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Science Fact!

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Daredevil is one of the ostensibly “realistic” super-heroes. He is no god, he cannot fly, he cannot shoot rays with his eyes, nor is he invulnerable or able to teleport. Mostly, he is a super-hero in the Batman mold; highly trained, driven by vengeance, and uses fear as his main weapon. Even his super-human abilities were conceived as balancing a serious handicap, his blindness. However, realism is a word that takes a singular meaning in the context of a super-hero narrative: Daredevil may be easier to accept than Spider-Man or most of the X-Men, but does that mean his abilities are plausible? How would he fare if the laws of physics applied to him? These are the questions we have sought to answer.

Child of the Atom

Daredevil’s origin has not changed much since *Daredevil* Vol. 1 #1 (Apr 1964): after being exposed to radioactive material when hit by a truck carrying the dangerous load unsafely across New York City, young Matt Murdock becomes blind but witnesses a notable increase in the efficiency of his other senses, even thinking to himself in a manner indicatively expositional of the time: *Everything seems easy for me now! All my senses are razor sharp!* Daredevil is thus another child of radiation, the default origin story for Marvel heroes of the sixties.

The main flaw with that story, of course, is that radiation is unlikely to give anyone superpowers. Radiation had been known by scientists to cause genetic mutations since the late twenties,¹ but the popular image of the radioactive mutant has little basis. Radiation cannot generate mutations that would not occur naturally, and even more problematically, they only affect the descendants of the exposed individuals. The more likely outcome of exposure to radiation is cancer, or in cases of direct and severe exposure, the “Acute radiation syndrome,”² with dramatic, spectacular, and ultimately deadly effects. After the creation of a regulatory body, the Federal Radiation Council, in 1959, and after Congressional enquiries on the subject in 1960, information about these adverse effects was widely available and what may have been a sustainable explanation for the powers of Marvel’s earlier heroes was therefore a lot less convincing in 1964. Is it plausible that a regular truck would carry radioactive material with no safety device in New York in 1964, even leaving aside the idea that this material may be contained in easily opened cylinders? Depending on the type of material, it is

¹ Hermann Joseph Mueller, an American geneticist, published the first article on the subject, “The Problem of Genetic Modification,” in 1927, in which he detailed his work on the effects of X-rays on the genome. He received the Nobel Prize for his work in 1946.

² The acute radiation syndrome, also known as radiation sickness, occurs after a severe irradiation of the bone marrow, the gastrointestinal tract or the brain. It rapidly causes nausea, vomiting, and then, depending on the level of irradiation and on the affected parts of the body, it may become lethal in a few hours to a few weeks. See A. C. Upton, John M. Last . “Radiation, ionizing”. *The Oxford Companion to Medicine*. Stephen Lock, John M. Last, and George Dunea. Oxford University Press 2001. Oxford Reference Online. Oxford University Press. <<http://www.oxfordreference.com/views/ENTRY.html?subview=Main&entry=t185.e419>>

not entirely unimaginable. Among the three types of radiations, alpha radiations can cause mutations or cancer in case of direct contact, yet this type of radiation can be stopped even by a single sheet of paper.

The implausibility of this origin story should not be overemphasized, for radioactivity is not what Daredevil is about. Its presence in the narrative reads like an afterthought: were it not for a panel on the truck and three mentions in speech balloons later on, it would be utterly absent from his origin story. As early as the first issue, Daredevil finds himself in a criminal, urban setting, which has remained the default environment and mood for the character. Radioactivity works as a simple excuse, an added thrill rather than a thematic component.

“This is D.D.’s greatest secret”

Among the things that radioactivity did not alter is Murdock’s physical strength. From the origin story to *Daredevil: The Man Without Fear* (1994), writers have consistently emphasized rigorous training as the source of Daredevil’s impressive feats, though Miller himself noted that he appears “nearly super-human” (Vol. 1 #167 Nov 1980). To consider the physical feats Murdock has been shown to master with ease through a prism of pragmatic consideration and applied mathematics, we can scientifically discuss how realistic and thus exactly how amazing his body and its abilities are.

In *Daredevil* Vol. 2 #86 (Aug 2006), in the climactic conclusion to the storyline during which Murdock is imprisoned on Rykers island, Daredevil is restored, morally and physically, through a show of strength and skills. Michael Lark’s realistic and photo-referenced environments allow us to evaluate just how extraordinary these strengths and skills are. At one point, Daredevil jumps from the prison floor to catch a guardrail, four meters above him, without a run-up. Since the measurement of one’s vertical high jump is routinely used to evaluate athletes, points of comparison abound. If we subtract Daredevil’s size (1.83 meter) plus the length of his arm from our four meter estimate, he needs to accomplish a vertical jump of roughly 1.64 meter in order to catch the rail above him. The average person has a vertical high jump of about 0.5 meter,³ but the height of the jump is proportional to the expanded energy, which makes substantial improvements possible. Trained athletes will go three times as high as regular people, and the world record, held by basketball player Kadour Ziani, stands at 1.52 meter. This is close to the figure we inferred from that issue, and specific training combined with an exceptional physiology could explain that 8% difference. Since Murdock is shown displaying exceptional predispositions – he blows a punching bag off its hook before his accident in Vol. 1 #1 – in all the versions of Daredevil’s origin stories, to accomplish this jump may be an extraordinary feat, but it can hardly be described as super-strength. All of Daredevil’s powers are on display in this issue (including super-human stamina) as he resurrects his super-heroic persona but his strength is still depicted as falling within conceivably human parameters.

The same sense of measure does not apply to all of Daredevil’s acrobatics, however. His journey over the city roofs typically involves spectacular jumps and catches, but we rarely get to gauge exactly how impressive they are. In *Daredevil* Vol. 1 #7 (Apr 1965), however, the man without fear lets go from a plane flying over the city and breaks his fall by catching the horizontal bar of a traffic

³ See David D. Patterson and D. Fred Peterson, “Vertical Jump and Leg Power Norms for Young Adults,” *Measurement in Physical Education and Exercise Science*, 2004. 8(1), 33-41

light. The plane is an unusual feature, but it appears to fly as high as a six-story building; a very similar fall, from a comparable height, is pictured by Frank Miller seventeen years later, in Vol. 1 #178 (Jan 1982). How likely is Murdock, in either of these cases, to fall without dislocating his shoulders or spraining his wrists?

Six floors mean around 18 meters, and the traffic light must be around six meters high, so as not to hamper the passage of tall vehicles. This is thus a 12-meter fall, and we can safely ignore air friction, thanks to Daredevil's aerodynamic position. Daredevil's vertical speed when he catches the bar is thus about 15.5 m/s.⁴ However, after his first half-revolution around the bar, his vertical speed reaches 0 m/s, since he is no longer moving downward. To reduce his speed this much, he must first have pushed on the bar, when he was above it, and then have pulled on it, while under it.

It takes approximately 0.26s for his center of gravity to complete the semi-circular movement around the bar (with a diameter of 1m) and for the deceleration to be over. Daredevil's body, muscles, bones, and sinews have to furnish the force necessary to absorb this speed, 5000 N:⁵ the first part of the effort is tantamount to lifting 500kg, while the second part is equivalent to holding the same weight at arm's length. This is enormous: professional weight lifters, depending on the sport and the category, lift weights between 200 and 265 kg. Although the bench press record stands at 500kg, it seems too far from Daredevil's acrobatics – in the athlete's postures as well as in their morphology – for the comparison to be relevant.

The lack of emphasis put on Daredevil's agility, which he shares with other non super-powered characters, such as the Black Widow, makes it easy to forget that much of what he accomplishes relies not only on speed and coordination but also on superlative physical strength. Thus unbeknown to all, Daredevil must have received super-strength from his exposure to radiations, though perhaps it is only available to him when moving through the city.

"I can hear them two floors away"

Without his sight, Daredevil becomes blessed with hyper-acuity in his other remaining senses. Considering the personal nature of many of these senses, some are easier to run through the scientific grinder than others.

Of the side effects that were supposedly induced by radiation, the improvements in the way Daredevil smells and tastes can hardly be tested, since they rarely, if ever, feature in the narrative. The principle in both cases is clear, implying a multiplication and an improvement of the dedicated receivers. Expertise and focus significantly improve one's capacity to discern subtle variations in taste and smell, as any oenologist will demonstrate. It appears therefore non-problematic for Daredevil to display super-human uses of these two senses, as long as it remains impossible to quantify.

Touch, however, is used more often and is integral to the character. In most cases it functions as a useful narrative shortcut that gives Daredevil access to printed matters, since he is able to read the content of a printed page by running his fingers over it – "His super-sensitive fingers could 'read' ordinary print if he wished, merely by feeling the impression of the *ink* on the page!" Vol. 1 #4 (Oct

⁴ Newton's laws provide us with a relationship between the height of the fall (h) and its vertical speed (v): $v = \sqrt{2gh}$ where $g \approx 10 \text{ m/s}^2$.

⁵ Newton's second law ($F = m \times \Delta v / \Delta t$) allows us to estimate this force at $F = 83 \times (15.5 - 0) / 0.26 \approx 5000 \text{ N}$.

1964). Blind people generally see the efficiency of their other senses improve, simply because these senses then receive more attention. This could account for an increase in the sensitivity of Daredevil's fingertips, but it would not be sufficient to read a newspaper article. An increase in the number of appropriate receptors may bridge the gap from braille to regular print to the point where even the tiny volume of ink dots on paper may be detectable. Additionally, trained readers can usually reconstruct the meaning of a text through very incomplete information: the top half of the characters will usually suffice; vowels can often be inferred, etc. The ability can therefore be explained by a combination of specific physiological aptitudes and by Daredevil's oft mentioned capacity to process information.

This does not account, however, for Daredevil's ability to perceive colors by touch. It would be a marginally extravagant use of the character's powers if it were not mentioned to explain how he conceived his costumes: "Each colored fabric has a different *feel* to me!" remarks young Murdock in Vol. 1 #1. A possible explanation was given nearly ten years later, in Vol. 1 #106 (Dec 1973), and used a couple of times afterwards: Daredevil is able to sense minute differences in the heat absorbed by different types of materials. There is a scientific basis for this claim, as objects placed in the light will become hotter at a different rate depending on their color: dark objects rise in temperature faster than light ones. However, while this would allow Daredevil to distinguish between different tones, different colors may absorb heat at the same rate, making it impossible to distinguish between them. Thus, he may sense the difference between dark and light material to a certain extent (differences in heat are minute, this would not work in the dark, different materials conduce heat differently which makes comparisons even more complex, etc.) but would still be color-blind. That also implies that any text printed on a colored background will probably be illegible to Murdock, since he would not be able to distinguish between the various types of inkblots, such as what is seen with offset printing and similar techniques.

However, of all his super-human senses, Daredevil's heightened hearing is unquestionably the most defining feature of the character. When Mark Waid and Marcos Martin reintroduced him in "Here Comes Daredevil," the backup story to *Daredevil* Vol. 3 #1 (Sept 2011), it is through the pairing of blindness ("Sometimes, in my dreams... / ...just sometimes... / ...I can see") and super-hearing. In the opening scene, Murdock is disturbed by the sound of Foggy Nelson eating crisps a corridor away, represented in gigantic letters. Super-hearing is easily imagined: there are a variety of sounds the normal human ear will not discern because they are pitched too low, too deep or because they are too weak. These limitations are interconnected, since at the extremes of the hearing spectrum (sound deeper or higher than the human voice, basically), a sound has to be louder to be heard by a normal human being. In the scene from "Here Comes Daredevil," volume is an issue but frequency is not: normal ears tend to perceive the sound of crisps.

If we estimate this sound to be at a level comprised between a normal conversation and a whisper, a normal human being would be unable to hear the sound in the described situation: a closed door and a ten-meter long corridor lie between the sound and the listener. The threshold for audibility by the human ear is 0 decibel (dB), and in this configuration the sound would have a level of -15dB. If that threshold is lowered by super-hearing, the scene works. On the other hand, we have a plausibility issue if the doors were closed at both ends of the corridor, a possibility left open in the sequence. A closed door muffles a sound and reduces it by approximately 25 dB. A sound at -40 dB does not exist. Sound is a wave carried by molecules and below a certain volume, the natural

movement of these molecules becomes an obstacle: if a sound is weaker than -23dB, the signal is utterly lost in the noise. In other words, beyond this threshold, even super-hearing becomes useless, because there is no "sound" to be heard, just a continuous hissing sound with no informational value. If the second door was closed then Nelson could eat his crisps without disturbing anyone.

In the open, however, a normal human being can hear a conversation a hundred meters away, while Daredevil could do so at 1.4 kilometers. Standing in the exact center of Hell's Kitchen, he could theoretically notice a conversation anywhere in the streets within the area, as he does in Vol. 2 #98 (Aug 2007), for example. On the other hand, the muffling effect of walls and ceilings is such that to have Murdock overhear a conversation two floors away in Rykers appears strictly impossible (Vol. 2 #86 Aug 2006). This is the same theory for Murdock hearing the gates of the prison being locked in the same issue while being taken back to his cell, that goes far beyond any physical property of sound.

For all its limitations, super-hearing can yield unexpected results. In *Daredevil* Vol. 1 #7 (Apr 1965), Daredevil fights Namor, and at one point makes a remark about Namor's pulse indicating that the Submariner is still angry while in the same panel a gigantic "BA-ROOM" signals that a wall is being battered down by a wrecking ball. Super-hearing would indeed allow Daredevil to make that distinction. Hearing a pulse from a distance is difficult, since its frequency makes it hard to distinguish for a normal ear, but once one can do that, sounds with different frequencies (the pulse and the BA-ROOM) do not affect each other. There may be a slight masking effect, but the louder sound does not cancel the weaker one. That example also explains why Daredevil can be neutralized by sounds that allow normal human beings to function. Since he perceives frequencies the human ear cannot process, all one has to do is blast him with extremely loud sounds within these frequencies. Of course, they may be disagreeable to normal humans as well, because sounds are not pure and tend to be heard over several frequencies. This is exactly what happens in Garth Ennis's "The Devil by the Horns", in *The Punisher* Vol. 5 #3 (Jun 2000), a story which includes judicious remarks about the Punisher's choice of frequencies and the possible side effects.

Thus, super-hearing is not a ludicrous notion. If you improve the threshold of sensitivity and the range of frequency, through a physical transformation of the ear itself, you do get impressive results. The only factor that does not seem to exist in Marvel physics is the dissolution of sound into random air movement under a certain level.

"His Pulsebeat is steady, he's telling the truth"

What of Daredevil's lie detector ability, then? In its most straightforward appearances, it appears to rely on a very simple test, derived from his super-hearing: *His pulsebeat is steady, he's telling the truth*, reads a thought balloon in *Daredevil* Vol. 1 #194 (May 1983), echoing the explanation given as early as Vol. 1 #1 when Daredevil thinks, *I can hear his pulse rate! It's speeding up, indicating he's lying!* There is however no reason to suppose that Daredevil ignores the other signs that may indicate someone is lying, primarily body language. He was even famously fooled once by a man with a pacemaker, first in *Daredevil* Vol. 1 #184 (Jul 1982), then in the movie, *Daredevil* (2003). If lying is tied to an intense emotional reaction, it is likely to cause an increase in breathing frequency, of body heat, of blood pressure, and a dilatation of the pupil. In addition to the heartbeats, Daredevil's super-hearing and his training as a lawyer should also help him spot variations in the pitch of the suspect's voice, caused by the shaking of his larynx: "I *wanted* to believe him, but I heard it in his

voice”, *Daredevil* Vol. 2 #96 (Jun 2007). His sensibility to minute variations in heat may also allow him to spot the increase in temperature around the eyes and on the cheeks commonly caused by a state of unrest, or to know someone is sweating without a direct contact, as the evaporation of water lowers the temperature of the skin.

Having access to all these parameters enables Daredevil to function as a human polygraph: he has the necessary tools to spot any sign of nervousness. What he often does not have, though, is a frame of reference, since all these tests work through a comparison with the person’s normal physiological pattern. To pass judgment on the state of nervousness of an old acquaintance, such as the Gladiator in *Daredevil* Vol. 2 #95-96 (May-Jun 2007) is quite different from reaching any conclusion from a short discussion with a stranger. Furthermore, what is detected is not a lie as such, but tension. This is acknowledged at times – “I still think you’re lying...but your heart is beating *so fast*, I can’t tell if I’m *wrong* or not,” Daredevil notes after beating down Leland Owlsley, the Owl, in Vol. 2 #83 (May 2005) – but conveniently ignored when Daredevil’s intimidating presence is by itself likely to disrupt the test.

Again, science seems mostly on Daredevil’s side in this case. The difference between actual physics and Marvel physics lies in the transformation of high probabilities into certainties, of long procedures into instantaneous tests. In extreme cases, it also means that Murdock is also able to interpret the state of mind of an entire people just by listening to pulses from a car – *All through the countryside is that feeling of hatred...overshadowed only by an even stronger feeling of stark fear!!*, Vol.1 #9 (Aug 1965) – but that was uncommon, even early in the character’s existence.

Bouncing off history

Marvel physics, however, raises some thorny questions when it comes to Daredevil’s last and most efficient power, his “radar” sense, which allows him to scan his entire environment. While Daredevil’s senses are merely improvement on existing human capacities, his radar offers a very different challenge, starting with its definition. A radar emits electro-magnetic waves – radio waves – at regular intervals and the time it takes for these waves to bounce back to their point of origin serves to establish a map of the environment: the longer the delay, the further away the object. The problem of course is that there is nothing in the human body to emit or receive radio waves.

An alternative representation, the bat’s “echolocation,” provides a different explanation that fits more neatly with Daredevil’s other abilities. Echolocation works the same way a radar does, with one important difference, it relies on sound at extremely high frequencies rather than on electro-magnetism. Since Daredevil can hear frequencies much beyond the normal human ear, echolocation resolves at least half of the problem. This explanation has the further advantage of being used by actual blind people, though with sounds at a lower frequency and hence with a lower definition: using brief clicks of their tongues to send the necessary signal, they can nevertheless spot objects as narrow as a flagpole from five meters away.⁶ As the echoes reach the right and left ears at slightly different intervals, the technique permits to reconstruct a three-dimensional environment. The alterations affecting the echoed sound also provide information about the type of material, as the sound will not bounce the same way off a carpeted wall or off a wood panel. Minor mutations could even serve to generate ultrasonics, in ways similar to the aforementioned tongue clicking, though

⁶ See Lore Thaler, Stephen R. Arnott SR, Melvyn A. Goodale. “Neural Correlates of Natural Human Echolocation in Early and Late Blind Echolocation Experts”. *PLoS ONE* 2011. 6(5): e20162. doi:10.1371/journal.pone.0020162

this is left unexplained in the comic book. Unsurprisingly, *Daredevil* Vol. 3 #1 mentions the character's "radar-like" sense and offers echolocation as a possible analogy, but as early as Vol. 1 #1, the new ability merely works *like* a radar. Although the word is most often used without quotation marks, the "radar" is not meant to be one.

Well, it sometimes is. In Vol. 1 #10 (Oct 1965), Murdock's "radar hearing" enables him to pick up a radio message, while a few issues earlier, he needed special antennas in his costume's ear to do this. This was, again, a short-lived variation. By contrast, David Michelinie explicitly linked the radar to sound waves, as in Vol. 1 #167 (Nov 1980): "Daredevil has an uncanny *radar-sense*. Like a bat, he emits probing, high-frequency waves...waves which break against any solid object, and breaking, send back signals audible only to Daredevil."

As with super-hearing, echolocation has interesting applications. For instance, Daredevil would indeed be able to see through some walls. If he emits a burst of ultrasonics at 50 kHz it would travel at sound speed until it encountered an obstacle whereupon only part of it would be reflected back, depending on the nature of the material. Since Daredevil has apparently learned to process information optimally (he was disrupted by objects moving too fast early on, but as noted in Vol. 3 #1, "it really seems to have gotten sharper over the years"), he could deduce the nature and the depth of the object, but also "see" through some material, from clothes to plaster walls. Glass is problematic, though. For obvious narrative reasons, Daredevil's perception mostly coincides with what the reader is shown: he perceives his immediate environment with no difficulty and he "sees" through windows. The problem is that glass will reflect 99,999% of the sound coming through, and since the signal has to cross it not once, but twice, it will be reduced by around 80db, making it utterly opaque to Daredevil from a distance. This also means that the representation currently used in Vol. 3, a colorless, texture-less three-dimensional environment, does not fit with Daredevil's penetrating perception.

Does the radar-sense work then? To a certain extent, it does. It simply improves on an existing, efficient technique, and this improvement is mostly a direct consequence of Daredevil's super-hearing, combined with his intensive training. Nevertheless, a serious limitation lies in the fact that to form a coherent picture of his environment, Daredevil needs to emit bursts at regular intervals to refresh his perception. However, a new burst of ultrasonics cannot be emitted before the previous one has been processed, otherwise the two signals would interfere. Since the range of the radar-sense is approximately 25 meters – at least according to *The Official Handbook to the Marvel Universe Master Edition* Vol. 3 #7, more recent Handbooks do not give a figure – it means there needs to be 0.2s between each burst.⁷ Daredevil would therefore be able to update his perception roughly five times per second, which is fine when it comes to locating fixed or slow-moving objects but may be a lot more problematic in a combat situation. If a man walks in and moves within the range of the radar sense, by the time the information gets to Daredevil, the man will have moved by about 12 centimeters, an acceptable margin of error. However, a vehicle going at 100 km/h will have moved by 2.4 meters by the time it is detected. In order to appreciate its trajectory, Daredevil will have to wait for a second ping, 0.2 seconds later. Similarly, it takes a tenth of a second for him to perceive movement taking place 25 meters away from him, but also to hear the sound of gunshot, for example. It is possible that in Marvel physics, the speed of sound is different from ours, but that

⁷ $t = 2 \times 25 / 340 = 0.147$ s, with 340 m/s being the speed of sound.

would be a major, world-altering difference. Barring that, however, Daredevil has a serious handicap to overcome when fighting from a distance people who can see, rather than hear.

Fortunately, the radar-sense is complemented by super hearing. At a very simple level, it means that he will be aware of the car long before it enters the 25-meter range. In a more sophisticated fashion, the Doppler effect means that sound also carries information about trajectory and speed: the sound of an object moving towards us will be pitched higher than if it were moving away from us. If a knife is thrown in Daredevil's direction at 20m/s, and assuming as we did that he emits sounds at a frequency of 50kHz, the reflected signal will have a frequency of 53.1 kHz, a semitone and a very noticeable difference. Therefore, he does not have to wait for his fairly slow radar-sense, and can act accordingly. This would explain how Murdock is able to save Milla from the Gladiator's spinning blade thrown across a restaurant, in Vol. 2 #97 (Jun 2007). Generally, the radar-sense is only efficient in conjunction with Daredevil's other heightened perceptions. A specifically outrageous example is to be found in the same issue. Daredevil walks into a bathroom, finds a body in a bathtub, and with "radar" circles filling the panel, states: "The crime scene doesn't feel staged. / It's clear to me that no one *else* has been in here for weeks". That can only make sense if we take into account his heightened smell.

All of this points to the fact that the radar sense is an extremely useful scouting device, since it performs a 360° scan and can penetrate certain objects. It is, however, a very unreliable way to apprehend fast-moving objects, which should put Daredevil at a notable disadvantage in direct confrontations. In particular, bullets go much faster than sound: extremely fast reflexes may theoretically allow someone to dodge one, but in Daredevil's cases, the bullet would hit him before he could notice it, either through his radar or through his other senses. Having him deflect a bullet with his cane in *Daredevil: The Man Without Fear* #5 (Feb 1994) makes no sense in a world bound by physical laws.

Marvel physics

When we started thinking about Daredevil's powers and physical feats, we were expecting them to contradict every single known fact about physics and the human body. In a way, they do, since particularly egregious examples of misuse can be found for each of his abilities. If we consider, however, their depiction in the long run, they generally make sense. As noted above, there is a tendency to turn high probabilities into certainties and to go to the limit of what physics and physiology allow, and sometimes above that. However, these simplifications and exaggerations apply as well to all the other aspects of Daredevil's life, from his nigh-instantaneous love affairs to his bafflingly simple legal cases. The point is to be realistic enough not to shock the reader out of his willing suspension of disbelief, and the use of science in *Daredevil* accomplishes that. The origin story is of course the most problematic aspect of the character, but radioactivity should really be seen in this context as a mere excuse, rarely discussed, and even more rarely used in the narrative afterwards. Daredevil may live in a world where Marvel physics apply – with nearly instantaneous sound travel and mutation generating radioactive material as its salient features – but this world never devolves into a pure fantasy.