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The biological basis of Marvel Comics mutants

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"Feared and hated by a world they have sworn to protect" is the catchphrase always present in nearly all comics of Marvel's mutants, the X-Men. This phrase was coined by Stan Lee, the co-creator of the X-Men together with Jack Kirby. A popular proverb states that "we fear what we do not understand" and this is probably the case with the mutants within Marvel's comic book universe. Therefore, the question is: can we understand Marvel's mutants? That is the main aim of this essay.

The word 'mutant' is often found in science fiction literature, television and movies. The mutant condition is not an invention of these arts and media. In the decade of 1960, Stan Lee (hallmark comic book writer of Marvel Comics, born as Stanley Lieber) was in his peak of creativity (e.g., *Fantastic Four, Spider-Man, Hulk, Thor, Iron Man, Ant-Man* are inventions from those years) and he was searching for new and different ideas for the origin of his characters' superhuman powers. 'Cosmic rays', 'nuclear radiation', 'radioactive animal bites', were some of the causes of these origins. Stan Lee and Jack Kirby shaped a new excuse: instead of giving to their characters an event that causes their powers, they could create characters born with those powers. They could not escape from the radioactive influence of the Nuclear Age (the decades of 1940 and 1950), but they chose a new way to make use of it. In this new concept, the radioactive waste of nuclear tests generates changes in human offspring, and mutants were the consequence (Accorsi & Accorsi, 1994; Clemente, 2000; Kakalios, 2005).

Beyond Stan Lee and Jack Kirby, this is the same concept used in the Japanese *Godzilla* films of previous years. Thus, the word 'mutant' was often used in sci-fi literature of the 1950s to designate human variations with strange superpowers. The term was used a few times during those years in some Atlas (previous name of Marvel Comics editorial during the 1950s) comic books from 1952 to 1963 (for example, in *Tales of Suspense #6*, from 1959). Officially, according to the established cannon, the first time the term 'mutant' was used in the modern sense was in *Amazing Adult Fantasy #14*[1] (July 1962, written by Stan Lee) for Tad Carter, a character with flight and psychic abilities. Then, on late 1963, the first issue of the comic book *The X-Men* was released, and comic books' concept of mutants was born. The X-Men have been one of the most important superhero teams in comic books from their creation until this day (Fig. 1).

The aim of this essay is to take a biological approach to the features of mutants in Marvel Comics, considering their comic book appearances and the biological modern concepts used for describing their features by several comic book authors. From it, an attempt will be made to build a logical proposal for 'mutant' and mutant genetics and biology with a real-world biological basis.

[1] This is the same comic book that presented *Spider-Man* in its next issue.

Figure 1. Hallmark issues in the history of mutants. From left to right (all from Marvel Comics): *The X-Men* #1 (1963), *Giant Size X-Men #1* (1975), *X-Men Vol. 2* #1 (1991), *House of X* #1 (2019).

METHODS

Biological and genetic concepts considered for this review include: cell, mutant, mutation, gen, genotype, phenotype, genome, protein, nucleic acid, genetic code, DNA, among others. All of these terms were considered in their widely accepted and simple meaning, taken from general Biology textbooks. For guidance, the main books used are Alberts et al. (2010), Curtis et al. (2015), and De Robertis et al. (2012).[2]

In Biology, the term mutant refers to an organism with a variation within a genotype (or a particular gene) from the expected wild type. The complete set of genes of a species, the genome, contains all the genes. Each gene is an arbitrary portion of the genome that codifies for a particular protein. As a consequence, these proteins can be translated into a particular trait. Genes (and the complete genome) are stored as nucleic acid molecules (in the case of all living organisms this molecule is DNA, deoxyribonucleic acid). The DNA molecule contains monomeric units, the nucleotides, and shape the genetic information. Changes and errors in the genetic information between parents and offspring could be the origin of mutations. These changes and errors could be generated during duplication, transcription, translation or other internal processes of cells. Also, external events can produce mutations, for example exposition to radiation. This incomplete and extremely reduced explanation is the brief basis for the following questions and answers. For the purpose of this essay (and for fun), the biological basis of the comic book universe is considered to be identical to the real-world's biology basis, despite the fictional nature of comic books.

For the purpose of this essay, only comic books are considered. Movies, TV shows, videogames, and other appearances beyond comic books will not be included. The first Marvel comic book taken in account is *The X-Men #1* from 1963 and the last ones are *Powers of X* and *House of X* (both by Jonathan Hickman, 2019). All other Marvel comic books including mutants or information about mutants between these two points was considered. This comprises 56 years of publications scattered in numerous comic book series. The main resources mentioned are the series *Amazing Adventures Vol. 2* (AA), *Astonishing X-Men Vol. 3* (AX3), *Avengers Vol. 3* (A3), *Black Panther Vol. 4* (BP4), *District X* (D), *Excalibur* (E), *Extraordinary X-Men* (EX), *Further Adventures of Cyclops and Phoenix* (FACP), *Fantastic Four Annual* (FFA), *House of M* (HM), *House of X* (HX), *Inhumans Vol. 2* (I2), *New Avengers: Illuminati* (NAI), *New Mutants* (NM), *New X-Men* (NX), *The X-Men* (X), *Uncanny X-Men Vol. 1* (UX1), *Weapon X Vol. 2* (WP2), *What*

[2] A summary of these terms in Spanish can be found in Sabbatino et al. (2020).

If? Vol. 1 (WI1); *Wolverine and the X-Men Vol. 1* (WX1), *Wolverine First Class* (WFC), *X-Factor Vol. 3* (XF3), *X-Force* (F), *X-Men Vol. 2* (X2) and *3* (X3), *X-Men Forever* (Xfor), *X-Men: Messiah Complex* (XMC), *X-Necrosha* (XN), and *Young Avengers* (YA). The abbreviations indicated above, followed by issue number (with '#'), are used from this point onward as references to these resources.

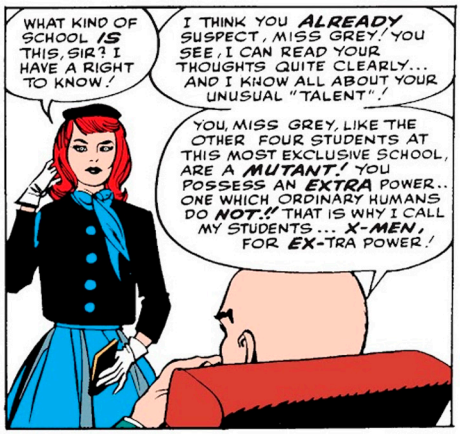

Figure 2. Charles Xavier explains to a young Jean Grey what is a 'mutant' for the first time. From *The X-Men* #1 (X#1: p. 8; Marvel Comics).

DISCUSSION

Definition of 'mutant' in Marvel comics

On the very first issue of *The X-Men* (X #1) (Fig. 2), Professor Charles Xavier explained to a young Jean Grey the meaning of 'mutant'. He said "you (…) are a mutant! You possess an extra power… one which ordinary humans do not!". In other words, mutant is a term used for designating beings with superpowers that regular humans do not possess. But this definition is not clear, because there are many others beings with superpowers in that universe that are not called mutants (Captain America, Spider-Man, Hulk, Captain Marvel, etc.). The following issues of *The X-Men* and other comic book series restricted this term to beings born with superpowers. Following that, the term mutant was once again adjusted to include only beings with a particular variant of a gene denominated X-Gene.

Basis of Marvel's mutant genetics

The 'wild type' for the X-Gene can be considered to be the regular humans in the Marvel Universe. This X-Gene constitutes a single locus with phenotype expression (WX1#5) (Fig. 3). Therefore, this gene is expressed by the manifestation within mutants of extraordinary morphological changes and superpowers. However, some mutants do not possess superpowers, as is illustrated by Jazz, a mutant presented in D#2, whose mutation includes just blue-coloured skin. According to this explanation, a unique gene is the cause of very diverse phenotypic mutations including morphological changes (such as extra-arms, horns, unusually-coloured skin, hairy or scaled integuments, presence of wings or tails, among others), psychic powers (telekinesis, telepathy, mind projection, levitation, among others), physical extreme abilities (superhuman strength, increased velocity, enhanced senses, feral behaviour, among others), thermodynamic manipulation (increasing heat, cold or atmospheric factors), etc.

The species *Homo sapiens* has 3.1 billion of nitrogenous base pairs, but only 30% are transcripted and translated to proteins (International Human Genome Sequencing Consortium, 2001, 2019), which means we have near to 23 thousand genes (Salzberg, 2018). With this relatively small number of genes in the species, there are almost four times the amount of proteins. This is possible because a gene can codify for more than one trait. Different mechanisms are implied in this phenomenon. One of them are the transcription factors. These are proteins that act as triggers to codifying chains with successions of genes and proteins, and regulate the expression of particular genes. By activating the expression of some genes, they can change the processing of others.

There are many mechanisms regulating the expression of genes, in different stages of the process of transcription and translation. Transcription factors are themselves codified by other genes. Therefore, it is very plausible to consider that the X-Gene codifies for one or multiple transcription factors with multiple subsidiary codifying chains.

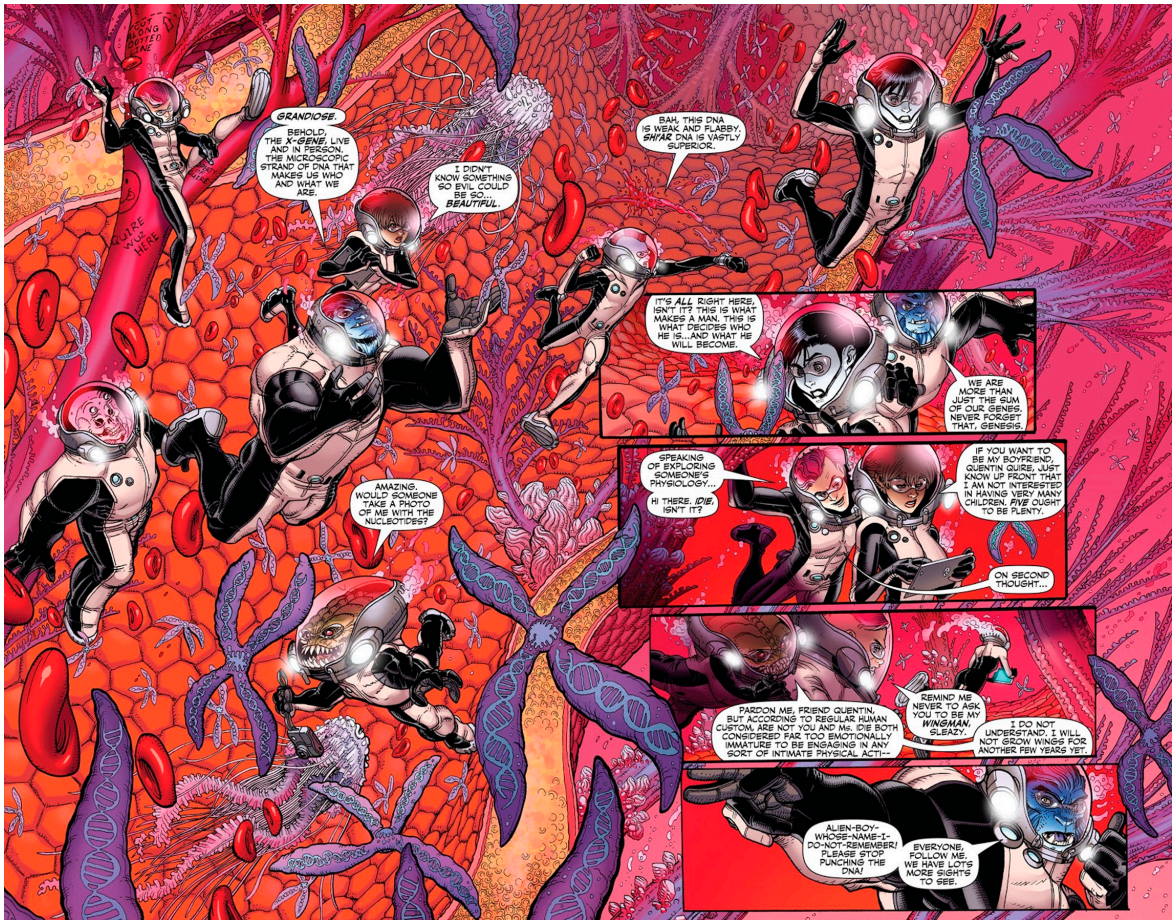

Figure 3. Beast teaches his students about the X-Gene. From *Wolverine and the X-Men* #5 (WX1#5: p. 6; Marvel Comics).

A specific mutation of the expression of a basal transcription factor can "wake up" to a different portion of DNA previously unread. Different pathways of codifying could trigger the development of various features and traits or even more than one trait. Usually, mutations in the Marvel comics are not restricted to a unique trait as is the example of Cyclops (Scott Summers, with optic beams) or Professor X (telepathy). Most of the mutants have a combination of connected traits, as in the examples of Wolverine (James Howlett, with feral senses, claws, healing factor, etc.) or Nightcrawler (Kurt Wagner, with blue fur, prehensile tail, reduced number of fingers and toes, etc.). Also, another name frequently given to X-Gene is X-Factor (F#86; UX1#380).

An intriguing possibility is that transcription factors could be enhancing the codifying of non-codifying known portions of genome (the other 70%) or silenced genes in heterochromatin. The latter was thought to be relatively devoid of genes, but researchers have found them in organisms such as the fruit fly *Drosophila melanogaster* (Yasuhara & Wakimoto, 2006). One of the possible effects of the X-Gene could be to generate epigenetic changes. It is interesting to observe that these changes and their effects are random from individual to individual at some point. These explanations can shed light upon the great variety of mutations recorded and also upon recurrent or similar mutations, such as magnetic mutants (e.g., Polaris [Lorna Dane] and Magneto [Max Eisenhardt a.k.a. Erik Lehnsherr]), winged mutants (e.g., Angel [Warren Worthington III] and Icarus [Joshua Guthrie]), or psychic ones (e.g., Marvel Girl [Jean Grey], Psylocke [Betsy Braddock], Charles Xavier), because the same codifying chains could be expressed in the latter cases. Cases of parental relationships expressing similar mutations (as in the example of Polaris and Magneto) are also included in these explanations.

The emergence of other animals' features in some mutants (such as wings, fur, tails, sharp claws, insect eyes, gills, etc.) could be related to those genes being preserved in human genome without expression, shared with other animals. For example, human beings and chimpanzees share close to 99% of their genomes (King & Wilson, 1975).

An interesting possibility is that the X-Gene could be a homeobox, a 'master-gene', involved in the regulation of patterns of anatomical development in several life forms (Bürglin & Affolter, 2016). Homeobox genes are extremely conserved across different animals, such as the well-known example of the Pax-6 gene (Callaerts et al., 1997).

According to some references (A3#24 and #27, and BP4#17) we know the location of the X-Gene is in the 23rd chromosome (the sex-determining chromosome). The mentioned placement helps to explain the existence of human individuals without mutations born from mutant parents, such as Graydon Creed (son of Sabretooth [Victor Creed] and Mystique [Raven Darkhölme]). According to this assumption, the X-Gene is located in the X chromosome, more precisely in the portion not present in the Y chromosome. Graydon did not inherit the X-Gene from either parent. A more interesting consequence extracted from this example is that the X-Gene is present in at least two alleles, one of them non-active for expression of mutations.

In summary, all mutants are 'mutants' (i.e., different to the 'wild type', the regular humans) due to a unique trait: presence of the X-Gene. This gene codifies for one or more transcription factors, which can be called X-Factors here. These factors trigger different codifying sequences that can be different for each individual. These codifying sequences are the genetic origin of mutant superpowers observed in the Marvel Universe. Codifying sequences mentioned are present in the genome of all regular humans, but the presence of the X-Factor is needed to activate them. Drugs such as 'Mutant Growth Hormone' (or MGH, YA#2 and UX1#490) may be refined from some X-Factors. These drugs give superhuman capacities to non-mutants, and could increase mutation expression in mutants (as is illustrated by Beast's feral changes in AA#11).

A "historical" dataset in the study of mutations mentioned in the comic books is the presentation of Victorian naturalist Nathaniel Essex (a.k.a. Mister Sinister) to the Royal Academy of Sciences of London in the late 19th century about the discovery of 'Essex Factors'. They could be the same X-Factors mentioned above. His investigations were discredited by contemporary colleagues, such as Charles Darwin (FACP #1) (Fig. 4).

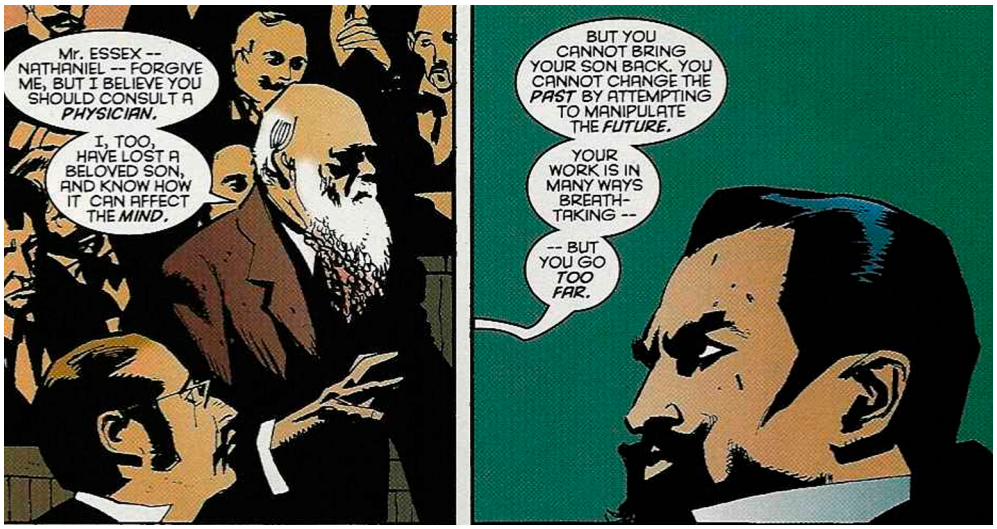

Figure 4. Charles Darwin, as a character from the Marvel Universe, discusses the proposals of Nathaniel Essex. From *Further Adventures of Cyclops and Phoenix* #1 (FACP#1: p. 8; Marvel Comics).

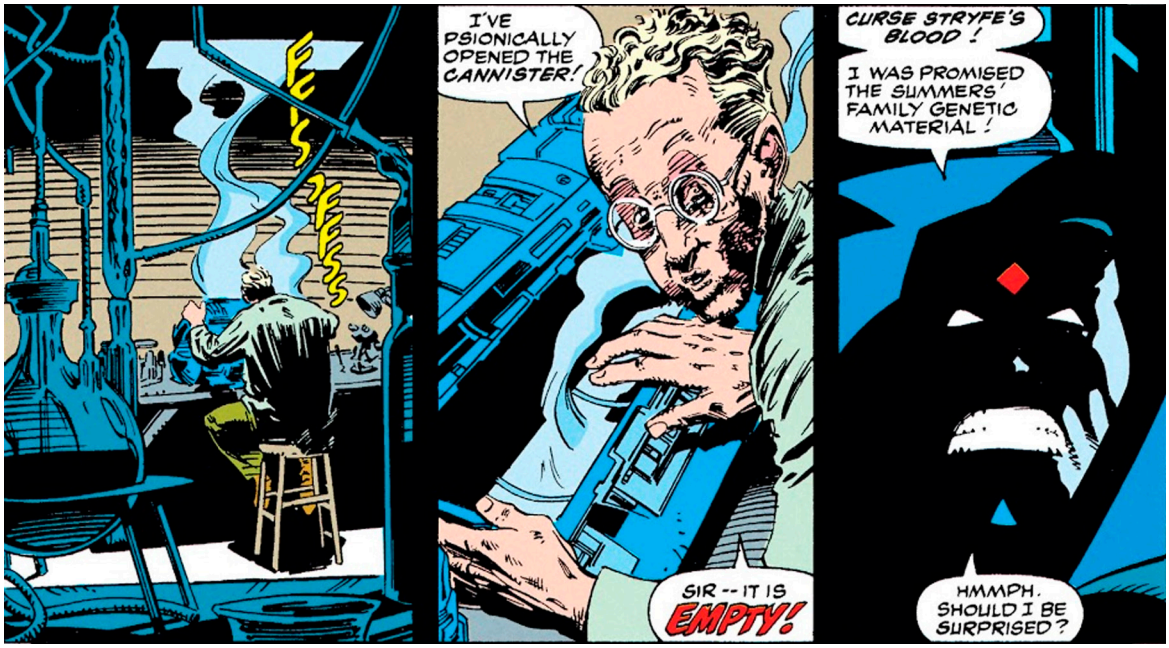

Figure 5. The Legacy Virus is released. From *X-Force* #18 (F#18: p. 23; Marvel Comics).

Diseases and "cures" for the X-Gene

The main disease known for mutants is the Legacy Virus, an artificial virus created and released by the villain Stryfe (F#18) (Fig. 5). This pathogen affected mutants between 1993 and 2001 in all mutant comic book series. Viruses are specific to determinate target cells and gene sequences. The mutant specificity of the Legacy Virus can be explained because this virus only binds to the X-Gene. The only human affected by the Legacy Virus was Moira MacTaggert (E#80), a fact originally explained by a possible new strain of the virus. An alternative explanation was the presence of the inactive allele of the X-Gene in Moira (she was the mother of the mutant Proteus). Recently, it was revealed that Moira is a mutant (HX#2) and so, no explanation of her contagion is needed anymore.

A second plague affected the mutants, the M-Pox (EX#1). This disease is caused by the Terrigen Mist, a substance with religious value to the Inhumans, another superhuman group of the Marvel Universe. Terrigen Mist activates morphological changes on inhumans, with the capacity of developing superhuman powers. In this case, the condition generated by the Terrigen Mist could be different to the Legacy Virus, modifying the X-Gene or transcription factors. No further information has been provided.

Several "cures" to mutations were proposed. The more remarkable was that developed by Dr. Kavita Rao (AX3#1): a serum capable of reversing mutations. The possible mechanisms implied was the suppression of X-Gene codification; or complete modification of it. This could be analogue to the mechanism of CRISPR gene editing technology (Doudna & Charpentier, 2014).

Triggering mutations

Among individuals with the X-Gene, mutations are not expressed from birth. Usually, the mutations are expressed at some point of puberty or adolescence, and related to stress situations. This behaviour is shared with several other genes, such as those related to sexual maturity and secondary sexual characters. On these examples, changes are preceded by the action of some hormones. A possibility is that the activation of the X-Gene is similar and hormone-mediated. Nevertheless, there are some examples of mutants with active mutations from birth (e.g., Nightcrawler and Multiple Man). Evolutionary explanations were provided for these examples (XF3#11),

that implies the retarded expression of mutations was a secondary acquisition of mutants, and the examples mentioned are remnants of these previous stage.

Some mutants expressed at some point secondary mutations (UX1#412; NX#116). Usually, these secondary mutations are activated latter in life, and they are also connected to stress situations. A relation with the increase of human populations and an adaptative origin was proposed for explaining secondary mutations (NX#114). No further information about it is known.

Taxonomy of mutants

In the very first issue of *The X-Men* (X#1), mutants are denominated as *Homo superior*, denoting their difference to regular humans. If the presence of the X-Gene (and its consequences) is a shared condition of all mutants, is this enough to consider mutants as a new species? We should consider that this gene may be a homeobox one. Excluding minimal genotypic differences, and considering important phenotypic ones, we can strongly differentiate mutants. Frequently, comic books refer to mutants as either a distinct species (*Homo superior*, for example in NX#124, Xfor #1, WFC#1, or WP2#28) or a subspecies (*Homo sapiens superior*, for example NX#114 and #118, A3#42). The situation is similar to what occurs with *Homo neanderthalensis* (Pääbo, 2014).

The species name *Homo superior* was erected by Erik Lehnsherr (an alias of Magneto) and first mentioned in 1963 (X#1) (Fig. 6), proposing to indicate the authority over the name as *Homo superior* Lensherr, 1963. A brief systematic appendix about this species is provided further below.

Difference between mutants and other genetics-based superhuman groups

In the Marvel Universe, there are other human "species" differentiated from regular humans. Some of them are the results of experiments of extra-terrestrial beings such as the Celestials; for example, Deviants (*Homo descendus*) and Eternals (*Homo immortalis*). Other known groups are the Atlanteans (*Homo mermanus*), like Namor, and the Inhumans (*Inhomo supremis* or *Homo sapiens inhumanus*).

Figure 6. Magneto mentioned for the first time the name *Homo superior*. From The X-Men #1 (X#1: p. 11; Marvel Comics).

Relationships between Atlanteans and mutants has been discussed (FFA#1; X1#6; NAI#1). Frequently, mutants and inhumans are compared, because they share some characters. Inhumans are a group with superhuman powers resulting from genetic differences to regular humans. They go through a process known as 'terrigenesis' that activate their superpowers. The genetic changes driven by terrigenesis could explain the effects of Terrigen Mist in mutants (M-Pox mentioned above). Apparently, the genetic basis of inhumans powers seems not restricted to a unique gene. This can be the reason why changes incurred in inhumans by terrigenesis frequently are more radical than those observed in mutants (I2#1-12). Terrigen Mist may be an external transcription factor that activates those genes.

In the other main superhero universe of comic books, the DC Universe, an analogue of the X-Gene can be found. It is called 'Metagene', and is present in some humans (known as 'metahumans'). This gene acts as a primary condition for developing superhuman powers. Characteristics of this gene are confusing and poorly explained: in

Figure 7. The Celestials experimented with early hominins and generated, in consequence, mutants and other variations. From *What If…? Vol. 1* #23 (WF1#23: p. 26; Marvel Comics).

some cases it is activated by stress situations and in others by external agents (for example, the Gene-Bomb of the Dominators in the crossover Invasion!). This concept is not very well-developed in DC comic books.

Origin of mutations

In the beginning, Stan Lee considered radiation of nuclear plants as the explanation that gave rise to mutations. In the example of Beast (Hank McCoy), the radioactive influence was located in the job of Hank McCoy's father (Back-up stories of X#49-53). The denomination "Children of the Atom", usually referred to the X-Men, is due to that. Other mutants are also related to radiation of nuclear bombs, as the Japanese mutant Sunfire (Shiro Yoshida) (X#64) and the villain Dragoness (Tamara Kurtz) (NM#94). Nevertheless, the presence of mutants before the "Nuclear Age" of the 20th century contradicts this assumption.

A non-natural origin was proposed for mutants. Celestials (specifically, the Celestial known as Oneg the Prober), a group of extra-terrestrial beings that experimented with life forms across the galaxy, implanted in a group of *Homo erectus* the genetic latent potential to give rise to mutants (WI1#23) (Fig. 7). This experiment could be the prelude to the origin of the X-Gene. From this point, evolution drove the fate of the mutants.

Gradualistic or punctuated origin?

Phyletic gradualism and punctuated equilibrium (Eldregde & Gould, 1972) are two extremes in a continuous model of evolution. The first one claims a uniformly and more gradual accumulation of changes that subsequently generate new species. In contrast, punctuated equilibrium proposed that once a species appears, it becomes stable, showing little evolutionary change; then, an event can trigger a rapid speciation process. The first appearance of the mutants in historical/archaeological record is abrupt (UX1#422), so it is possible to consider their origin as a punctuated process. Further research is needed to clarify this question.

First mutants and mutant lineages

The Celestials' experiments would have happened a million years ago (to public knowledge of mutants in Marvel Universe). Selene is claimed as the first mutant born (XN#1), during the Hyborian Age (17,000 year ago, the age of *Conan the Barbarian*). She was still alive during the times of the Roman Empire and is part of a particular group of immortal mutants, the Externals (F#10). After Selene, the villain Apocalypse (En Sabah Nur, born in Egyptian times), Azazel and the Neyaphem (UX1#422) are recorded. Historical mentions of probable mutants become more frequent from the Middle Age onward. For example, the villain Exodus (Bennet du Paris) lived during

the Crusades. According to Damian Tryp (XF3#11), a transitional human-mutant species (informally known as 'Homo kill-crop') lived around the 12th century. 'Proto-mutants' species lived during the Black Plague (X3#30-33). Status and relationships of these lineages are poorly known, but it is very possible that they are transitional or split lineages branching from early mutants. Many other lineages are mentioned between mutants: the Neyaphem, and the angelic Cheyaraphim (UX1#422) (Fig. 8), the lupine mutants (known as Dominant Species, UX1#420), the Neo (X2#99), among others. Origin of mutants seems to be a complex evolutionary story, with more than one simple lineage. Mosaic evolution could better describe the evolutionary trends of the group.

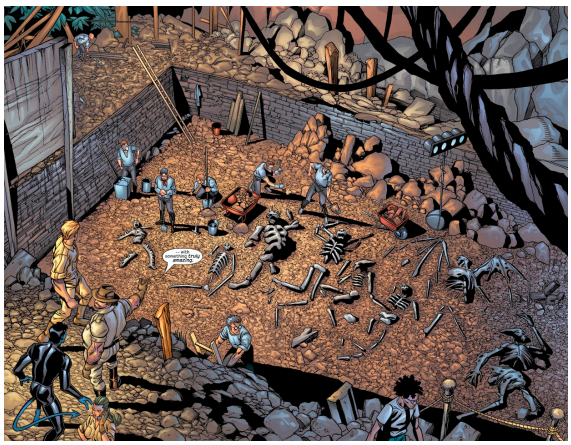

Figure 8. The finding of fossils of early mutants. From *Uncanny X-Men* #422 (UX#422: p. 3; Marvel Comics).

Extinction of mutants

Extinction is a frequent element around mutants in the Marvel Universe. The group has faced this possible destiny more than once, and due to different causes. In two points in their history, they were very close to extinction. The first one was during the story arc "Powerless!" (UX1#379-380, X2#99), due to the actions of the villain High Evolutionary (geneticist Herbert Wyndham). All mutants around the world were de-powered, perhaps by disabling the expression of the X-Gene. The second (and more dangerous) one was known as "M-Day" (HM#7), caused by Scarlet Witch's (the avenger Wanda Maximoff) magic spell. The words "No more mutants" cancelled the mutations of 90% of mutants and could have acted in a similar form to the cure of Kavita Rao mentioned above, but with a magical origin. The biological effects of this spell were indicated by the mutant scientist Beast in the story arc "Endangered Species" (X2#200) (Fig. 9). Also, no new mutants were born after that event, dooming the mutant species to extinction. Fortunately, the birth of Hope Summers occurred during Messiah Complex (XMC#1) and the extinction of mutants was prevented.

REFERENCES CITED

Two types of references are listed separately below: comic books and other literature (academic, encyclopedic, etc.). Comic book references are in accordance to the

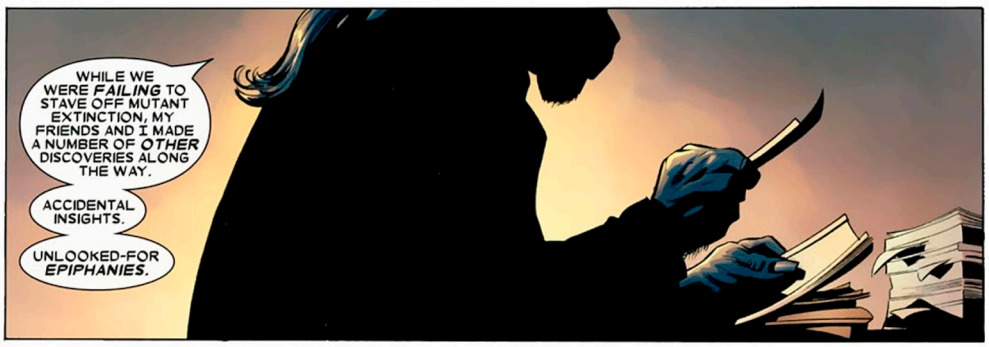

Figure 9. The mutant scientist Beast faces the extinction of mutants. From *X-Men Vol. 2* #200 (X2#200: p. 41; Marvel Comics).

system mentioned in the Methods section. Only writers and artists are mentioned as authors of the comic books, but many people (colourists, letterers, inkers, etc.) are involved in their production.

Marvel Comics

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A3#42: Avengers Vol. 3 #42, by Kurt Busiek & Alan Davis (July 2001).

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SYSTEMATIC APPENDIX

Genus *Homo* Linnaeus, 1758

Species *Homo sapiens* Linnaeus, 1758

Subspecies *Homo sapiens superior* Lensherr, 1963 (X1#1)

Diagnosis. Species of genus *Homo* with variable external appearance, with the presence of active X-Gene. This gene is expressed in different forms, some of them including superhuman powers.

Remarks. Despite the difficulties to differentiate species and subspecies of the genus *Homo* based on morphological features (Stringer & Buck, 2014), genetic particularities are enough to distinguish mutants as unique. Also, mutants often present

extraordinary characters that allow them to be recognised even in fossil or archaeological records (UX1#422) (Fig. 8) and their past record can be tracked. Mutants have a great amount of diversity among individuals and developed their own cultural signs and social behaviours, but they represent the great diversity present in real-world humans (Morrison, 2011). The choice of mutants as a human subspecies instead of as a separate species is due to the possible interbreeding between both groups, according to the well-established Biological Concept of Species (Mayr, 1942). A second reason is to follow "Xavier's dream", a statement frequently pointed out in mutant comic books about coexistence of humans and mutants as a single species.

Disclaimer

The present article uses real-world scientific knowledge to interpret a comic book universe; it is written in a playful manner, as if we were part of that latter universe. Neither the author nor the Journal of Geek Studies or its editors endorses eugenics, genetic modification of humans, or the division of Homo sapiens into subspecies.

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About the author

Dr. **Damián Pérez** is a big fan of comic books who spends a lot of time reading them. His favourite mutant characters are Wolverine and Nightcrawler. Also, he is a paleontologist studying the evolution and systematics of bivalves (among other things). He is currently a researcher in the Instituto Patagónico de Geología y Paleontología at Puerto Madryn, Chubut, Argentina.