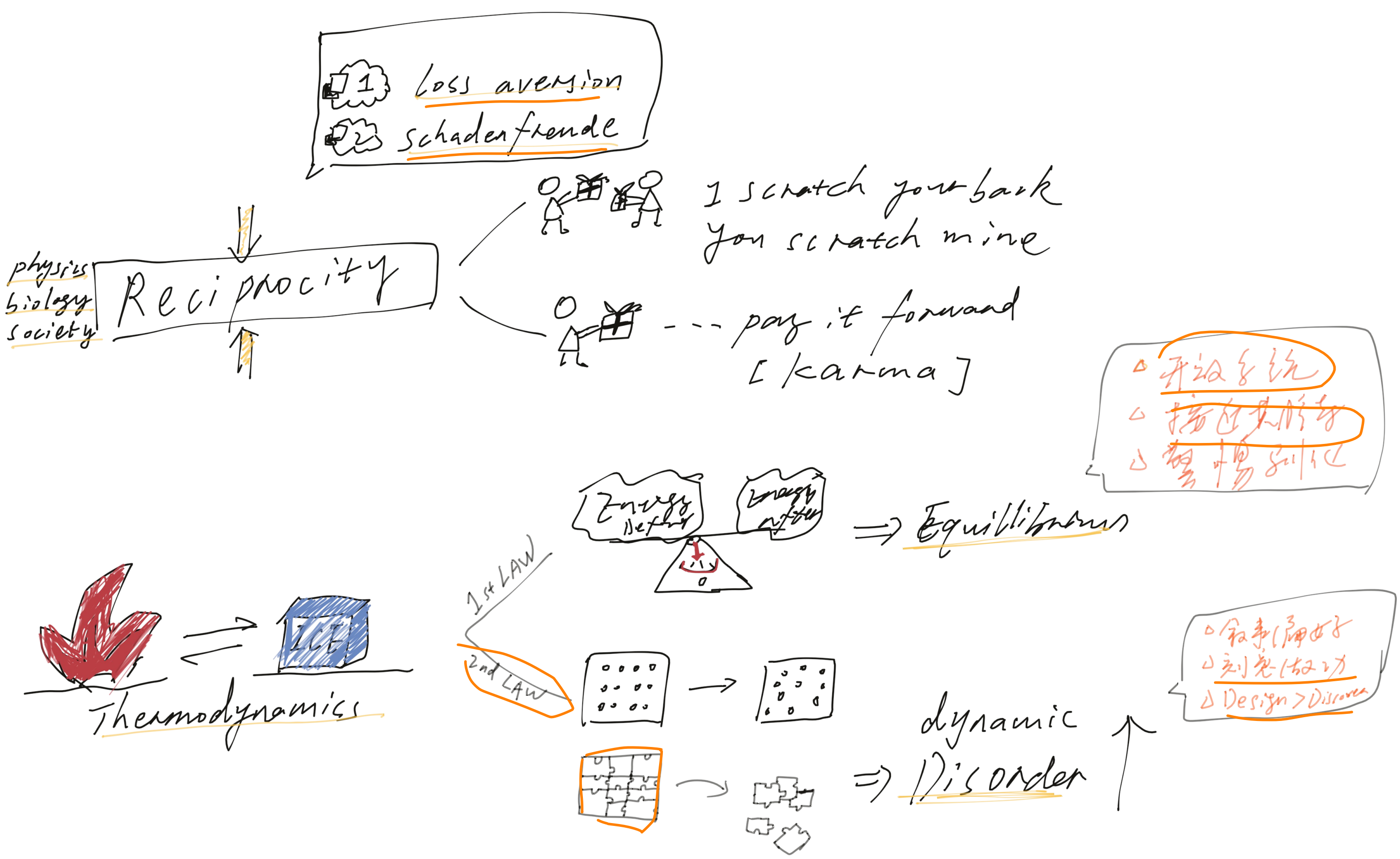
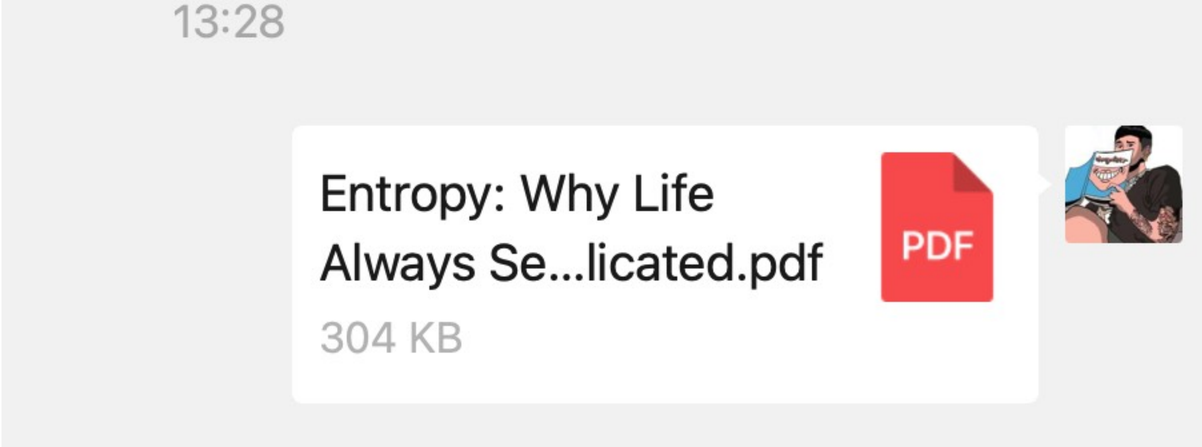
不过最后我什么都没说，人最终是要自助。病急乱投医和蜻蜓点水式的思考无法从根本上解决问题。所有的经历都是成长的机会，抓住它认识自己，然后自己做决定，为这个决定负责。如果你已经关注了我，读读我写过的东西，听听我的故事，可能会找到一些安慰和力量。在我看来这也是基本的自学、自救能力。

我能做的有限，我也不给自己贴什么标签加什么义务责任。我们都是芸芸众生，没那么特别，没那么多不同。践行热力学第一定律，向你想成为的人靠近，拥抱另一种思考生活方式。世界注定不可控注定混乱，那就做一个开放系统，用做功抵抗熵增。





Why Art is Beautiful

Entropy offers a good explanation for why art and beauty are so aesthetically pleasing. Artists create a form of order and symmetry that, odds are, the universe would never generate on its own. It is so rare in the grand scheme of possibilities. The number of beautiful combinations is far less than the number of total combinations. Similarly, seeing a symmetrical face is rare and beautiful when there are so many ways for a face to be asymmetrical.

Beauty is rare and unlikely in a universe of disorder. And this gives us good reason to protect art. We should guard it and treat it as something sacred.

Why Marriage is Difficult

One of the most famous opening lines in literature comes from Anna Karenina by Leo Tolstoy. He writes, “Happy families are all alike; every unhappy family is unhappy in its own way.”

There are many ways a marriage can fail—financial stress, parenting issues, crazy in-laws, conflicts in core values, lack of trust, infidelity, and so on. A deficiency in any one of these areas can wreck a family.

To be happy, however, you need some degree of success in each major area. Thus, all happy families are alike because they all have a similar structure. Disorder can occur in many ways, but order, in only a few.

Why Optimal Lives Are Designed Not Discovered

You have a combination of talents, skills, and interests that are specific to you. But you also live in a larger society and culture that were not designed with your specific abilities in mind. Given what we know about entropy, what do you think the odds are that the environment you happen to grow up in is also the optimal environment for your talents?

It is very unlikely that life is going to present you with a situation that perfectly matches your strengths. Out of all the possible scenarios you could encounter, it's far more likely that you'll encounter one that does not cater to your talents.

Evolutionary biologists use a term called "mismatch conditions" to describe when an organism is not well-suited for a condition it is facing. We have common phrases for mismatch conditions: "like a fish out of water" or "bring a knife to a gunfight." Obviously, when you are in a mismatch condition, it is more difficult to succeed, to be useful, and to win.

It is likely you'll face mismatch conditions in your life. At the very least, life will not be optimal—maybe you didn't grow up in the optimal culture for your interests, maybe you were exposed to the wrong subject or sport, maybe you were born at the wrong time in history. It is far more likely that you are living in a mismatch condition than in a well-matched one.

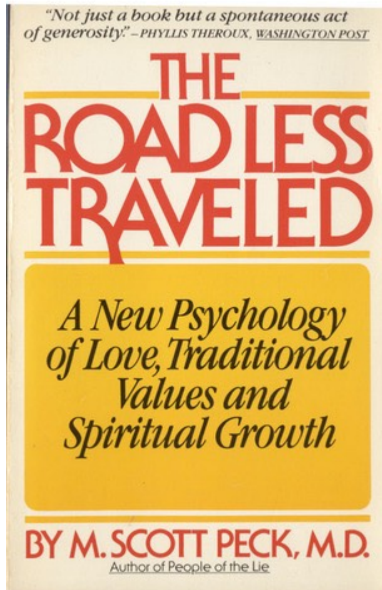
Knowing this, you must take it upon yourself to design your ideal lifestyle. You have to turn a mismatch condition into a well-matched one. Optimal lives are designed, not discovered. [7]

Murphy's Law Applied to the Universe

Finally, let's return to Murphy's Law: "Anything that can go wrong, will go wrong."

Entropy provides a good explanation for why Murphy's Law seems to pop up so frequently in life. There are more ways things can go wrong than right. The difficulties of life do not occur because the planets are misaligned or because some cosmic force is conspiring against you. It is simply entropy at work. As one scientist put it, "Entropy is sort of like Murphy's Law applied to the entire universe." [8]

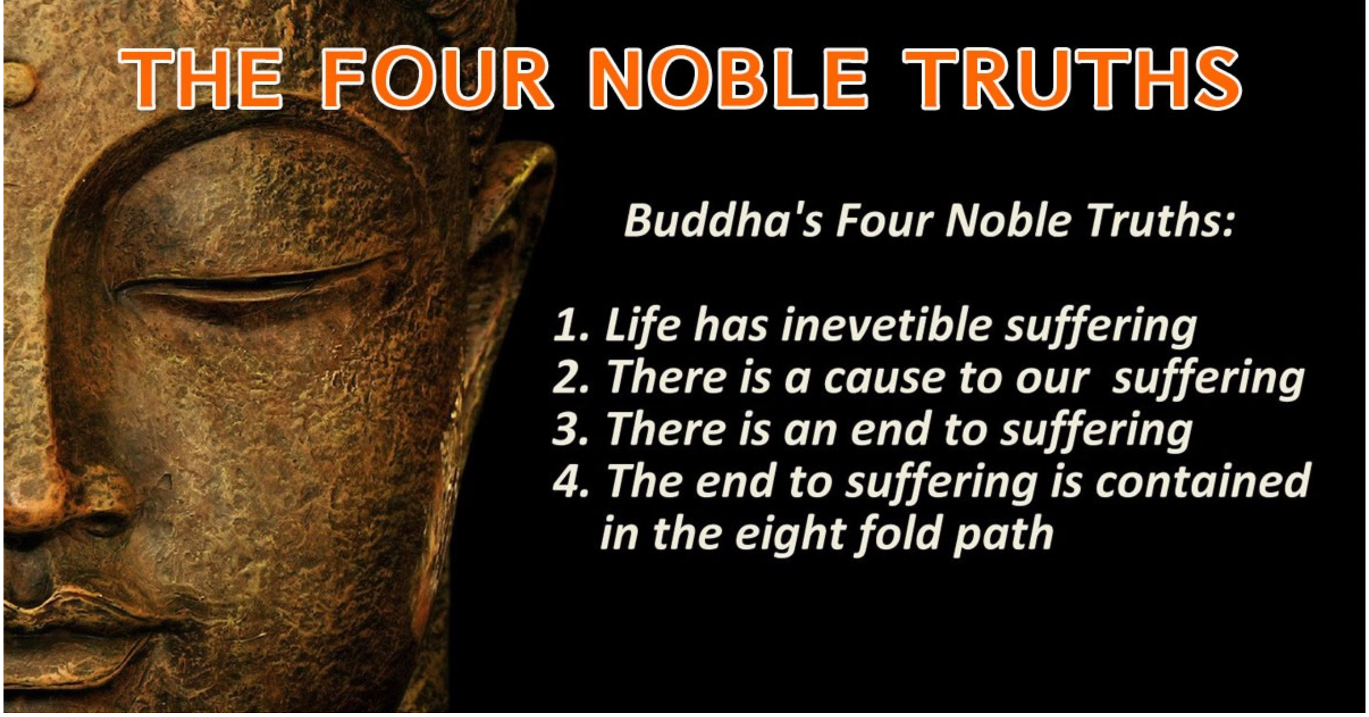
It is nobody's fault that life has problems. It is simply a law of probability. There are many disordered states and few ordered ones. Given the odds against us, what is remarkable is not that life has problems, but that we can solve them at all.



Problems and Pain

Life is difficult.

This is a great truth, one of the greatest truths.* It is a great truth because once we truly see this truth, we transcend it. Once we truly know that life is difficult—once we truly understand and accept it—then life is no longer difficult. Because once it is accepted, the fact that life is difficult no longer matters.



Dukkha

- Dukkha is the first of the Four Noble Truths: Life is suffering.
- It is one of the three marks of conditioned existence.
- It is part of the Buddha's analysis of the human condition
- it is generally translated as unsatisfactoriness
- There are three different levels of dukkha
- First is ordinary suffering and includes: birth, death, grief, physical pain mental anguish etc.
- Not getting what we want and the limits of human existence are dukkha
- Dukkha is caused by craving or attachment to impermanent things

Quid pro quo

Sometimes, if you want to understand how pervasive a concept is, you can look at the vernacular of a society. English speakers from Commonwealth countries have many expressions that suggest the basics of reciprocity are foundational for how we expect our society to function. "Quid pro quo," Latin for "something for something," appeared in regular usage in the 16th century. We also have "give and take," "tit for tat," and "if you scratch my back, I'll scratch yours." The meaning behind list some English vernacular expressions related to "reciprocity"

Certainly! Here are some English vernacular expressions related to "reciprocity":

1. "You scratch my back, I'll scratch yours": Refers to the idea of mutual assistance or favor exchange, highlighting the principle of reciprocity.
2. "Tit for tat": Describes a situation where one person responds to an action or behavior with a similar action, emphasizing the concept of reciprocal actions.
3. "Two-way street": Implies that a relationship or interaction requires equal participation and mutual give-and-take, reflecting the idea of reciprocity.
4. "Quid pro quo": A Latin phrase that means "something for something," suggesting an exchange of goods, services, or favors on an equal basis, emphasizing reciprocity.
5. "What goes around, comes around": Indicates that the actions or behavior one puts out into the world will eventually come back to them, reflecting the principle of reciprocity.
6. "In kind": Describes responding to an action or favor with a similar action or favor, reflecting the idea of reciprocity.
7. "Reciprocate the gesture": Encourages responding to a kind act or favor with a similar act or favor, highlighting the concept of reciprocity.
8. "Give and take": Describes a balanced exchange of actions, favors, or compromises, emphasizing the idea of reciprocity in a relationship or interaction.
9. "Mutual understanding": Sugg[...] or recognition of each other's needs, interests, or perspectiv[...] of reciprocity.

Regenerate response

list some English vernacular expressions related to "inertia"

Certainly! Here are some English vernacular expressions related to "inertia":

1. "Going with the flow": Describes a tendency to follow the current or prevailing direction without actively initiating change, similar to the concept of inertia.
2. "Lethargic as a sloth": Refers to being slow-moving or lacking energy, reflecting a state of inertia.
3. "Stuck in neutral": Implies a lack of progress or movement, similar to a car that is not in gear and cannot accelerate.
4. "Mired in complacency": Indicates being trapped in a state of contentment or satisfaction that hinders progress or change, reflecting a sense of inertia.
5. "Motionless as a statue": Describes someone or something that remains completely still, emphasizing the lack of movement or action associated with inertia.
6. "Tied to the past": Suggests being strongly influenced by previous experiences or traditions, which can hinder forward progress, similar to the resistance to change often associated with inertia.
7. "Drag one's heels": Refers to intentionally delaying or procrastinating, often due to a lack of motivation or resistance to taking action, reflecting a sense of inertia.
8. "Stuck in a time warp": Describes being trapped in a particular era or mindset, unable or unwilling to adapt to new circumstances or ideas, similar to the concept of inertia.
9. "An object at rest tends to stay at rest": This phrase, derived from Newton's first law of motion, is often used metapho[...]s or people that are inactive or

Regenerate response

Physics

Inertia

–
Nothing happens until something moves.

inertia ★☆☆☆☆

1 [N-UNCOUNT 不可數名詞] 惰性;遲鈍;怠惰; If you have a feeling of inertia, you feel very lazy and unwilling to move or be active.

//...her inertia, her lack of energy...
她的怠惰和缺乏活力

This might help you overcome inertia.
這可能有助於你克服惰性。

2 [N-UNCOUNT 不可數名詞] 慣性; Inertia is the tendency of a physical object to remain still or to continue moving, unless a force is applied to it. [Technical]

Inertia

Starting something is hard, but so is stopping something. In physics, inertia refers to the resistance a physical object has to a change in its state of motion. Things at rest don't start moving on their own, and planets continue to circle the sun without a means of propulsion. The phenomenon of inertia is the subject of Isaac Newton's first law of motion, which states, "An object at rest stays at rest and an object in motion stays in motion with the same speed and in the same direction unless acted upon by an unbalanced force." If a force—for example, friction—is not present, the object will continue as it was, moving in the same velocity or remaining at rest. Left to themselves, systems resist change.

Galileo discovered the principles of inertia through an experiment by setting two inclined planes against each other, almost like a skateboard halfpipe, and then rolling a ball down one of them. The clever experiment made it easy to see that the smoother the surface, the closer the ball would come to reaching its initial height on the opposite plane. From this finding, he argued that any difference in initial and final height of the ball was due to the presence of friction, an opposing force.

In his book *Principles of Philosophy*, Descartes talks about inertia as well, stating that the first law of nature is that "each thing, as far as is in its power, always remains in the same state; and that consequently, when it is once moved, it always continues to move." [1]

Inertia is a useful model to try to understand some elements of our behavior, including our thinking patterns and habits. Our natural inclination to reject the new is in part normal resistance to the effort required to change. Keeping things as they are requires almost no effort and involves little uncertainty. We need force to effect change, and force requires effort. This model offers a lens to help us understand resistance to change and why we fail ourselves when we get complacent.

Inertia implies that once we stop doing something, getting started again is harder than continuing the whole time would have been. At a basic level, many brain studies have shown that the idea of multitasking is a myth. When we shift our focus from one input to another, we exert more energy and use more time to finish everything than if we would have completed one task before starting another.

Inertia also helps to explain why we continue on with bad habits and why it's hard to make systematic change. Many cities continue to rely on cars for short commutes instead of implementing an infrastructure to facilitate public transportation, walking, or cycling. We stay at jobs we hate, avoid meaningful conversations with people of different opinions, and almost never change the religion our parents imposed on us at birth. All because it is easier to stay on our current path, however stagnant and unfulfilling it may be.— Sidebar: Momentum

> « For, like a mass in Newton's first law of motion, once our minds are set in a direction, they tend to continue in that direction unless acted on by some outside force. »

Leonard Mlodinow [2]

Once an idea gets rolling, it can be hard to stop

Why do some products hang around for centuries, even when better and cheaper ones come on the market? Why do others burst onto the scene with so much promise only to flame out quickly? We can use the lens of inertia to provide part of the answer to these questions.

Most of the time, our consumption patterns are based on habit, not new thinking. We buy what we buy and have the preferences that we do because we've had them for a long time. When we go to the grocery store we seldom invest the energy to apply critical thinking to the products we've bought dozens of times. The longer we've been buying something the more ingrained this product is in our lives. Even if we find out it is unhealthy, we seldom switch immediately, if at all. We can understand why this happens by looking at Newton's second law, relating force to acceleration, which show us that mass matters when it comes to inertia. When a force acts on an object, the object accelerates in the direction of the force. If mass stays the same, increasing force will increase acceleration. If the force on an object remains constant, increasing mass will decrease acceleration. Essentially, the greater the mass, the greater the inertia. Heavier objects require more force to accelerate or slow them down than do lighter objects.

Momentum

Imagine a train pulling into a station and screeching to a halt. The driver doesn't press the brakes when they want to stop. They do it well in advance, allowing enough time for the full length of the train, weighing hundreds or even thousands of tons, to come to a standstill.

A train can't just stop moving as soon as the driver applies the brakes because of momentum. The equation for calculating momentum is $p=m*v$, where p is momentum, m is mass and v is velocity. When something with mass is moving, it has momentum.

The greater the mass and the greater the velocity, the greater the momentum of an object. If you're out for a run, it takes a lot less effort for you to stop than it does for a train because you're lighter and slower. Doubling either the speed or the mass of an object will double its momentum.

Isaac Newton's second law of motion states that the acceleration of an object is the result of two factors: the forces acting upon it and its mass. This is in contrast to the first law of motion, which states that an object will remain at its current velocity if the forces acting on it are all balanced. So, acceleration is the product of unbalanced forces. Outside of physics, we consider something to have momentum if it is progressing in a particular direction in such a way that it would take a weighty outside force to stop it or change its direction. [1]

The relevance of mass has analogous application in our habits. The longer we've been doing something, the more it has become part of both our identity and our understanding of the world. Thus, the amount of effort required to change a habit is greater proportional to the length of time we've had it. What is true for the individual is also true for our larger societies. The longer a product has been used by a society, the harder it is to change to a new one, even if there are obvious benefits. Let's take a look at two products, lead and absinthe, and compare their social inertia.

About 2000 years ago, Marcus Vitruvius Pollio* wrote *On Architecture*, a wide-ranging series of books, covering not only architecture, but engineering, philosophy, and medicine. He had many suggestions and observations, one of which was, "Water ought by no means to be conducted in lead pipes if we want to have it wholesome." Before we had gunpowder, compasses, or forks, we had strong indications that we shouldn't be exposing ourselves to a lot of lead.

No one really heeded his advice. Over the next millennia, lead was added to makeup, gasoline, and paint, and it was part of many manufacturing processes, such as printing. Concerns about its side effects kept cropping up as people kept noticing a high correlation between death and exposure to lead. Nonetheless, it was used to dilute wine, it made the pipes that carried drinking water, and it was added to face cream to help women achieve the paleness that was the social standard of beauty.

In 1910, Alice Hamilton* was appointed to head a survey on industrial illness in Illinois, USA. Over the next few years, she became America's leading expert on industrial toxicology, providing definitive evidence of, among other things, the dangers of lead exposure in the workplace.[3] Despite this evidence, the American car company General Motors proceeded with the creation of leaded fuel in the 1920s. Hamilton campaigned extensively against the introduction of leaded fuel, and she and her colleagues provided an extensive overview of the toxicology of leaded gas and the dangers of lead-tainted exhaust.[4] And yet fuel laced with lead wasn't banned in the USA until the 1980s.

Lead still crops up in other places despite all we know of its dangers. For example, lead is added to paint to prevent cracking with changes in temperature. Leaded paint is still used in many countries today to paint homes and toys even though nontoxic options are available at a similar price.

The story of lead can be contrasted with that of absinthe, whose rise and fall occurred within 50 years.

"Absinthe was made from a combination of plants and aromatics, including wormwood, aniseed, fennel and wild marjoram, which were first bruised and then soaked in alcohol and distilled, creating a bitter, pear-colored liqueur. A measure would be placed in a glass, and was then diluted with ice-cold water poured through a sugar cube, turning the whole thing milky pale."[5] Starting in the 1860s, absinthe became a wildly popular aperitif—an alcoholic drink taken before dinner. "In the latter half of the nineteenth century whole districts of Paris were said to smell faintly herbal between 5 and 6 p.m., a time that became known as *l'heure verte* ('the green hour')."[6]

Fifty years later it was being compared to opium and being considered a major social ill. Furthermore, "in France, doctors began to suspect that it was really a poisonous drug. People were reporting hallucinations and permanent insanity."[7] Experiments were conducted, and animals sacrificed. Then, "in Switzerland, the final straw came in 1905, when a man called Jean Lanfray killed his pregnant wife and two young daughters, Rose and Blanche, after he had been drinking absinthe. The case was dubbed 'the absinthe murders' and the drink was outlawed completely in Switzerland three years later."[8] France followed in 1914.

Within 50 years it was used, abused, and abandoned. Interestingly, "subsequent tests have shown that much of the supposed proof of absinthe's inherently deleterious effects were nonsense."[9] It is actually no worse for you than any other alcohol of the same strength.

So, on the one hand, we have lead, proposed as poisonous for 2000 years and we still use it, and on the other absinthe, whose suspected effects caused it to be taken off the market within 50 years. Lead, now proven toxic, is still kicking around in consumer products. Absinthe, absolved of all responsibility, remains unobtainable in many liquor stores. Why the difference? Obviously the reasons are complex, but the use of mental models is about the insight they provide. So, by using the lens of inertia, we can make some observations.

Mass matters. It is much easier to apply the force to stop a light object versus a heavy one. Lead and absinthe had different societal masses. Lead performed a number of highly useful functions in multiple manufacturing processes. Absinthe got people drunk. Lead had been integrated into many other substances, and so there is also an incentive angle. The cost of containment and remedy for lead was extremely high, and people would have had to abstain from using products they found useful, not to mention the cost of retooling manufacturing systems that relied on lead. Absinthe stood on its own. Thus, it took far less effort to remove absinthe than it is taking to remove lead.

This is part of the reason why the proof of something being harmful is not always enough to produce a change in behavior. The inertia of a product, a habit, or an idea increases the longer it is around. There are countless urban legends and popular myths that have been around for a long time and have woven themselves into our understanding of the world, despite available evidence of their inaccuracy. Sometimes it can seem monumentally frustrating when reliable information doesn't seem to change an erroneous popular opinion. Using inertia as a lens helps us understand the dynamics that are involved and gives us some insights on how to tackle addressing the motion we want to change.

—Sidebar: Inertia in war —Sidebar: Escape velocity

> « For the need to think can never be stilled by allegedly definite insights of "wise men;" it can be satisfied only through thinking, and the thoughts I had yesterday will satisfy this need today only to the extent that I want and am able to think them anew. »

Hannah Arendt [10]

What it takes to persevere

Inertia as a lens shows us that beliefs can become habits. Habits are entrenched behaviors, some of which are good, while others are bad.

In *Learning from the Octopus*, Rafe Sagarin writes that belief systems have an “enormous evolutionary inertia behind them,”[11] explaining that our capacity for belief has been one of our survival mechanisms and that this biological relevance helps explain why beliefs are so resistant to change. Thus, sometimes the inertia of our beliefs hinders us, such as when they make us blind to new opportunities. Or when we dismiss new information or ideas because they don’t fit with what we think we know about the world. For example, the history of invention is a story of the dismissal of new ideas. From radio and the telephone, to cars, airplanes, and laptop computers, many life-changing inventions were dismissed initially as irrelevant or useless. There are many stories of people who lost out on opportunities to develop and invest in these new technologies later lamenting their lack of foresight.

4/95

Inertia in War.

Inertia plays a role in warfare. Clausewitz wrote[1] that it is easier to get well-rested men to move. Exhausted men have greater inertia so it's harder to get them moving. Men who have had a chance to eat and sleep are easier to motivate and thus they build momentum faster.

Escape Velocity

Objects also have escape velocity, which is the speed they need to reach in order to break away from the gravitational force of a large body. For instance, when a space rocket is taking off, it needs to reach an extremely high speed in order to get away from the strong gravitational influence of the earth. As it moves further away, it can slow down a bit. This is because the gravitational force, pulling it back to earth, is no longer strong enough to overcome its kinetic energy. As the rocket gains altitude its fuel and kinetic energy are converted to gravitational potential energy. If the rocket is able to build enough velocity it can escape the pull of earth's gravity indefinitely even without further propulsion—this is referred to as the escape velocity and is equal to 7 miles per second on the surface of the earth. We can relate escape velocity to an idea that comes up later in the book, that of activation energy. How much effort do we need not only to overcome resistance, but to set an object on a new path?

The flip side is that while we often look back and shake our heads at the lack of vision, it suggests that new ideas have to prove themselves in the long haul. And given that these technologies eventually did become an indispensable part of our world, there are obviously some visionaries whose beliefs were flexible enough to lend their support in combating the inertia.

Thus, the inertia of belief can also be a good thing. At the most basic level, when our beliefs have persistence we don't have to relearn everything all of the time. Furthermore, values with strong inertia can also help us persevere through obstacles and setbacks. This does not mean that we should hold onto our beliefs blindly, unwilling to update them once we become adults. Strong beliefs can stay strong while being flexible. In fact, if we continually refine and develop them based on new information and experiences, they can continue to support us through challenges.

Often the stories behind new theories and invention show both aspects of the inertia of belief. The positive aspect that propels scientists and inventors to carry on the face of rejection and ridicule, and the negative aspect that fuels those reactions.

The inertia of belief can make it difficult to cause real change in the world. But that same inertia can help those who are determined to cause change to hold onto their beliefs and push through. The story of nuclear physicist Lise Meitner * demonstrates this dichotomy. She started off with the deck stacked against her in terms of the strong negative social beliefs that she had to navigate.

In a more just world, she would not have had to do what she did, but her determination gave her the willingness to adapt herself to an unfair system.

Lise Meitner was born in Austria in 1878. At age 23 she was the first woman admitted to the University of Vienna's physics lectures and laboratories and was the second woman to receive a PhD in physics at the university. In 1907 physicist Max Planck invited her to Berlin, where she worked for years as an unpaid research assistant.[12] During this time she met Otto Hahn, with whom she would collaborate professionally for decades, and together they discovered protactinium, the element with atomic number 91 on the periodic table. The university would not allow women to do independent research, so she and Hahn had to get creative in order to pursue their ideas. As described in her biography by Patricia Rife on the *Jewish Women's Archive*, "At first she was an unpaid 'guest' under Hahn, but most people knew they were equals in their research team." [13] Officially though, her contributions were always minimized. As Ruth Lewin Sime describes in *Lise Meitner: A Life in Physics*, "In every publication Hahn was first author, to which Meitner apparently did not object, even though she had done much of the work."[14]

Despite the slights, she maintained her friendship with Hahn for the rest of her life, even becoming godmother to his only child.

Eventually her work, the respect of her colleagues and her growing contribution to radiation and nuclear physics led to her being asked to create and supervise the Physics Section of the Kaiser Wilhelm Institute for Chemistry. It was a position she held for 20 years. On being asked to establish the physics department, Meitner "took it as a sign of recognition, trust, and professional coming-of-age."[15] In 1919 she became a professor at the Institute, and thus was the first woman in Prussia with the title.

During the 1920s and early 30s, she continued her work researching different aspects of physics. Any results achieved were the result of careful and patient work. She was the first person to observe and describe multiple transitions without the emission of radiation, and, with colleague Kurt Phillip, was "the first to identify positrons from a noncosmic source and to show, moreover, that positrons appear together with negative elements."[16] Her accomplishments during this time put her in "the first rank of experimental physicists."[17] She began to see her teaching duties expanded as she climbed the academic title hierarchy and received a series of prizes in recognition of her work.

In 1933 things began to change. That year the Nazi party decreed that Jewish academics were no longer allowed to be professors. Meitner continued her research, but in 1938 fled Germany for Sweden with the assistance of legendary physicist Niels Bohr. During the war she worked in a seemingly more limited capacity at the Nobel Research Institute of Physics, living on a small research assistant's salary, and feeling cut off from the work she had been doing in Berlin.[18] [19]

However, it was during this time that Meitner made her most significant discovery. Hahn continued to communicate with her, detailing the results of his experiments and asking her to come up with the explanation for his results. Meitner began to ponder the data, and through an insight gained while discussing the matter with her physicist nephew Otto Frisch, put together the first explanation of nuclear fission. Her work provided the first indication of the power contained in nuclear reactions and eventually led to, among other things, the making of the atomic bomb. It was Meitner's most significant contribution to nuclear physics.

Despite Meitner's work, Otto Hahn was the sole recipient of the 1944 Nobel Prize for the discovery of nuclear fission. Lise Meitner was nominated 29 times for the Nobel Prize, including three times by Niels Bohr, but was never awarded the honor. [20] [21]

We do not have to look hard to find beliefs with incredible inertia that Meitner had to fight against. First were cultural beliefs about women, what their capabilities were, and what their place in society was. At so many turns, Meitner had to navigate prejudices about women. On everything from receiving an education to her ability to conduct research in a lab, she had to work hard to overcome the inertia she faced.

In addition, being of Jewish descent in Nazi Germany meant having to deal with a mass of beliefs that had gained a frightening amount of momentum with incredible inertia. The political conditions in Germany were partly responsible for Otto Hahn's masking Meitner's contributions to the discovery of nuclear fission.

The remarkable aspect of Lise Meitner's story, however, is how her passion for physics propelled her through the challenges. First, it takes dedication to be a research scientist. Ruth Lewin Sime's accounts of Meitner's patience while conducting research suggests that she had total belief in her work. Not that there was a particular answer she was trying to prove, but that there was value in scientific process itself. Thus her beliefs were not a rigid dogma, but a flexible understanding that grew through investigating and discovering new ideas. It was these beliefs that likely supported her when she had to take secondary position on papers she had done most of the work on, or when she had to work in subpar lab conditions for low pay.

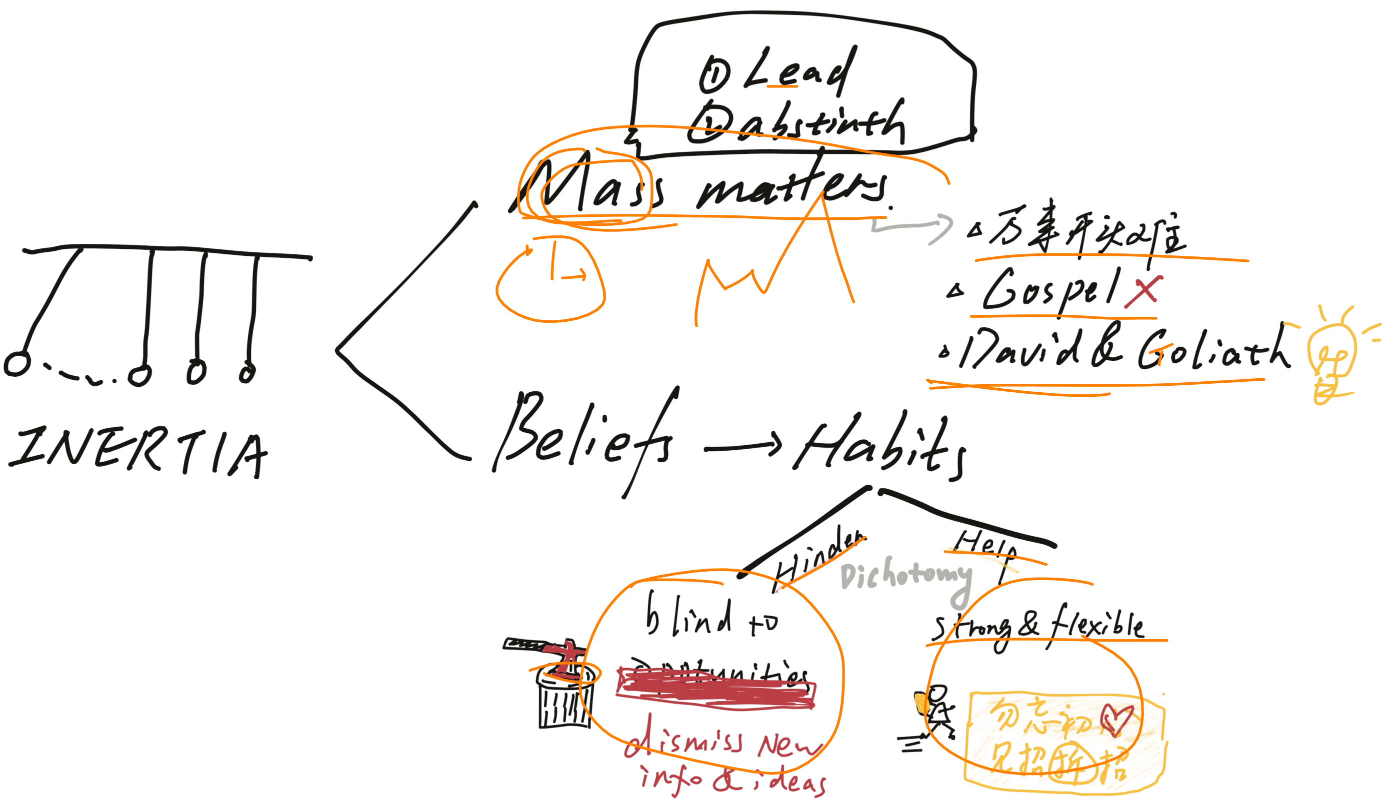
Meitner achieved more than possibly any other woman working in physics at the time—not only the discoveries in experimental physics but also leading a department and earning widespread respect and prestige. She was treated as an equal within her field, and until the Nazis came to power, she enjoyed a position as the only female physics professor in Germany.

Meitner's beliefs in both physics and herself increased their inertia as her life went on, allowing her to respond to the challenges presented by the prejudice she encountered. Although she never won a Nobel, she was awarded many honorary doctorates and other prizes. In her later years she gave many talks to support women's progression in the sciences and continued her research until she was 81. She was widely respected by colleagues all over the globe and Lewin Sime writes that Meitner made friends for life wherever she went.

Meitner persevered in the sense that she continued to do what she loved despite the obstacles she faced. To other female scientists she said, "remember that science can bring both joy and satisfaction to your life." [22]

Conclusion

Energy is precious and we employ it sparingly. It's human nature to allow the current state to remain as changing it requires us to expend energy. Getting started is the hardest part. Once something is moving in a direction, it's much easier to keep it in motion. But once something is in motion, it's hard to stop. The bigger the mass the more effort required.



Physics

Friction and Viscosity

–

Movement is a battle.

Friction and Viscosity

Friction is a force that must be overcome to achieve an outcome. There is always something trying to slow us down.

While we can never eliminate the forces that impede our progress, we can work to minimize them. Like a smooth surface provides less challenge to a rolling ball, or how water is easier for a human to swim through than a krill, shaping our environment to reduce the challenges of opposing forces is a key to improving productivity.

Friction is a force that opposes the movement of objects that are in contact with each other, such as the wheels of a pair of roller skates moving across the ground. For objects to move, they must overcome friction that pushes in the opposite direction. This requires extra energy, which produces heat and sound. Smooth surfaces cause less friction than rough ones, which explains why walking on pavement is much easier and less tiring than walking on gravel. There are no frictionless surfaces, only surfaces with less or more resistance.

All objects experience friction. There are two key types of friction: kinetic and static. Kinetic friction occurs when two objects are sliding past each other. This explains why an object in motion, without consistent forces pushing it forward, will come to a halt. For example, if you place a book on a table and give it a push, it will move a bit then stop. The kinetic friction absorbs the energy you transfer to the book in the push. Static friction, on the other hand, occurs when an object is stationary; it's what prevents it from moving.

Although scientists have been examining friction for about 600 years, there are still gaps in our understanding. Despite some of its mysterious qualities, friction remains a useful mental model because it captures how our environment can impede our movement.

Viscosity, which can be seen as the partner of friction, is the "measure of how hard it is for one layer of fluid to slide over another layer."[1] If a liquid is hard to move it is more viscous. If it is more viscous there is more resistance. Viscosity isn't usually an issue for humans in our day-to-day lives. We have to deal with gravity and inertia, although viscosity is always present. But for small particles, gravity and inertia become a nonissue compared to viscosity. So if you make things bigger, viscosity is less relevant.

A tiny plankton moving in the ocean is going to have to struggle through the viscous water and will stop coasting forward almost as soon as it stops moving. For a whale, on the other hand, the viscosity of the water hardly registers. Its size means it can push water out of the way with ease, and capitalize on other forces such as inertia to keep forward motion.

There are two important aspects to using friction and viscosity as a model. First, what is easy in one environment might be harder in another. For instance, what we can accomplish in times of peace is different than what we can accomplish in times of war. Second, we also learn that the main forces relevant to a particular situation depend on the scale you are operating at.

—Sidebar: Surface Tension

Slowing the flow

Everything that moves has to move through something, including information. Why does some information get disseminated quickly, whereas other times it gets bogged down and seems to go nowhere? The answer often has a lot less to do with the content of the information than with the environment it has to move through. To understand just how much a communications environment can be manipulated to affect the pace of information exchange, let's take a look at Soviet Russia. By the 1980s the Soviets had created a high-viscosity communications environment that made it hard for information to flow through it. Like a goldfish trying to swim through honey, people had an unrelentingly difficult time trying to communicate information to those who might need it.

Surface Tension

"Viscosity matters when something small is moving through a single fluid—surface tension, its partner in the world of the small, matters at the place where two different fluids touch."[1] The story of the measuring of surface tension is the story of an individual who persisted: one woman working in a society that made it almost impossible for a woman to move in the environment of scientific study. Agnes Pockels wanted to study physics, but at the end of the 19th century in Germany women were not allowed into the universities.[2] Her younger brother became a physicist, sharing his textbooks and, throughout his life, advances in the discipline.

At home, taking care of aging parents, she maintained her curiosity and passion as best she could in the limited setting. She developed a tool called the Pockels trough, and "although simple, the trough was able to measure the surface tension of water under the influence of different surface concentrations of the oils and soaps she worked with."[3] She went on to publish several papers on surface tension, essentially forming the base of the research on the concept, without ever receiving formal training and education in science. Her tool and her research were built upon by others who went on to receive awards like the Nobel prize. But her accomplishments are all the more remarkable when we consider the high viscosity of the environment in which she succeeded.

During the Cold War era, the Soviets amplified forces that negatively impacted the free flow of individual bits of information, potentially because it's easier to control things that are moving slower. The viscous information environment they created may have been useful to the state for maintaining control, but it also caused the broad scope of the Chernobyl disaster.

During and after the explosion at the Chernobyl nuclear power plant in 1986, there was a lack of information getting to those affected, from citizens to supporting government departments to other countries. A lot of information was out there, but it had a hard time flowing to those who needed it because the structure of the Soviet system.

In *Chernobyl: The History of a Nuclear Catastrophe*, Serhii Plokhy describes the entire scope of the disaster. He explains that the leadership of the Soviet Union was characterized by an approach of burying the past instead of learning from it. Their complicated bureaucracy created an environment that made it very hard for correct information to get to those who needed it. This was manifested in censorship, the criminalization of sharing certain information, regular domestic spying and a total lack of empowerment of the people on the ground.

Chernobyl was not the first nuclear accident in the Soviet Union. However, it was illegal for anyone to officially report on or discuss any that had happened previously, notably the multiple accidents at the nuclear power plant in Leningrad, as if by not acknowledging something, the Soviets could pretend it out of existence.[2] Because information about previous issues was suppressed, there were no lessons learned that fed into the design of the Chernobyl plant or its procedures.

After the accident at Chernobyl, the pattern of zero communication continued, with nothing being reported both within the Soviet Union and to the foreign press. There were secret resolutions, and everything was classified. One consequence of this approach was that the people immediately affected—those who lived in the surrounding area—had no idea what was happening or how to protect themselves. "Intercity telephone networks had been cut, and the engineers and workers at the nuclear plant had been prohibited from sharing news of what had happened with their friends or relatives."[3] Information control was more important than the lives of people.

How does a situation like this come to be? There are a lot of aspects to consider, as a highly viscous information environment is not created by one factor alone.

To start, there was the Soviet preoccupation with image. They didn't want to look bad to their citizens or the West, as they believed this would weaken the Communist state. They insisted things go on as usual, including the large May Day parade in nearby Kiev, which exposed thousands to high levels of radiation. The Soviets accused the Western media of spreading rumors about Chernobyl, and kept repeating in official reports "that everything was fine, and that the party was in control."[4]

In addition, the Soviet mentality within the political structure was characterized by fear and a lack of accountability. Problems were pushed up the chain, because no one wanted to take responsibility and make a decision and thus have to potentially deal with the consequences of being wrong and embarrassing the government. But at the same time, “the protocol was to bully subordinates into submission and then demand the fulfillment of unrealistic production quotas.”[5] People couldn’t safely say, “No, we can’t get that done in the timeframe you are asking for.” With no one wanting to communicate negative information up the chain, and erroneous information being pushed down the chain, building operations like those at Chernobyl cut corners to meet unrealistic deadlines.

Chernobyl itself was built on shaky foundations with questionable reactors, and with safety standards that would never have cut it in the North America or western Europe. No one in the Soviet Union seemed to want to hear accurate assessments of problems or projects. Thus, the information that moved up and doctor down the chain was often totally and completely fabricated. Essentially there was high viscosity for true information, whereas false information faced a low viscosity medium. Similar to fluid hitting a boundary with different viscosities, false information was disseminated further because it flowed easier.

Finally, the Soviet leadership “was still deeply grounded in the Soviet tradition of secrecy and neglect for the immediate well-being of the people while allegedly staying focused on the greater good and a better future.”[6] In the aftermath of the Chernobyl accident, this attitude manifested in a total lack of information sharing with those affected. Radiation levels increased while the residents of nearby Prypiat had weddings and played in the streets. Even though radiation levels were damagingly high, it took days for evacuations to start. And even then, nothing true was communicated, with residents being told they would be back in their homes in three days. The Prypiat hospital, in the town where all Chernobyl workers lived, "was equipped to deal with almost anything but radioactive poisoning."[7] Because whether Chernobyl ever had problems or not, the Soviet leadership had already decided that radioactivity was never going to be an issue.

Even though Chernobyl is in the Ukraine, the Ukrainian leadership often found out what was going on from Moscow.

All of these elements combined to create a highly viscous information environment that made it near impossible to speak the truth of what was happening or to communicate it to anyone. As Plokhy describes, "The immediate cause of the Chernobyl accident was a turbine test that went wrong. Immediately after the accident, as panic spread, the authoritarian Soviet regime imposed control over the flow of information, endangering millions of people at home and abroad and leading to innumerable cases of radiation poisoning that could otherwise have been avoided."[8]

What is interesting is that their approach ultimately undermined Soviet goals. Many people felt betrayed by their government and pushed relentlessly for details about the accident. As these started to trickle out, outrage was displayed by many Ukrainians, which helped to fuel the Ukrainian push for independence from Moscow. Creating greater viscosity for information flow may seem like a way to control people and protect them from difficult information, but it easily backfires. If people get an inkling something is hidden from them, they'll push as hard as possible to find it. If they succeed, they'll pay far more attention to it than they would have done otherwise. The negative consequences that result from a lack of information sharing in situations like Chernobyl often undermine the control that a government was trying to exert in the first place.

Trickle up innovation

How else can the lens of opposing forces like we find in the Friction and Viscosity model be useful? One area is organizational effectiveness. If we think of an organization, we can appreciate that the forces that influence innovation are different for the executive team and the frontline worker. So, if the goal is to encourage more innovation on the front lines, then you need to pay attention to what encourages and limits movement in that environment, not in the C suite.

The Ford Model T left two legacies: the iconic image of the beginning of the automobile age, and the mass production system. For Ford, and later GM, mass production systems were not designed to incorporate the potential for innovation at the level of the factory worker. Essentially, "the workers on the shop floor were simply interchangeable parts of the production system."[9] Massive amounts of inventory were kept on the floor, and problems were not fixed until the end of the line. Workers were not there to address problems or improve the system. They were just there to perform their repetitive task, leaving any rework or problem-solving to specialists.

In the 1940s, Toyota, the Japanese car company, was struggling to survive after the war. Japanese government expectations were that financial support and success meant exports, which meant being internationally competitive. Studying the mass production system of the North American car manufacturers, Toyota knew it wouldn't work for them. They didn't have the initial capacity to get a machine of that size functioning.

But they noticed something else. Mass production produced a lot of waste, was inefficient because it deferred the addressing of mistakes to the end of the line where they were most costly to fix, and took an exceptionally long time to change when a new production model of car came out. Toyota development guru Taiichi Ohno * thought there was room for improvement. One of his insights was to focus on the environment of the frontline worker.

He saw that output could be significantly affected by reducing the friction happening at that level. "If workers failed to anticipate problems before they occurred, and didn't take the initiative to devise solutions, the work of the whole factory could easily come to a halt."[10] Therefore, getting more effective output from the shop floor worker was not about speeding up performance or setting higher quotas. It was about creating a smoother environment that empowered workers to engage with their work.

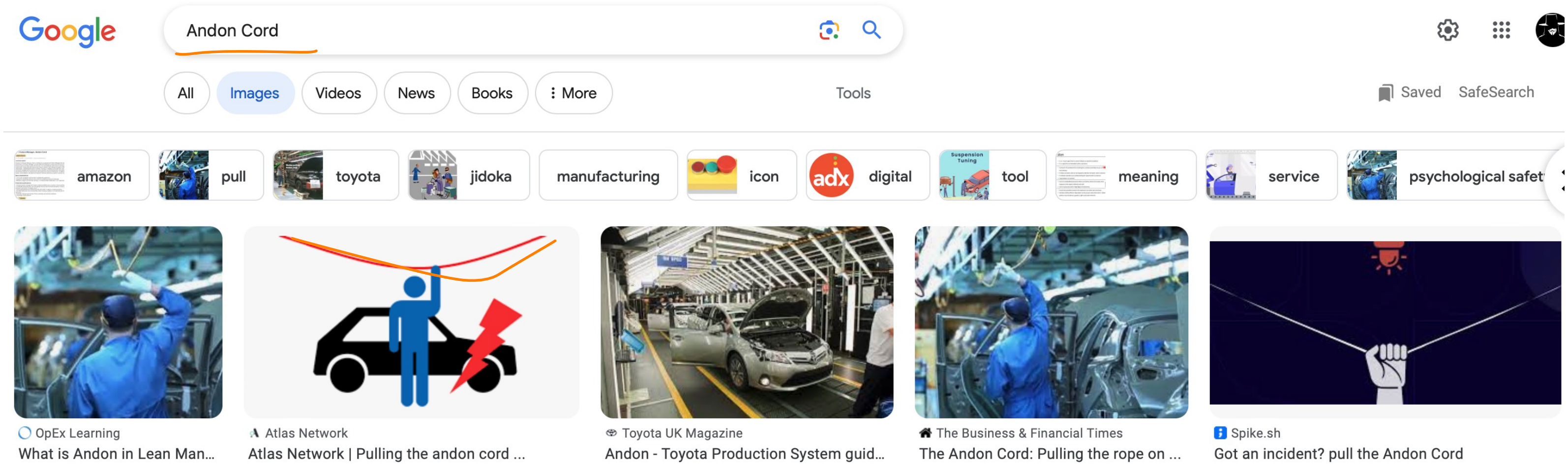
If we want people to innovate and take initiative in real time at the ground level, then the organizational culture and structure has to be one where it is supported and safe to do so. What creates an environment with low friction for the worker, so they are better able to move to create positive change?

One of the things that Ohno noticed in the mass production system was that "none of the specialists beyond the assembly worker was actually adding value to the car. What's more, Ohno thought that assembly workers could probably do most of the functions of the specialists and do them much better because of their direct acquaintance with conditions on the line."[11] A first step was to change the behavior on the line by including responsibilities like minor repairs and quality checking. Every worker was given the ability to stop the line "if a problem emerged that they couldn't fix."[12]

As James P. Womack, Daniel T. Jones, and Daniel Roos explain in *The Machine That Changed the World*, "In striking contrast to the mass production plant, where stopping the line was the responsibility of the senior line manager, Ohno placed a cord above every workstation and instructed workers to stop the whole assembly line immediately if a problem emerged that they couldn't fix. Then the whole team would come over to work on the problem."[13] Pulling this "Andon cord" created a lot of immediate friction—like going from water to cement in a second—but allowed for mistakes on the line to be addressed immediately. Furthermore, the day was arranged so that time was set aside for workers to share ideas on how to improve processes. All of these changes were about reducing the friction of the worker environment in the long term.

The result of the changes to the assembly line was a system that produced cars that needed less rework at the end. So even though "every worker can stop the line... the line is almost never stopped, because problems are solved in advance and the same problem never occurs twice."[14] The culmination of these tangible changes made to the factory worker environment resulted in improved car quality, production efficiency and worker morale.

Morale is critical to an environment that fosters innovation. In order to take risks people need to feel supported. Toyota fostered an environment on the factory floor that emphasized communication and collaboration. Workers helped each other solve problems and could switch their focus with ease depending on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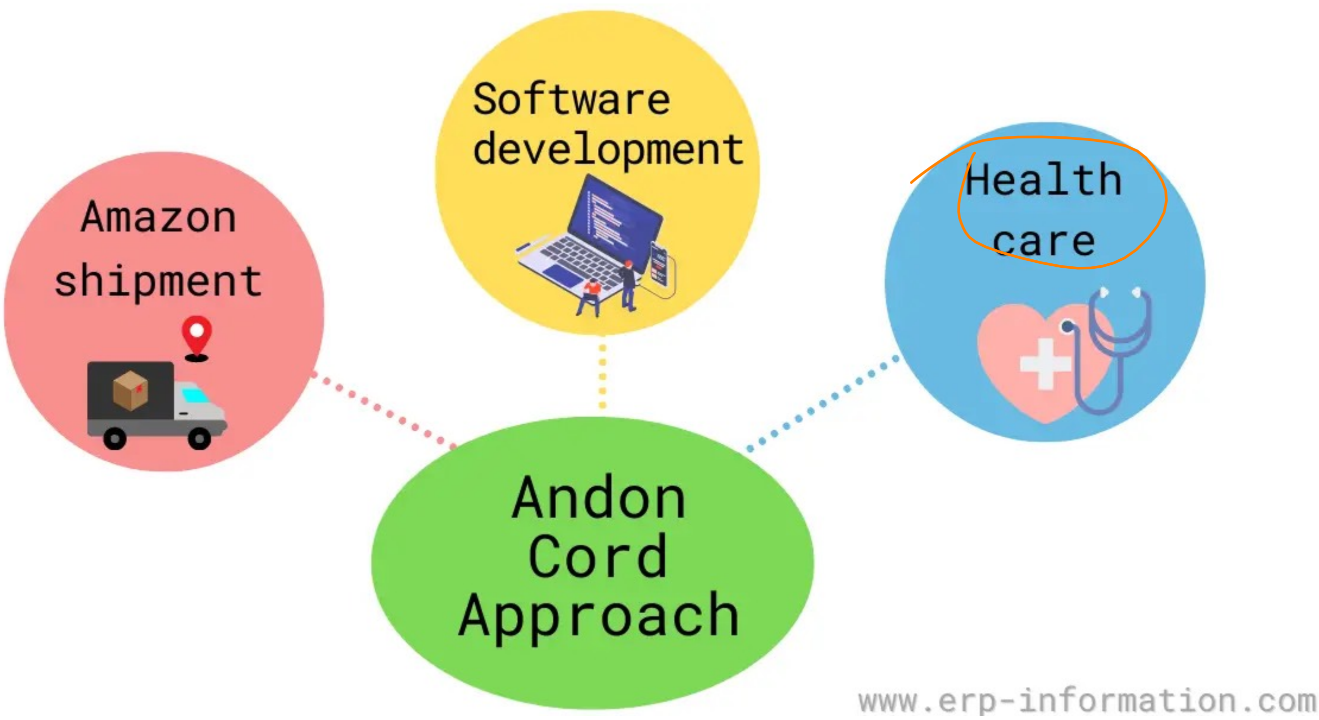
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what the situation called for. The system developed by Ohno encouraged them to be knowledgeable about the entire process and get curious about finding solutions and efficiencies. The resulting process is called "lean" and is summed up in the following: "It transfers the maximum number of tasks and responsibilities to those workers actually adding value to the car on the line, and it has in place a system for discovering defects that quickly traces every problem, once discovered, to its ultimate cause."[15] Paying attention to the environment of workers is a way for organizations to metaphorically keep their feet on the ground. By "touching the territory" they can empower the people closest to the problem and reduce the friction in their organization.

Changes have to be supported up to the top, and everyone needs to recognize that the forces at higher levels, which push for things like strategy or visions, are not as relevant at the working level. It's all fine and nice to put out messages of where a company wants to go, but it needs to make sure that the environment doesn't have such high friction that everyone feels like they are trying to move a cement wall in order to get there.

Toyota designed an environment that "provides workers with the skills they need to control their work environment and the continuing challenge of making the work go more smoothly. While the mass production plant is often filled with mind-numbing stress, as workers struggle to assemble unmanufacturable products and have no way to improve their work environment, lean production offers a creative tension in which workers have many ways to address challenges."[16] (Unmanufacturable here refers to having to put together components which have flaws and which will require rework at the end.)

In lean manufacturing, the environment is designed and continually improved to encourage workers to take initiative and innovate. Using the lens of friction, we can see how a recognition that what impacts the environment of a factory worker is not the same as what shapes the environment of the executive. If you want to change a situation, you have to appreciate the forces that are strongest in that particular environment.

Conclusion

To achieve our aims, reducing resistance is often easier than using more force. While often hidden, friction and viscosity work against us whenever we try and do something. To overcome resistance, we often default to using more force when simply reducing the friction or viscosity will do. Doing both is more effective than either in isolation. Friction and viscosity can also be wielded as a weapon. Rather than try and catch up to the competition with more effort, you might want to explore slowing them down by adding resistance.