Molecular motors cooperate in moving cellular cargo, study shows

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Researchers using an extremely fast and accurate imaging technique have shed light on the tiny movements of molecular motors that shuttle material within living cells. The motors cooperate in a delicate choreography of steps, rather than engaging in the brute-force tug of war many scientists had imagined.

"We discovered that two molecular motors -- dynein and kinesin -- do not compete for control, even though they want to move the same cargo in opposite directions," said Paul Selvin, a professor of physics at the University of Illinois at Urbana-Champaign and corresponding author of a paper to appear in the journal Science, as part of the Science Express Web site, on April 7. "We also found that multiple motors can work in concert, producing more than 10 times the speed of individual motors measured outside the cell."

Dynein and kinesin are biomolecular motors that haul cargo from one part of a cell to another. Dynein moves material from the cell membrane to the nucleus; kinesin moves material from the cell nucleus to the cell membrane. The little cargo transporters accomplish their task by stepping along filaments called microtubules.

To measure such minuscule motion, Selvin and colleagues at Illinois developed a technique called Fluorescence Imaging with One Nanometer Accuracy. The technique can locate a fluorescent dye to within 1.5 nanometers (one nanometer is a billionth of a meter, or about 10,000 times smaller than the width of a human hair). Recent improvements to

FIONA now allow scientists to detect motion with millisecond time resolution.

Selvin's team used FIONA to track fluorescently labeled peroxisomes (organelles that break down toxic substances) inside specially cultured fruit fly cells. This was the first time the imaging technique had been used inside a living cell.

"Our measurements show that both dynein and kinesin carry the peroxisomes in a step-by-step fashion, moving about 8 nanometers per step," said Selvin, who also is a researcher at the Frederick Seitz Materials Research Laboratory on the Illinois campus.

"Because we see a fairly constant step size, we don't believe a tug of war is occurring," Selvin said. "If the dynein was fighting the kinesin, we would expect to see a lot of smaller steps as well."

The researchers also noted that faster movements occurred with the same step size, but with greater rapidity. When measured outside the cell, kinesin moved about 0.5 microns per second. Inside the cell, the speed increased to 12 microns per second.

"There must be a mechanism that allows the peroxisomes to move by multiple motors much faster than independent, uncoupled kinesins and dyneins," Selvin said. "It appears that motors are somehow regulated, being turned on or off in a fashion that prevents them from simultaneously dragging the peroxisome."

In the future, Selvin wants to combine FIONA and an optical trap technique to monitor the speed and direction of a peroxisome, and the force acting upon it.

"By measuring force we can determine how many molecular motors are working together," Selvin said. "This will help us further understand these marvelous little machines."

Source: University of Illinois at Urbana-Champaign

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