Evolution of diverse and bizarre stag beetle weapons

Stag beetles evolved an impressive diversity of weapons because the shape and size of the armature hardly influence the cost of flying. Computer simulations of flying stag beetles have shown that the energy cost is solely determined by the weight of the armature, and not by the size or shape thereof.

Fig. 1. Fighting male stag beetles.

Several male animals have ferocious weapons to fight each other over mating opportunities: red deer stags have antlers, elephants wrestle with their tusks and male stag beetles use their elongated jaws in battles. Male stag beetles have one of the largest weapons in the animal kingdom: their jaws can grow to be as long – or even slightly longer - than their own body. Because of their length, the jaws are conveniently used to grab rivals. In spectacular battles, they try to lift their opponents above their own head and to throw them on the ground. For this purpose, males have evolved massive bite muscles, that enable them to bite 7 times as forceful as females. Being bitten by a stag beetle feels as if you are balancing two soda cans on tooth picks (one for each jaw) on your finger.

Because of the large bite muscles and jaws, male stag beetles have very heavy heads (18% of their body mass). Our computer simulations of stag beetles in a virtual wind tunnel indicate that this increases the energy cost of flight by as much as 26%. However, males cannot avoid this cost by running, instead of flying, when searching for mates or fleeing from predators. Their heavy heads

increase the energy cost of running even more than that of flying: running a certain distance is 40% more costly for male than for female stag beetles. Moreover, the heavy heads make males instable, which causes them to tumble every now and then. And obviously, they have a hard time manoeuvring through the litter in forests with two large jaws protruding in front of their head.

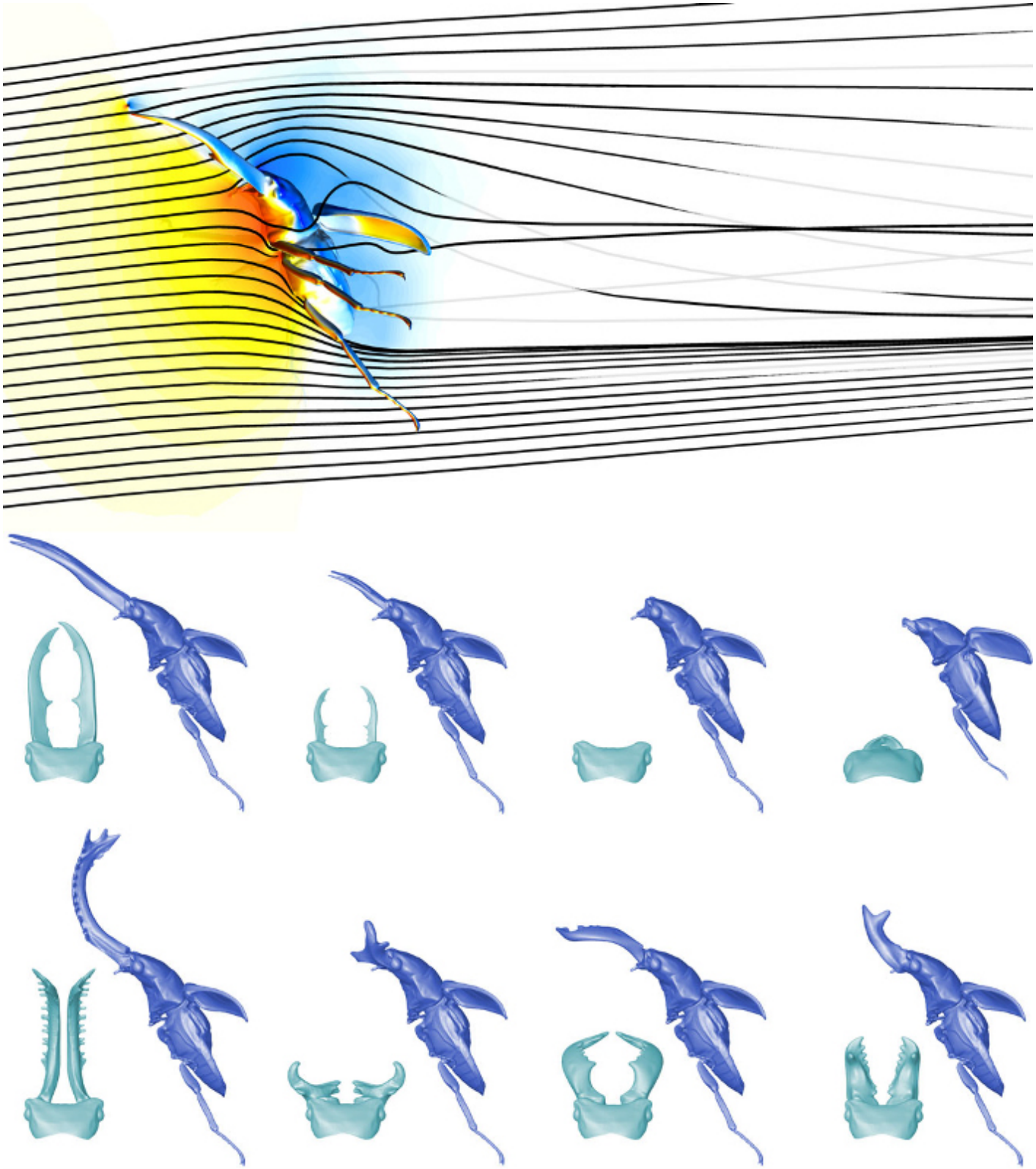

Fig. 2. Top: Air flow over a flying male stag beetle. Colors show the air pressure and the pressure on the beetle body (red: high pressure; blue: low pressure). Bottom: Stag beetle bodies that are

compared in this study, with jaws of different sizes and shapes.

While the heavy weight impairs male running and flying substantially, our simulations indicate that there is no cost associated with the shape or size of the jaws (as such). We removed the male jaws, and virtually glued jaws of other stag beetle species on the male body. The different size and shape of the jaws hardly changed the cost of flight in our virtual wind tunnel (a maximal energy difference of less than 0.1%).

http://atlasofscience.org/wp-content/uploads/2016/02/GoyensJ_stagbeetles.mp4

As long as a male stag beetle retains a certain weaponry weight, it can change the shape or size of its armature without increasing its cost of flight. Hence, the stag beetle family experiences no selective pressure to streamline the jaws, or to enhance their lift properties. This provided freedom to evolve the wide range of extraordinary jaw shapes which is characteristic for the stag beetle family (including more than 1000 species).

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Publication

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