The Suspended-load Backpack, converts mechanical energy into electricity.

Image Courtesy of Dr. Lawrence Rome

MBL Scientist Invents Backpack that Uses Muscle Power to Generate Electricity

Whitman Investigator Larry Rome, a biomechanics expert who studies how muscle moves skeletons in fish and frogs, has invented a backpack that gives new meaning to the term muscle power.

In a paper published this fall in Science, Rome, a University of Pennsylvania biology professor who spends his summers at the MBL, and three colleagues described the mechanics of, and physics behind, the Suspended-load Backpack. The invention will someday enable field scientists, hikers, explorers, soldiers, and disaster workers to convert the mechanical energy they create while walking with a heavy load into electricity.

By carrying a load weighing from 44 to 84 pounds (20 to 38 kg), Suspended-load Backpack testers were able to generate up to 7.4 Watts—more than enough electricity to simultaneously power an MP3 player, a PDA, night vision goggles (or 3 LED headlamp), a handheld GPS, a CMOS image decoder, a GSM terminal in talk mode, and Bluetooth. The faster the testers walked, or the more weight they carried, the more power they generated.

The backpack electricity can be used while it is being generated, or it can be stored in a lightweight rechargeable battery for later use, greatly reducing the need to haul and use heavy replacement batteries.

"The need for electronic devices in remote areas is an increasing reality these days," says Rome. "Throughout history, humans have solved many problems by inventing passive devices to enhance the movements made by their muscles, such as springy bamboo poles to carry loads and skis to move through snow," he says. "The Suspended-load Backpack represents another passive device that may help solve a growing problem in the 21st century."

The backpack, which was funded by the NIH’s National Institute of Arthritis and Musculoskeletal and Skin Diseases and the Office of Naval Research, is currently in its working prototype stage. The design is based on the external frame design once popular with overnight backpackers and it works by capitalizing on the up-and-down motion of the body during walking.

When walking, the body is like an inverted pendulum. After the foot is put down to take a step, the body vaults over it, causing the hip to move up and down about 1.6 to 2.7 inches (4 to 7 cm). The Suspended-load Backpack frame sits still on the wearer’s back, and the load is mounted on a load plate that is suspended from the frame by springs. The springs allow the load to slide up and down on bushings constrained to vertical rods, thus allowing the load to move with the same vertical motion as the hip, but lagging it by a fraction of a second, producing differential movement between the frame and load. The pogo-stick-like movement of the load generates mechanical energy that drives a rack-and-pinion device that powers a geared DC motor that acts as a generator mounted on the frame. The load plate can be locked to stop the device from sliding up and down and generating electricity.

To assure that the backpack wouldn’t require users to expend too much additional metabolic energy, Rome and his colleagues performed a variety of tests on six male subjects, who used the backpack while walking on a treadmill. The tests measured the amount of mechanical energy going into the backpack’s generator and gauged the metabolic cost of generating electricity with the backpack.

The tests showed that the Suspended-load Backpack altered the gait of the test wearers, causing them to walk more efficiently. Because of this, the testers used less metabolic energy to generate electricity than anticipated.

While Rome and his colleagues haven’t yet determined the biomechanical causes of the backpack’s better-than-expected efficiency, they say it confirms that the backpack is practical and that the technology can also be applied to making a standard backpack that is more ergonomic.

A Pennsylvania-based company called Lightning Packs LLC has been formed to further develop and refine the Suspended-load Backpack and to develop an ergonomic backpack based on the working prototype and initial findings. Lightning Packs has applied for patent protection on both inventions.
"It seems that most everyone in the world uses a backpack to carry things, and the possibility of doing it more ergonomically and also providing electricity in remote areas may have widespread benefits, some of which we can’t even anticipate today," says Rome.

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Meet Backpack Inventor Larry Rome

When the Office of Naval Research (ONR) sought someone to develop a means to assist over-burdened soldiers in Afghanistan, who were lugging as much as 20 pounds of spare batteries to power their high-tech field equipment, the search quickly led to Whitman Investigator Larry Rome.

"I’m one of the few experts on the design of muscular systems for locomotion," says Rome, who used his knowledge to design the Suspended-load Backpack in response to the ONR’s request. The MBL has contributed to this expertise since he first arrived in 1986 as MBL Summer Fellowship recipient.

Rome, who is also an Invertebrate Zoology course alumnus, comes to the MBL every summer to study how fish muscle is designed on a biophysical level. He spends the rest of the year in Philadelphia, doing research and teaching biology at the University of Pennsylvania.

One of Rome’s favored research models is the toadfish (Opsanus tau), a species that is readily available at the MBL. "We’ve used the toadfish as an experimental model because they contain the greatest range of contractile properties of any vertebrate," he says.

In fact, the toadfish has some of the slowest swimming muscles ever measured, as well as the fastest vertebrate muscle known: a swim bladder that males contract and relax 200 times per second to create a boat-whistle mating call.

Rome studies molecular mechanisms of toadfish and other marine organism muscle systems because he says knowing how a healthy motor system works will make it easier to identify what happens when muscles don’t work properly.

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