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Creativity in the Art, Literature, Music, Science, and Inventions

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Abstract. This essay aims to stimulate reflection on the creativity characterising *Homo sapiens* in the different realms in which it occurs. Over recent decades scholarly research into creativity has extended the original concept, restricted to geniuses, to a broader field that encompasses the qualities and abilities of every individual, in line with a democratisation of the creative act. However, the aim of this contribution is to illustrate the creativity of geniuses, referring to examples in various fields, according to Poincaré's definition of connecting pre-existing elements into new combinations that are novel and useful. The objective of this study is to show that pre-existing elements can be found in works of art, literature, poetry, and music, as well as in scientific discoveries or inventions. Having demonstrated the existence of concrete and real analogies in the various – and apparently profoundly different – fields of human creativity, a second objective was to construct a convincing proof of a notion of a culture characterised by an essential unity, without any separation between humanities and sciences. I trust that the analysis of the creative acts that generated Picasso's *Les Demoiselles d'Avignon*, Michelangelo's *Vaticano Pietà*, Primo Levi's *The Periodic Table*, Giacomo Leopardi's *L'infinito* (*The infinite*) and Wisława Szymborska's *Liczba Pi* (*Pi*), the beginning of Beethoven's *Fifth Symphony* and Brahms' *Fourth Symphony* the finale of Stravinsky's *Sacre du Printemps*, the discovery of X-rays by Wilhelm Conrad Röntgen and of the therapeutic properties of lithium salts for psychiatric disorders by John Frederick Joseph Cade, the invention of incandescent light bulbs by Thomas Alva Edison and many other inventors and of the electronic television by Philo Taylor Farnsworth, may succeed in achieving the first objective and, by extension, the second also.

Keywords: creativity, genius, cultural unity, science, art, literature, music, inventions.

1. INTRODUCTION

It is well known that the literature on creativity has significantly evolved from the initial approach focused only on creativity as a peculiarity of geniuses in the various domains of human activity to what it has recognised as a democratisation of the phenomenon.[1-6] In particular, in a recent very accurate and in-depth study by Corazza, a detailed recognition of the literature about this passage from creativity by only geniuses to a broader meaning including qualities and abilities by every individual has been done.[7] In the same paper,

besides discussing this phenomenon of "creativity for all", some other very interesting topics are considered, as the mental processes associated with this broad vision of creativity and even the socio-cultural aspects.[8] Indeed, the state of the art of the literature allows individuating another further extension of the domain where creativity takes place, in the sense that creativity not only belongs to every human being, but it is also going to become the most important skill for the hyper-technological societies of the future.[9] Considering this enlarged vision of creativity, it is possible to extend the classical definition according to which creativity requires both *originality and effectiveness*, in order to contemplate several other requirements, as novelty, utility, aesthetics and authenticity.[10-13] In this context, according to the work by Weisberg who focused the attention on the *intentional novelty* as the unique criterion eliminating the *effectiveness* and trying to bypass the question of value assessment to individuate the *novelty* and/or *originality*, we may recognise three pragmatic definitions of creativity as reported in the literature.[7,14] According to this background, which refers to creativity in a static view, many scholars have investigated the topic of a dynamic concept of creativity, where the adjective *potential* is put before *originality and effectiveness*, with the aim of taking into account all the *inconclusive outcomes* and stressing the dynamic nature of creativity, as selecting a focus, generating the outcomes through complex processes where *inconclusive outcomes* play an important and decisive role, assessing them, and finally transforming the outcomes to knowledge.[7] Independently on this wide vision of creativity, it is worthwhile to recall that, despite the new achievements on the creativity concept above resumed, it remains valid one of the most interesting and comprehensive definitions of creativity which underline *originality and effectiveness*, like that described by Poincaré according to whom creativity can be summarised as the capacity of connecting pre-existing elements into new combinations that be useful.[15] This idea was at the centre of a very interesting talk given by Umberto Eco in Florence, Italy for the Nobel Foundation in 2004 which is titled *Combinatoria della creatività* (*Combinatory of creativity*).[16] It is interesting to notice that the "usefulness" to which Poincaré refers is more appropriately relative to the beauty rather than to the effectiveness. Of course, he thinks of beauty not in a strictly aesthetic sense, but rather in the view of mathematicians, that is something associated with elegance, harmony, the economy of signs, operational correspondence to the aims.[17] It is curious and intriguing that this idea of connecting things thought at the beginning of the 20th century by Poincaré is repeated almost identically by one of the fathers of the ICT industry, Steve Jobs, who defined creativity in a very concise and incisive way. "Creativity is just connecting things. When you ask creative people how they did something, they feel a little guilty because they didn't really do it, they just saw something. It seemed obvious to them after a while. That's because they were able to connect experiences they've had and synthesize new things. And the reason they were able to do that was that they've had more experiences, or they have thought more about their experiences than other people. Unfortunately, that's too rare a commodity. A lot of people in our industry haven't had very diverse experiences. So, they don't have enough dots to connect, and they end up with very linear solutions without a broad perspective on the problem. The broader one's understanding of the human experience, the better design we will have."[18] It is obvious that what is written until now about creativity strongly clashes with the etymology of the terms 'creativity' and 'to create', according to which the word comes from the Latin *creare* with shares with the word *crescere* (to grow in English) the root *kar*.[19,20] Indeed, the most common meaning of the word creativity is associated with the 'making from nothing', which is referred especially to God and that, in a figurative sense, becomes inventing, generating new and original things.[1-14] In the Sanskrit language *kar-tr* is 'the person who makes' (from nothing), the 'creator'.[19] Leaving this divine interpretation to philosophy and theology and reminding the previous introductory remarks on creativity, in particular as defined by Poincaré, it is worthwhile to mention that even Marcel Proust agrees, albeit more lyrically, with Poincaré. «The only true voyage of discovery, the only fountain of Eternal Youth, would be not to visit strange lands but to possess other eyes, to behold the universe through the eyes of another, of a hundred others, to behold the one hundred universes that each of them is; […]».[21] This lyric vision according to which the true discover, the fruit of the creative act, does not consist in finding new territories, but rather in seeing them with different eyes, perfectly matches with Poincaré's statement where the new territories are simply the pre-existing elements that the creator succeeds to connect generating *originality and effectiveness*, due to his ability in seeing them in a new combination thanks to his capacity in seeing them with different eyes. In conclusion, we can imagine creativity as an unlimited domain, because the pre-existing elements are in the number of billions and billions, and the combinatory calculus individuates several combinations truly tending to infinite. Therefore, we could define creativity as a bottomless pit; indeed, such pit has two negative aspects not coherent with creativity: it is dark, and one has to dive in a random fashion and therefore it is almost impossible

to sharpen one's different eyes, to use Proust's expression. Another metaphor for creativity is perhaps more appropriate: a sea that offers always new and unpredictable horizons. The present paper aims to illustrate with some examples taken from the art, music, literature, poetry, science, and the world of inventions how creativity continuously opens these new horizons simply by connecting pre-existing elements in some combinations that generate originality and novelty. By this approach we hope to succeed in extending the Poincaré's definition from the domain of the mathematical invention for which it was coined to all the other fields of the human creativity.[15] Indeed, we will revisit some fruits of creativity in the various domains of human activity we mentioned above discovering many analogies and to possibly conclude that there is no division, in contrast with Snow's idea, between science and art, science and literature, and that humanistic and scientific cultures are two complementary sides of the same medal hanging from the neck of *Homo sapiens*.[22-23]

2. CREATIVITY IN ART

To investigate the connection between pre-existing elements used to create new original and novel combinations in art, two examples will be illustrated, one from painting and the other from marble sculpture. The painting by Pablo Picasso *Les demoiselles d'Avignon* (https://www.moma.org/collection/works/79766) has been the subject of several studies focusing on its novelty and, above all, on the idea that it could represent the starting point of the nascent cubism.[24-25] The pre-existing elements can be recognised in the five women who had been already represented in the very famous painting cycle dedicated to *Les baigneuses* by Paul Cézanne. (See for example https://joyofmuseums.com/museums/united-kingdom-museums/london-museums/the-national-gallery-london/masterpieces-of-the-national-gallery/bathers-les-grandes-baigneuses-by-paul-cezanne/). It is still controversial whether this reference was in Picasso's mind or not at the beginning of his project to paint his *Demoiselles d'Avignon*.[26-27] Nevertheless, apart from the shapes of the bodies, clearly inspired by the nascent cubism, it is evocative the idea that the blue of the triangles, trapezoids, other irregular figures and some outlines of the bodies can be traced back to the blue of the water close to the bathers. In this view, the bathing women and the blue of the water are the pre-existing elements, and the new, unexpected, and amazing connection is the geometry of the nascent cubism. Among all the possible connections of these pre-existing elements – bathers and water – whether he is referring or not to Cézanne, Picasso sees with different and new eyes the shape of the bathing bodies and the blue-coloured geometries representing the water.

Another interesting case of connecting pre-existing elements into new combinations that generate beauty in art is the *Pietà* by Michelangiolo housed in *Saint Peter's Basilica,* Vatican City. (https://www.flickr.com/photos/jorge-11/48126571846) Here the pre-existing elements are the well-known sculptural groups called *Pietà* (*Compassion*) mainly made of wood and typical of Northern-Europe with the German term *Vesperbild*.[28] The tradition until Michelangiolo, both in painting and sculpture, was characterised by a rigid and geometric structure of the Madonna and Christ pair. The seated Madonna was the vertical element to whom the dead Christ in a horizontal position was opposed with a clear association with the geometry of the cross. All the paintings and sculptures focused on this iconography were characterised by rigidity: a striking example is the oil painting Pietà by Pietro Perugino housed at the Galleria degli Uffizi in Florence (https://www.flickr.com/photos/nikonpaul/31992383947) and executed a few years before Michelangiolo's *Pietà* in the Vatican.[29] Moreover, another example of the strong rigidity of the sculptures is in a *Vesperbild* by an anonymous German sculptor (ca. 1380-1400) conserved at *Liebieghaus Skulpturensammlung*, Frankfurt-am-Mein.[28] (https://www.foglidarte.it/luoghi-mostre-eventi/699-vesperbild-alle-origini-delle-pieta-di-michelangelo.html) Michelangiolo has in front of him the following pre-existing elements: the dead body of Christ which of course must remain in an almost horizontal position, the seated Madonna who has to hold her son. His extraordinary creativity is to combine these two figures to compose the group with two amazing novelties: softness replacing the rigidity and the horizontal/vertical contrast that tends to dissolve. The artist concentrates his action to give softness to the marble – it may seem like a paradox or oxymoron while it is an inspired new combination of pre-existing elements! – working briskly at the Madonna's drapery. Another virtuoso combination concerns the two arms of the Madonna, obvious pre-existing elements. The left arm is completely autonomous and does not even touch Christ and the left hand is directed towards us, as if inviting us to meditate with the typical gesture of an almost open hand exposing the palm.[30] In sculpting the right arm Michelangiolo succeeded in capturing an amazing combination by achieving both the softness and the realistic effect of supporting the heaviness of a lifeless body. He concentrates on the region of the marble that connects Mary's arm, the Christ's right arm and ribs: these

three elements had to be connected in an original, never seen before way. The creative genius of Michelangiolo is expressed with a combination in that area of the statue which produces a kind of an elongated "sausage" of flesh between the arm and the ribs due to the firm hold of the Madonna opposed to the weight of Christ's listless body.

3. CREATIVITY IN LITERATURE AND POETRY

Probably the most impressive example of the connection of pre-existing elements ingeniously combined to generate the creation of a literary work is *Il sistema periodico* (*The periodic table*) by P. Levi.[31] In this wonderful book the writer, a chemist, succeeds in creating one of the most original connections of pre-existing elements. Indeed, he starts from the chemical elementary elements of the Mendeleev's table, the bricks of the whole universe, and he associates to each of the selected elements – twenty-one in total – an autobiographical life experience. Two extraordinary combinations are worthwhile mentioning in relation to the aim of the present contribution. The first deals with story that we find in the central pages of the book – the eleventh, entitled *Cerium* – where the pre-existing chemical element, apparently completely removed from the dramatic experience of the lager deportation, becomes the fulcrum around which the theme of the "*saved and drowned*" is developed, building in a few pages one of the crudest and most realistic testimonies of the Shoah.[32] In the second – the book's last one, entitled *Carbon* – the masterful combination of pre-existing elements is that between carbon, the very atom of life and the author's act of writing: the continuous *panta rei* of the matter finds concrete realisation through a "labelled" carbon atom that passes from a compound to another travelling in space and time until it arrives in Levi's brain, driving his pen or typewriter to write the final full stop of both the story and the book. Keeping the focus on Levi's work, there is another excellent example of an almost jarring combination between two elements: a make-up item such as lipstick and its main chemical component called alloxan which is also found in chicken droppings, a kind of revival of the old Latin motto *aurum de stercore*! «The fact that alloxan, destined to embellish ladies' lips, would come from the excrement of chickens or pythons was a thought which didn't trouble me for a moment. […] I will go further: far from scandalizing me, the idea of obtaining a cosmetic from excrement, that is, *aurum de stercore* ("gold from dung"), amused me and warmed my heart like a return to the origins, when alchemists extracted phosphorous from urine.» (See ref. 31 English transl. story "*Nitrogen*", pp. 180-181). Some years before the publication of the book by the chemist-writer Levi, the Italian songwriter-poet Fabrizio De André combined the same elements in his very famous song *Via del Campo*: «*dai diamanti non nasce niente, dal letame nascono i fiori*» (transl. « *diamonds bring nothing, manure brings flowers* »).[33]

Concerning creativity in poetry, it is particularly interesting to analyse two different examples: the poems *L'infinito* (*The Infinite*) by the Italian G. Leopardi and *Liczba PI* (*Pi*) by the Polish W. Szymborska.[34-35] The theme of the infinite is a subject that drew the interest of philosophers, theologists, mathematicians, physicists and astronomers alike since the beginning of human civilisation. Indeed, even writers and poets have been fascinated by this topic, but the amazing ways that Leopardi finds to describe the infinite in his poem are truly unparalleled. Leopardi, according to Poincaré's definition of creativity, establishes several new combinations (see bold below) by connecting pre-existing elements.[15,35] The hedge as the limit of finiteness and the farthest horizon as a symbol of infinity; the visual boundless spaces opposed to the auditory, superhuman silences; the same silence and the voice both combined with the wind that moves the plants; the present time perceived through its sound, that is, the living season as opposed to eternity, dead, silent; the final paradoxical and oxymoronic connection between the drowning of the thought on the one hand and the shipwreck of the thinker at the other. How many combinations of these pre-existing elements could the poet choose? We can very well say, an infinite number! But Leopardi selected the ones marked in bold below in the poem quoted in its entirety (Box 1).

We could venture that the reason why among the various possibilities for such combinations only some – very few – extraordinary ones, the fruit of the ingenious creativity, succeeded in generating eternal cultural products, resides in a kind of evolutionary theory involving natural selection. The literary "species", the fruit of creativity, that show the best "fitness" to the judgment of the posterity survive and do not become extinct, all the others do not survive the natural selection process and end up in oblivion. Something similar has been established by a group of scientists who have recently concluded that mutations and gene variability explain why a lot of music of a single genre with various species is produced in each period. Then, the free choices of the listeners determine the pressure of the external environment – fitness – and cause some species to become extinct, making certain others durable and transmissible for centuries.[37]

Another fantastic example of an ingenious and incredible combination of pre-existing elements used to

Box 1.

L'infinito	The infinite
Sempre caro mi fu quest'ermo colle, e **questa siepe**, che da tanta parte **dell'ultimo orizzonte** il guardo esclude. Ma sedendo e mirando**, interminati** **spazi** di là da quella, e **sovrumani** **silenzi**, e profondissima quiete io nel pensier mi fingo; ove per poco il cor non si spaura. E **come il vento** **odo stormir tra queste piante**, io quello **infinito silenzio a questa voce** vo comparando: e mi sovvien l'eterno, e le morte stagioni, **e la presente** **e viva, e il suon di lei**. Così tra questa immensità **s'annega il pensier mio:** **e il naufragar m'è dolce in questo mare**.	Always dear to me was this solitary hill and **this hedge**, that excludes so great a part **of the farthest horizon** from my sight. But sitting and gazing, **boundless** **spaces** beyond it, and **superhuman** **silences**, and deepest quiet, I envision in my mind; where almost awed is the heart. And as the wind **I hear sighing through these plants**, I that **infinite silence to this voice** go comparing: and I remember eternity, and the dead seasons, and **the present** **and live one, and its sound**. So in this immensity **my thought is drowned:** **and sweet to me is shipwreck in this sea**.

build a wonderful, unique, and original poem is *Liczba Pi* (*Pi*) by the Polish poetess W. Szymborska.[34] In this poem there are a number of brilliant connections of many pre-existing elements to constitute an extraordinary combination: a transcendental number, the number Pi, is the pretext to lyrically suggest reflections on mankind, nature, life, consciousness, eternity. A poetic way to look at an ancient philosophical subject, that of finiteness and infinity, thanks to the very ingenious combinations: "*five nine two* because it never ends", "the longest snake on earth calls it quits at about forty feet", but it "doesn't stop at the page's edge" and finally it nudges the "sluggish eternity to continue" (Box 2). Starting from an ordered, infinite set of integers that seem randomly put one behind the other, and which instead represent a very tangible concept, i.e., the ratio between the length of a circle and its diameter, the poetess combines some elements to evoke feelings and emotions perfectly succeeding in making warm and throbbing what is considered by everybody one of the coldest and driest objects, a number! Another perfect demonstration of what Poincaré intended for connection of pre-existing elements to generate an ingenious combination.

4. CREATIVITY IN MUSIC

Trying to apply Poincaré's definition of creativity to music is a truly difficult challenge, since the pre-existing elements are the most abstract and intangible. So far, the pre-existing elements have been well tangible and concrete, like marble or coloured pigments, or intangible like words, but still evoking specific concepts or things. In music the combination is made of sounds whose physical frequency and mathematical duration give melody and rhythm, whereas Fourier's spectral analysis and simultaneous presence of different frequencies give timbers and harmony, respectively.[37] It is almost impossible to show how some combinations of sounds originate music that becomes original and encounters the appreciation of the listeners: therefore, the strangest and somehow most absurd combination of pre-existing elements which will be illustrated as capable of originating novelty and originality is that of sounds and silence, that is, the use of breaks in music generating something truly original and ingenious. Every musical piece obviously starts from silence, but we cannot conclude that the combination between the silence before the first sounds of the musical piece represents a demonstration of an ingenious combination of pre-existing elements, i.e., silence and sound. Nevertheless, there are some cases where the composer intentionally combines a break with the first sounds to start his or her musical piece in a very original way, as if the music gushed out of nowhere. Two very famous examples where Poincaré's definition could be applied to creativity in music are the beginning of Beethoven's 5th Symphony and that of Brahms's 4th Symphony. How did Beethoven succeed in starting his Symphony so that just based on its beginning it was celebrated as "the destiny knocking on the door"? By a combination of a quaver rest, followed by three identical quaver notes and by a final minim note with a crown. The knocking on the door by the destiny is a rest, that is, a silence! The combination between the rest and the four

Box 2.

Liczba Pi	Pi
Podziwu godna liczba Pi *trzy koma jeden cztery jeden*. Wszystkie jej dalsze cyfry też są początkowe *pięć dziewięć dwa*, ponieważ nigdy się nie kończy. Nie pozwala się objąć *sześć pięć trzy pięć* spojrzeniem, *osiem dziewięć* obliczeniem, *siedem dziewięć* wyobraźnią, a nawet *trzy dwa trzy osiem* żartem, czyli porównaniem *cztery sześć* do czegokolwiek *dwa sześć cztery trzy* na świecie. Najdłuższy ziemski wąż po kilkunastu metrach się urywa. Podobnie, choć trochę później, czynią węże bajeczne.	The admirable number Pi: *three point one four one*. All the following digits are also initial, *five nine two* because it never ends. It can't be comprehended *six five three five* at a glance, *eight nine* by calculation, *seven nine* or imagination, not even *three two three eight* by wit, that is, by comparison *four six* to anything else *two six four three* in the world. The longest snake on earth calls it quits at about forty feet. Likewise, snakes of myth and legend, though they may hold out a bit longer.
Korowód cyfr składających się na liczbę Pi nie zatrzymuje się na brzegu kartki, potrafi ciągnąć się po stole, przez powietrze, przez mur, liść, gniazdo ptasie, chmury, prosto w niebo, przez całą nieba wzdętość i bezdenność. O, jak krótki, wprost mysi, jest warkocz komety!	The pageant of digits comprising the number Pi doesn't stop at the page's edge. It goes on across the table, through the air, over a wall, a leaf, a bird's nest, clouds, straight into the sky, through all the bottomless, bloated heavens. Oh how brief — a mouse tail, a pigtail — is the tail of a comet!
Jak wątły promień gwiazdy, że zakrzywia się w lada przestrzeni!	How feeble the star's ray, bent by bumping up against space!
A tu *dwa trzy piętnaście trzysta dziewiętnaście* *mój numer telefonu twój numer koszuli* *rok tysiąc dziewięćset siedemdziesiąty trzeci szóste piętro* *ilość mieszkańców sześćdziesiąt pięć groszy* *obwód w biodrach dwa palce* szarada i szyfr, w którym *słowiczku mój a leć, a piej*	While here we have *two three fifteen three hundred nineteen* *my phone number your shirt size* *the year nineteen hundred and seventy-three the sixth floor* *the number of inhabitants sixty-five cents* *hip measurement two fingers* a charade, a code, in which we find *hail to thee, blithe spirit, bird thou never wert*
oraz *uprasza się zachować spokój*, a także *ziemia i niebo przeminą*, ale nie liczba Pi, co to to nie, ona wciąż swoje niezłe jeszcze *pięć*, nie byle jakie *osiem*, nie ostatnie *siedem*, przynaglając, ach przynaglając gnuśną wieczność do trwania.	alongside *ladies and gentlemen, no cause for alarm*, as well as *heaven and earth shall pass away*, but not the number Pi, oh no, nothing doing, it keeps right on with its rather remarkable *five*, its uncommonly fine *eigh*t, its far from final *seven*, nudging, always nudging a sluggish eternity to continue.

subsequent notes generated what is considered one of the most powerful beginnings of a musical work.[38]

The music gushes out of nowhere and it makes it in an abrupt and violent way thanks to the combination of the pre-existing elements above described. But the music can also gush out of nowhere like a silence that softly and gently becomes music, as if silence contained somehow music. Brahms succeeds in making this miracle with the beginning of his 4th Symphony: Beethoven started with the silence – the quaver rest – here Brahms starts with a quasi-silence, with all the instruments having a crotchet rest while first and second violins playing an upbeat B crotchet with anacrustic rhythm. The creativity manifests itself with this ingenious combination and the conductor's ability consists of realising this gushing out of music from nothing: one of the best realisations is by Carlos Kleiber, who brings music out of thin air with a masterful gesture.[39] Very appropriately, they have written that "this opening is a prime example of Brahms's natural ability to compose within the strictest and oldest of structures, yet with a fluid, modern sound that belies its rigidity".[40-42] One could conclude that in this case the quasi-nothing represented by those rests and by that short upbeat note he creates something truly original, novel, effective, and useful.[10-15] But the rests, the silence, can also be an ingenious inven-

tion for a sensational final twist: the example that comes to mind is represented by those three rests – dotted quaver, crotchet, dotted quaver – after the rapid ten-note sequence by flutes that precedes the thunderous finale chords of the *Sacre du printemps* by Igor' Fëdorovič Stravinskij.

5. CREATIVITY IN SCIENCE

Two examples of a combination of pre-existing elements to create new progress in science by means of an important and fundamental discovery will be illustrated. It is interesting to notice that a special role was played also by serendipity, i.e., "the faculty or phenomenon of finding valuable or agreeable things not sought for".[43] Therefore, the pre-existing elements can be found with some serendipity, but creativity consists of connecting and combining them so as to lead to a new discovery. In relation to this aspect, it is worth mentioning that in science, unlike in the other branches of the human activity described in this work, the above-mentioned combination/connection is associated with the importance of inductive reasoning in 'creating' creativity. We could state that inductive reasoning is some kind of prerequisite for the selection of the pre-existing elements to be combined; in other words, inductive reasoning is the sieve that separates wheat from chaff, but the 'creative jump' is linked to the ability of *Homo sapiens* to combine the wheat grains to give an 'original, novel, and useful bread'!

The first example is the discovery of X-rays by Wilhelm Conrad Röntgen in 1895. It is well known that several pre-Röntgen experiments had evidenced radiations of some kind, but as well characterised as to differ from cathode rays and fluorescence radiation.[44] Firstly, there were Morgan's experiments in 1785, followed by many other observations involving such great scientists as H. Davy, M. Faraday, P. Lenard, W. Crookes, F. Sanford, H. Helmholtz, H. Hertz, I. Puluj, N. Tesla.[45-47] It is difficult to ascertain the true origin of Röntgen's X-rays discovery, but the received hypothesis, as reported by the most important biographers, is that he succeeded in isolating the effects of fluorescent radiation visible to the naked eye, by wrapping in black cardboard a Crookes tube where experiments of electric discharges on very rarefied gases were carried out. Apparently, the differentiation with the already known cathode rays occurred by serendipity – as is testified by Lenard in 1888 who in his experiments observed the effects of cathode rays (perhaps, unknowingly, even of X-rays!) on photographic plates outside the tube in the region of the cathode and measured their penetration through various materials.[47-49] Indeed, at 1 m distance from the cathode of the Crookes tube there was a fluorescent screen painted with barium platinocyanide that showed a green glow even when nothing was apparently coming out of the tube. Röntgen thought to connect and combine the following two pre-existing elements: (i) no visible fluorescence coming out from the tube due to the black cardboard, (ii) a fluorescent screen painted with barium platinocyanide placed at a considerable distance far from the tube compared to Lenard's experiments. From this connection, Röntgen drew a novel idea, the fruit of his creativity: some invisible rays coming from the tube were passing through the cardboard and succeeding in crossing 1 m of air to react with the barium platinocyanide making it fluoresce. Two months of further experiments went by when he thoroughly investigated these new invisible rays before publishing his first paper. He decided to name the rays "X" same as the mathematical unknown.[50] But the combination of pre-existing elements did not stop here: during the experiments, Röntgen realised that one of the most impressive characteristics of such mysterious rays was the ability to go through some materials, such as paper, books, wood, but not others such as metals and stone. Connecting this experimental evidence, he designed three ground-breaking experiments: he made the invisible rays going through three different objects and placed a few inches beyond each object a photographic plate and then darkened the whole room. The first object was a wooden box that contained the small metal weights of a balance; the second consisted in the various parts of his shotgun's barrel; and the third was the hand of his wife. The amazing combination of pre-existing elements originated in a very short time three extraordinary applications of the newly-discovered X-rays: metal detector, quality control in the metal industry, and radiology and radio-diagnostics in medicine!

The second example deals with the discovery of lithium-ion therapy for manic depressive patients by the Australian psychiatrist Dr John Frederick Joseph Cade who worked at the Bundoora Repatriation Mental Hospital in Melbourne. Here the connection and combination of pre-existing elements are truly unbelievable, also because the means and laboratories available to Cade at that time were verging on what has been named "ramshackle pantry".[51] The first element from which Cade started his research was a conviction, the classical hypothesis to be validated by experiments: depressive diseases (i.e., manic syndromes and bipolar disorders) could be due to chemical metabolic disorders that should determine a change in the chemical composition of the urine of his patients compared to that

of healthy people. With the aim of checking the validity of such assumption, he injected urine of both ill and healthy people into the abdominal cavities of Guinea pigs and, probably due to some preliminary not statistically reliable results, he found that urine from patients with depressive diseases was more toxic to the Guinea pigs than that of healthy people.[51-53] This unreliability of the experimental result was the serendipity touch, since it convinced Cade about the rightness of his hypothesis and led him to focus on the two main nitrogenous components of urine, for which it was important to ascertain the possible specific lethal constituent that, coherent to the hypothesis and the preliminary unreliable experiments, could be particularly concentrated in the urine of ill patients.[55] The treatment with the urea solutions led to the same effect of urine from ill patients, but it was impossible to explain the greater toxicity of the urine of manic patients simply in terms of higher concentrations of urea. Indeed, urea is toxic for Guinea pigs from a certain threshold of concentration and there was no difference in the effect of the urine from healthy or ill people since it was the unreliability of the experiment described, a true mistake, that was going to generate the discovery! Cade had the idea to add the second constituent, uric acid, to test whether it had a synergistic – positive or negative – effect, or not.[54,55] In his first article in 1947, Cade noted that uric acid had a slightly enhancing effect on the toxicity of urea.[56] This result prompted him to continue this research strategy, but unfortunately, it was impossible to increase the concentration of uric acid due to its very scarce solubility in water (0.06 g/L equivalent to $3.57 \cdot 10^{-4}$ M compared to 1,193 g/L equivalent to ca. 20 M of urea). Therefore, Cade selected lithium salt as it was the most soluble salt of uric acid, to increase the concentration of the possible enhancer of urea toxicity. To Cade's surprise, when he injected the Guinea pigs with lithium urate in conjunction with urea, the toxicity was reduced rather than enhanced, suggesting that the lithium could have been protective. Cade further explored this lead by injecting the Guinea pigs with lithium carbonate in conjunction with urea, and once more observed a reduced toxicity. He concluded that lithium itself provided a protective effect against the action of urea. This belief then prompted him to wonder whether lithium per se would influence his Guinea pigs. Injecting them with large doses of lithium carbonate, he found them to become lethargic and unresponsive. Now we can deduce that the lithium ion itself had a protective function against the convulsant death caused by toxic doses of urea.[55,56] A mistake and a touch of serendipity coupled with the combination and connection of some pre-existing elements by the creative mind of Dr Cade: the toxic effect of urea and uric acid, the low solubility of uric acid, the higher solubility of lithium urate, the even higher solubility of Li_2CO_3 ($1.75 \cdot 10^{-2}$ M) resulted in a novel, original, useful, and effective discovery that had to wait another twenty years to become a worldwide-accepted therapy. But this is another story.

6. CREATIVITY AND INVENTIONS

Even the inventors can be considered creative in the sense illustrated in the previous section: two examples will be described to demonstrate once again the creative act always as a combination of pre-existing elements. The first case concerns the invention of the incandescent light bulb; despite the fact that the invention is attributed to Thomas Alva Edison the story is much more complex and involves several more inventors who worked for many years between the end of the 19th and the beginning of the 20th centuries.[57] These inventors combined pre-existing elements into an ingenious invention that led the American writer Oliver Sacks to entitle "Light for the masses" one of the chapters of his extraordinary book *Uncle Tungsten: Memories of a Chemical Boyhood* and here I will illustrate the pre-existing elements and the ingenious combination and connection thereof. The pre-existing elements were the following: (i) Joule effect condensed in the formula $Q = I^2 \cdot R \cdot t$, (ii) black body radiation, (iii) heat transfer by conduction, convection, and radiation, (iv) oxidation reactions, and (v) matter phase transitions. The combination of the first two elements led many inventors to design an ingenious new object consisting of a filament of matter that, when heated by an electric current at high temperature, emitted radiation in the visible region of the spectrum as a black body. The third element combined with the fourth convinced these ingenious men to put such filaments in a vacuum to enhance radiation against conduction and convection and inhibit oxidation processes that caused the light bulbs to have a very short lifetime. The combination with the fifth element was the most ingenious and came later: instead of the vacuum an inert gas like Argon was used. This prevented oxidation and simultaneously favoured conduction and convection, losing a little bit of radiation power, but lowering considerably the sublimation of the tungsten filament, because of the decrease in heat produced during this transition phase. As a matter of fact, sublimation reduced the life of the filament and caused a blackening of the glass due to condensation of tungsten vapour: in this way, for the first time in the history, humans succeeded in illuminating the dark not by

chemical combustion, but by radiation-induced electricity. It was the beginning of a new era.[59]

The second example is the invention of the electronics-based television. Probably this is the best example to illustrate Poincaré's definition of creativity. Philo T. Farnsworth was an extraordinary inventor and the idea to design a way to capture images in movement and reproduce them on a fluorescent screen came to his mind after observing a farmer ploughing a field.[60] The pre-existing elements were the following: (i) certain materials, submitted to an electrical potential when illuminated have the properties to generate an electrical current proportional to the illumination intensity, due to a decreased resistance induced by the light, (ii) the electrical signals so obtained can be transmitted at distance by means of radiofrequency waves, (iii) the cathode rays produced in a Crookes tube manage to illuminate the phosphors in the internal side of a fluorescent screen, and (iv) the electrical signals of element (ii), that are a faithful mirror of the image collected, can be used to attenuate the cathode rays according to the inverse proportionality law (i.e., strong electrical signal = high illumination of the photosensitive material = weak attenuation of the cathode ray = high illumination of the television screen). The extraordinary connection of these four elements was invented ingeniously by Farnsworth thinking of a fast-moving plough. According to the Italian standard, the plough (cathode tube emitting cathode rays) ploughed the field (scanned the fluorescent screen) with 625 furrows (lines) repeated 50 times per second! The lines were constituted of alternated microscopic black (no light) and white (light) spots moving exactly in the same way they were collected by the camera. The viewer does not notice this process of image composition due to the double phenomenon of the high speed of the electronic brush and the persistence of the image on the retina of the human eye ($1/16^{th}$ of a second).

7. CONCLUSIONS

Starting from the recent review of the literature on creativity research and recollecting the ever current definition by Poincaré for the creativity in the mathematical invention, the present contribution tried to demonstrate that the creativity jumps typical of geniuses in the various domains of the human activity can be aptly described in terms of combination and connection of pre-existing elements to generate novelty, originality, and effectiveness.[1-15] In particular, some examples of creativity outcomes in art, literature, poetry, music, science, and the world of the inventions were reviewed focusing on the pre-existing elements and on the ingenious combination and/or connection between them to generate the creative jump. The examples illustrated here, while belonging to apparently separate fields of human creativity, reveal, on the contrary, a common matrix precisely in the creative act by the genius who conceived it. In the end, we discovered the common traits of the creation of Michelangiolo's *Vaticano Pietà*, Beethoven's Fifth Symphony's beginning, Primo Levi, Leopardi or Szymborska's works, the X-rays' discovery, or television and light bulbs inventions. Besides confirming the shrewd intuition inherent in Poincaré's definition of creativity, it was demonstrated that the analogies found in the genesis of the above-mentioned products of creativity were very strong, enabling us to conclude that there is no division, in contrast with Snow's idea, between science and art, science and literature, and that the humanities and sciences are two complementary sides of the same medal hanging from the neck of the *Homo sapiens*.[22-23]

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