The rhythms of nature inspiring art and science

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The conquest of fire has been an essential component of the civilizing process. Milazzo and Buehler from MIT spearhead a novel direction of research by seeking inspiration from fire through deep learning, paving a new avenue for the design and fabrication of novel materials.

Nature has inspired science since the dawn of humanity. In recent years, a systematic effort has been put forth to create nature-inspired materials and designs. This is the field of bioinspiration, or biomimetics. These efforts are adding to the understanding of biological materials, especially in linking their structure (at various hierarchical levels) to their properties. In this process, new connections are revealed. Successful technological developments are also evolving, and Velcro,[1] inspired by burrs, and the Gecomer,[2] a robot with tailored attachment capability inspired by the van der Waals forces responsible for Gecko's ability to climb walls, are eloquent examples. Similarly, artists have always sought inspiration in nature and sentiment, the two being most often intertwined in complex relationships. The rhythms of life, including our pulse beat and regular breathing, were thecradles of audible sounds from which the miraculous world of music rises.

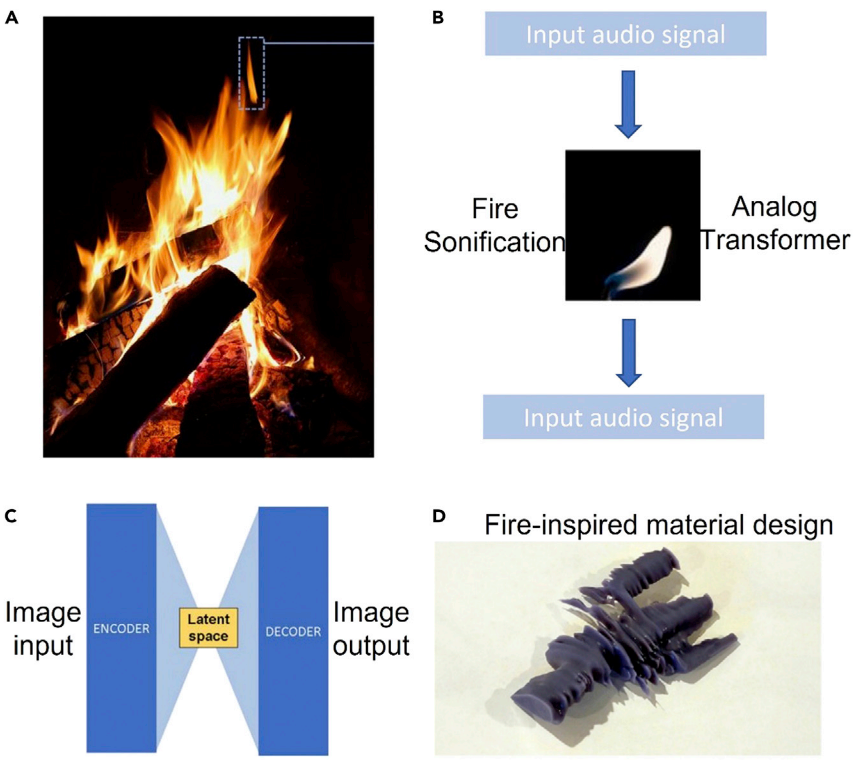

Figure 1. Methodology implemented by Milazzo and Buehler[5]
(A) The complex shape of flames in a dynamically changing fire.
(B) Fire sonification. The fire was exposed to sinusoidal audio with varied frequencies and the images of flames were imported and classified by a well-trained neural network. Based on the classification of images and identification of associated sounds, musical notes can be generated and outputted as new audio signals.
(C) Schematic drawing of the developing process of the autoencoder model using artificial intelligence.
(D) 3D printed fire-inspired material. Adapted from Milazzo and Buehler.[5]

By melding art and science, Markus Buehler and coworkers[3] recently created music extracted directly from amino acid sequences, using artificial intelligence (AI). The vibrational frequencies of twenty amino acids were used to create an equivalent number of tones in a piano. The music generated by the transduction of proteins can be translated into a musical score and the haunting sounds were presented in concerts at MIT to the awe of the audience.[4] The haunting sounds and melody connect the listener to the very foundations of life in a new, mysterious process. Modifications of the music can be, on their turn, converted into *de novo* proteins that do not exist in nature. This creative process generates new forms otherwise non-existent.

Following a similar procedure, a series of ingenious work from the Buehler group leads us to dive into the atomic space of amino acids and extract the vibrational cadence of these building blocks of life. Their efforts not only represent experimental music at its best, but also extend our knowledge of the inner workings of proteins unprecedentedly; the later significantly advances our understanding of the mechanical response of biological materials in a completely new manner.

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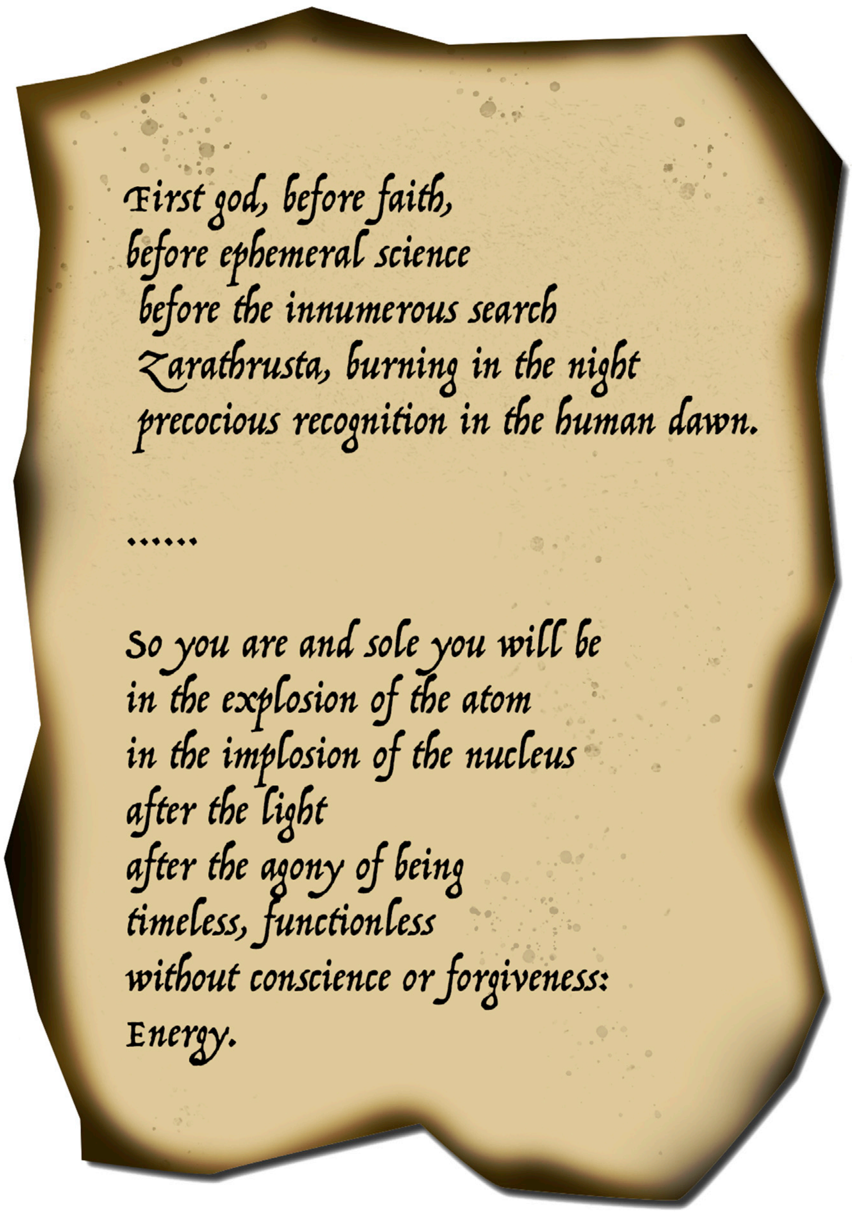

Figure 2. "Fire"
A poem capturing both the art and science of this universal and eternal phenomenon. Adapted from Meyers.[9]

Now, in a new tour de force, Milazzo and Buehler[5] direct their interest at fire. The unending variety of the shapes of flames are captured and transformed into sound. The interaction of sound waves and flames are also investigated. This is accomplished by generating image stacks that can be translated into 3D objects by additive manufacturing. Their goal is not to address a specific application, but rather to delineate a path, from a continuously changing image, to the creation of a physical construct that has characteristics and structure not found in nature.

When we think of fire, the first picture that comes into our mind is burning, smoking, heating, and eventual destruction. This may be because we now have alternative sources to generate heat and light, such as electricity and countless controllable chemical reactions. Igniting flammable materials is no longer necessary in daily life for most urban societies. Human and naturally produced wildfires across the Earth worsen the public image of fire. Actually, fire is one of the most common phenomena in nature and is deeply rooted in human civilization. It has generated advancements in science, technology, and art. The process of combustion represents the control of fire at different levels, and it is one of the pillars of power generation.

References to fire in myths abound across different cultures. In ancient Polynesia, the demigod Maui deceived the fire-maker mud-hen and tortured him/her to disclose the secret of ignition.[6] In North America, the mythical figure Spider Grandmother stole the fire from the land of light and gifted it to the Cherokee tribes.[7] The best-known fire theif is the Greek hero Prometheus, who stole it from Apollo and gave it to humans, together with genius, enabling them to use it in the arts and sciences. This infuriated Zeus, who punished him for the rest of his life. The ancient Zoroastrian religion contains the cult of fire, which is worshipped in special temples containing an eternal flame. These mythological stories indicate that no greater good has benefitted ancient humankind more than the discovery of methods of making and controlling fire.

In addition to lighting us in dark, heating us in winter, protecting us in forests and providing us with sterilized food, the utilization of fire also dramatically accelerated the human civilization by driving the development of materials science. Precisely controlling combustion enables us to refine elements from ore and forge metallic objects, advancing us out of the stone age.

The recently published article in *Matter*'s sister journal *iScience*[5] applies artificial intelligence, sonification, deep learning, and additive manufacturing to fire in an unprecedented manner, leading to a series of novel nature-inspired material structures, demonstrating a new approach that may be a path to study other natural phenomena and deriving inspiration for novel design ideas across artistic and scientific research fields. As a first step, they captured the topological features of flames and their changes with time. The transposition into sound was conducted by a technique that they name "sonification." In addition, they apply the technique to flames disturbed by external sound waves, using the flame from a candle exposed to different sound frequencies. The captured images are subjected to two deep learning methods, Convoluted Neural Network and Variational Auto Encoder, which produce new synthetic music and *de novo* flame image stacking for 3D structural rendering.

The current effort by Markus Buehler and his team represents a pioneering application of artificial intelligence, especially deep learning, to various natural and synthetic processes and matter at different length scales. Since 2018, they have applied machine learning algorithms to predict and optimize mechanical properties of a composite system at a macroscopic scale while downscaling the computational cost to a much lower level in comparison to other methods.[8]

The various stages of the methodology presented by Milazzo and Buehler[5] is schematically represented in Figure 1.

We conclude with a couple strophes of a poem entitled "Fire" that capture both the art and science of this universal and eternal phenomenon (Figure 2).[9]

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Wound-contractible hydrogel for skin regeneration, a new insight from mechanobiology

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SUMMARY

The mechanical forces of hydrogel dressing on skin can rebuild wound shapes, but the underlying mechanobiological functions were elusive. Recent studies conducted by Aragona et al. and Hu et al. revealed that hydrogel-induced skin stretch was beneficial to wound healing because it initiated the remodeling of cytoskeleton, promoted the epidermal stem cell renewal, and regulated the damage-associated inflammation. To fabricate such a wound-contractible hydrogel dressing, the shape-deformation and tissue-adhesion strategies should be highlighted.

As the first barrier of body, skin can adapt to different mechanical stimuli by stretching and contracting to defend against environmental injuries. In clinical practice, mechanical stretch is usually applied in plastic surgery for tissue expansion, which achieves extra skin to repair congenital defects and reconstruct organs.[1] Moreover, embryonic wounds can form actin cables to stretch the normal skin for contracting, leading to an excellent regeneration of fetal skin.[2] However, little was known about how skin cells responded to these mechanical stimuli and what the practical approaches were to apply stretch to skin during wound healing. Two recent studies carried out by Aragona et al.[3] and Hu et al.[4] applied hydrogel to induce skin stretch. The former helped people to understand the potential mechanisms at single-cell resolution, and the latter found feasible means of

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