Biomimetic Passive Cooling

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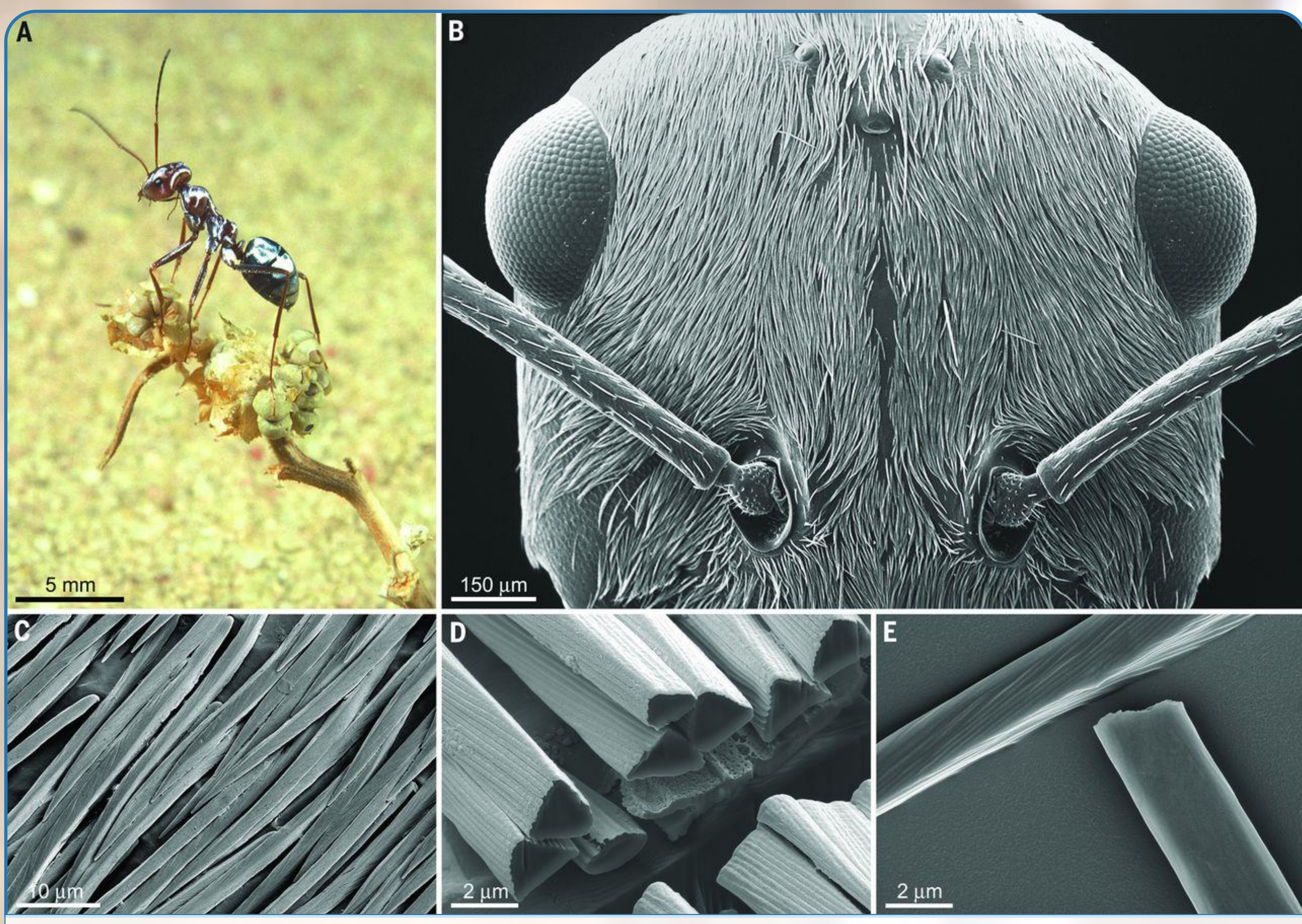


a) Saharan silver ant (*Cataglyphis bombycina*), © Rüdiger Wehner, 1989; **b)** Scanning electron microscope (SEM) image of the ant's hairy head; **c-e)** SEM image of the hair in different magnifications; **e)** It can be seen that the hair is corrugated on the top side and flat on the bottom side; © Shi et al., 2015 [3]

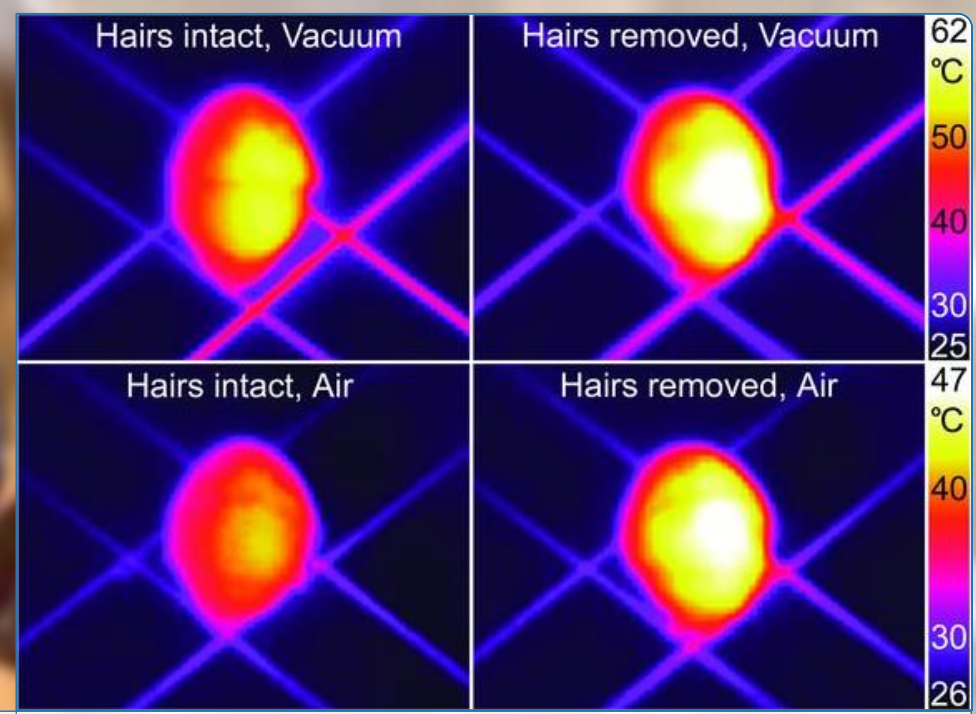
The Saharan Silver Ant (*Cataglyphis bombycina*)

The Saharan silver ant (*Cataglyphis bombycina*) is a remarkable insect. Only during midday, when the temperature reaches levels deadly to most animals, the ants come out of their nest to search for other insects that could not escape the deadly heat in time. Their main advantage over other animals, letting them survive for several minutes in this lethal environment, is their silverish hair coat, which accounts for their name. They are also the fastest ants on Earth. [1, 2]

Hairy Reflectors

Investigating the hairs with a scanning electron microscope, one can see the distinct triangular cross section of each hair. There is always one side which is flat, facing the ant's body. The other two sides are corrugated. As the periodicity of these corrugations is much smaller than the wavelength of visible and IR light, the corrugations emulate a gradual change of the refractive index. This decreases the amount of light being reflected off the sides of the triangle and redirected towards the ant's body. Instead, more light is caught and then reflected on the flat back of the hairs via total internal reflection and thus redirected away from the ant much more effectively. [1, 3, 4]

Background: Saharan silver ants shimmering in full sunlight, © P. Landmann, adapted from Willot et al., 2016 [4]

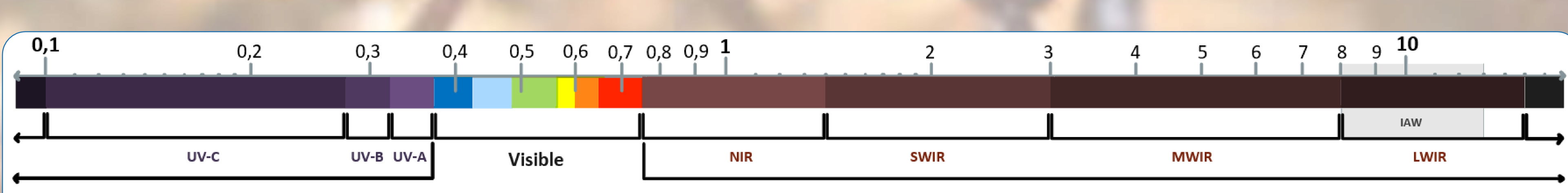


Infrared image of a silver ant's abdomen, showing the temperature under different conditions, © Shi et al., 2015 [3]

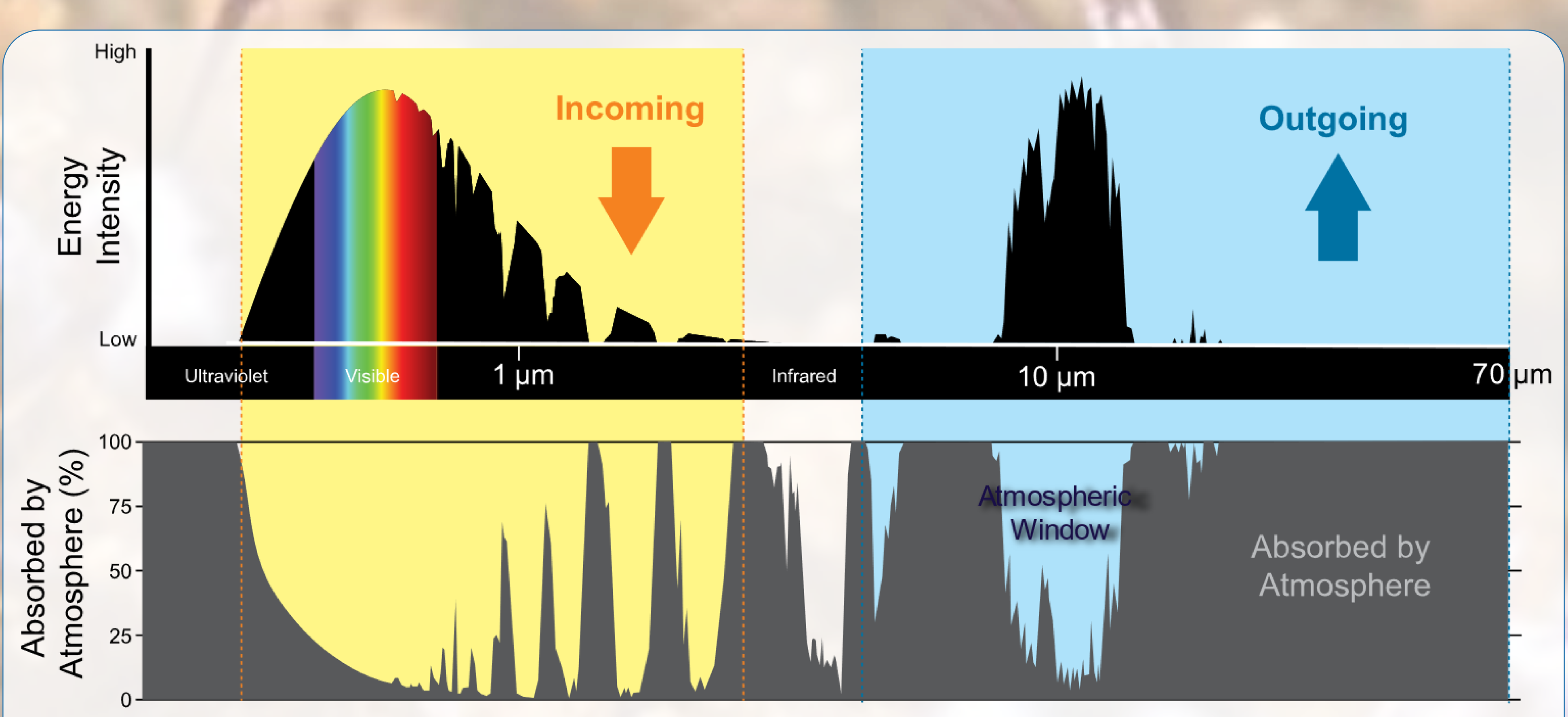
Shiny Heat Protection

Because the diameter of each hair is only a few times larger than the wavelength of visible light, any scattering processes of visible and IR light on the hairs can be described by Mie-scattering. This type of scattering is mostly wavelength independent and is the reason why the reflected light has such a metallic, silverish white look.

For much larger wavelengths in the region of thermal IR, the hairs are strong absorbers and therefore also strong emitters. This helps the Saharan silver ant to radiate excessive heat. As the desert sand also radiates a lot of heat, the ant lacks hair on its bottom side in order to not absorb even more heat from the sand. [1, 3, 4]



Subdivision of the electromagnetic spectrum in a logarithmic scale of the wavelength in µm



Incoming energy from the sun and **outgoing energy** from the Earth relative to the wavelength (top). **Absorbance** of the atmosphere relative to the wavelength (bottom); © National Weather Service [7]

Passive Radiative Cooling

The concept of radiative cooling is the reduction of heat uptake of a body by increasing the reflectivity of its surface, and the increase of heat loss via thermal radiation. In technical passive radiative cooling, this is attempted to be achieved without the need of electricity or finite resources. One way this can be done is to create nanostructures which transmit, reflect and scatter light in specific ways depending on its wavelength.

The wavelength of solar irradiation reaches from 0.25 to 2.5 µm with its peak in the visible range (from about 0.4 to 0.78 µm). The wavelength of thermal radiation at environmental temperatures is larger than 2.5 µm with its peak in an atmospheric window (between 8 and 13 µm). While the atmosphere is absorptive for a multitude of wavelengths, it is transparent in this window. This means that for optimized radiative cooling, a body must reflect as much as possible of the **incoming sunlight**, to prevent the buildup of heat, while being **highly emissive** especially in the range of this **atmospheric window**, to get rid of the excess heat. [1, 5, 6]

The Saharan silver ant achieves both the solar reflectivity and thermal emissivity needed to withstand the greatest heat of the Sahara with its tiny, nanostructured hairs.

Sustainable Methods

Inspired by these scientific results, a bachelor thesis in technical physics introduces concepts for technical radiative passive cooling [1]:

Finding ways to cool down large structures such as buildings or cars without the need of finite resources (electricity, some kind of fuel or water) is of increasing interest. In living Nature one can find various sustainable inventions for passive cooling, which are mostly structural cooling systems. The Saharan silver ant should serve as one example showing that it is possible to achieve a strong cooling effect using non-polluting materials, simply by creating correct nanostructures. Besides passive radiative cooling there are many more, different ways which Nature has found to stay cool – loads of research ahead!

References

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