quantumland, Stannard's Gedanken travels to Wonderland to learn about quantum mechanics. Although, at first glance separately transmitted into works that popularise science, Alice and Wonderland are still tightly connected. Gilmore's Quantumland and, for example, Bueno's Computerland resemble Wonderland in many details, while Gedanken and Lauren Ipsum share many of Alice's characteristics. It seems that

Alice is destined to discover curious lands full of elements inspired by contemporary science, while Wonderland keeps attracting curious, witty little Alice-types of girls.

However, due to the complexity of Carroll's works on Alice, it is not just Alice and Wonderland that are transmitted into literature on current scientific theories. It seems that some of the most absurd of Carroll's scenes, characters and concepts that open up numerous metaphysical questions without offering particular answers to any of them are quite perfect for use in science. Often, current scientific theories seem difficult to explain, not only to the lay public, but also to fellow scientists. For this reason, scientists often rely on Carroll's brainchildren to help them retell the story of a particular scientific theory. Thus, the Red Queen's race helps us grasp the current scientific description of the process of evolution, while in quantum mechanics the Cheshire Cat and its grin resemble the physical separation between a particle and its property.

It is characteristic for science to keep changing as new hypotheses and theories are constantly replacing old ones; however, Carroll's treatment of scientific and meta-scientific problems in his *Alice* books seems to retain its relevance for current science. Not only have Carroll's books on Alice already outlived many scientific theories, but it seems that Alice's new adventures in Scienceland are far from over.

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## Aličine pustolovine u Znanstvozemskoj

Velik dio nonsensnoga humora i začudnih tema u djelima *Aličine pustolovine u Zemlji Čudesa* i *S onu stranu zrcala* nadahnut je Carrollovim vrsnim poznavanjem logike i matematike. Godinama nakon nastanka spomenutih romana, u rukama novih autora, Alica doživljava nove pustolovine u raznim dijelovima Znanstvozemske: od Kvantozemske do Računalozemske. Situacije, likovi i pojmovi iz Carrollovih knjiga o Alici često se iznova

rabe u raznim znanstvenim područjima u svrhu ilustriranja znanstvenih pojava. Sama Alica postala je arhetipskim imenom za ispitanike u fizici i kriptologiji. Iako su neprestane mijene jedna od odlika znanosti, jedna se stvar zacijelo neće promijeniti: junakinja Carrollovih romana, koje je znanstvena zajednica dobro prihvatila, i dalje će doživljavati pustolovine u Znanstvozemskoj.

**Ključne riječi:** Alica, Lewis Carroll, logika, matematika, fizika, znanost

## Die Abenteuer von Alice im Wissenschaftsland

Zahlreiche Bespiele des Nonsens-Humors sowie eine Unmenge an sonderbaren Ereignissen aus den Werken *Alice in Wunderland* und *Alice hinter den Spiegeln* scheinen auf Carrolls ausgezeichneten Kenntnissen aus dem Bereich der Logik und der Mathematik zu beruhen. Noch jahrelang nach der Romanentstehung erlebt Alice unter den Händen anderer Autoren in unterschiedlichen Teilen des Wissenschaftslandes − von dem Quantenland bis hin zum Computerland − neuartige Abenteuer. Situationen, Gestalten und Begriffe aus Carrolls Alice-Büchern werden in zahlreichen wissenschaftlichen Bereichen immer wieder verwendet, um dadurch wissenschaftliche Begriffe zu illustrieren. Alice wurde sogar zum archetypischen Namen für Experimentatoren im Bereich der Physik und Kryptologie. Ist auch der stete Wandel eines der Merkmale der Wissenschaft, eines wird sich gewiss nie ändern: Einmal in der wissenschaftlichen Gemeinschaft gut aufgenommen, wird Carrolls Romanheldin in Wissenschaftsland auch weiterhin zahlreiche Abenteuer erleben.

**Schlüsselwörter:** Alica, Lewis Carroll, Logik, Mathematik, Physik, Wissenschaft