

## Study: Of mice and mended fingers

Research indicates that mammals, including humans, can sometimes regrow severed fingertips if wounds are allowed to heal without surgical intervention.

A study published in the Aug. 20 *SCIENCE* indicates that in most cases, mice with behind-the-nail amputations can regrow normal-looking toetips when wounds are simply cleaned and left to heal. Richard B. Borgens, a biologist at Purdue University School of Veterinary Medicine in West Lafayette, Ind., reports the amputation point is important because mice with more of the foretoe severed showed little or no regrowth.

Borgens reports that 16 out of 20 mice with amputations behind the nail level grew new foretoe tips that appeared normal; six of the 16 even regrew nails, but three were abnormal in character. The remaining four mice with behind-the-nail amputations had amputated wounds which healed to form stumps.

Foretoes of mice with level 2 amputations — the foretoe was severed through the middle phalange — showed quite different results. In 19 out of 20 mice, the severed foretoes showed no regrowth and healed as a stump. The remaining mouse showed slight elongation, but Borgens reports that it was not comparable to the regrowth seen in mice with level 1 amputations.

This is not the first instance of regrowth in mammals; there have been scattered clinical reports that children with severed fingertips will regrow fingertips if physicians do not close the wound surgically. But Borgens says there has been no controlled study of fingertip or toetip regrowth in the laboratory.

Marcus Singer, professor of anatomy at Case Western Reserve University in Cleveland, says the regrowth process observed in children with severed fingertips is poorly understood. Singer says an animal model might help researchers understand how this process occurs in humans.

According to Singer, Cynthia Illingworth, a physician in England, first reported fingertip regrowth in children. Illingworth reported that in over 300 cases when doctors cleaned and bandaged fingers severed between the nail and the first joint, good regrowth of the fingertip was observed with some fingertips looking cosmetically perfect in three to four months.

But Roy G. Farrell, an emergency physician in Seattle, says the accepted way to treat an amputated human fingertip in most U.S. hospitals is to sew a piece of skin over the wound. Borgens says amputations treated this way show no regrowth and heal to form a stump. He adds, however, that not every child with a severed finger would be helped by a non-surgical

treatment. He says regrowth has only been observed in fingertips amputated beyond the first joint.

Regrowth in mice foretoes and in human fingertips is probably not the classic regeneration that biologists see in salamanders, Borgens explains. Regeneration means regrowth of new tissue and bone without any remnant of the original bone or tissue to act as a template for new growth, he says, and salamanders will grow a new arm or leg even when the old one is cut completely off.

But a different process seems to be at work in mammal fingertip regrowth, since not only did mice foretoes cut beyond a certain point not grow back, but nail growth was observed only in mice that had portions of the nail bed left after amputation.

Singer says unpublished experiments with primates that his lab has conducted show that monkeys with nail base amputations will also regrow fingertips.

—K.A. Fackelmann

## Deep dives at sea with king penguins

Penguin parenthood involves a series of marine excursions to gather food for the chick. Scientists are now investigating just how South Georgia Island king penguins behave while foraging in the sea. With a new type of depth recorder and radioactive injections, the biologists are learning how often and how deeply the birds dive, their metabolic rates and the energy expense of the food brought back to the breeding colony.

"The depth to which the animals are diving is one of the most interesting findings," says Gerald L. Kooyman of Scripps Institution of Oceanography. The deepest dives, of more than 240 meters, are considerably deeper than those recorded for any aquatic bird except the emperor penguin. And the large number of dives of more than 100 meters indicates the king penguins gather food at greater depths than other birds living nearby, Kooyman, Randall W. Davis and Dan P. Costa of Scripps and John P. Croxall of the British Antarctic Survey report in the August 20 *SCIENCE*. They clamped pressure-sensing depth recorders to the back feathers of three king penguins just before the birds went foraging at sea.

To learn about the energy requirements of foraging, Kooyman and colleagues injected radioactively labeled water into three other king penguins. Blood samples before and after their 4- to 8-day food gathering excursions provided data to determine metabolic rates.

"Foraging at sea is not very expensive, energetically," Kooyman says. The ratio of metabolic rate while foraging to a standard resting rate is about the same as for terrestrial birds and mammals. Still, the energy required for foraging is twice the energy content of food delivered to the chick. Each bird expends about 20 kilojoules of energy on a sea excursion — the energy provided by about 8 kilograms of squid. To sustain the adult and feed the chick, the scientists calculate that 50 to 90 squid must be caught during the trip. The squid for the chick are carried back in the parent's crop, a pouch near the lower end of the esophagus.

However hard they work, the penguins' efficiency in catching squid is rather unimpressive. They appear to succeed on



Randall Davis

*Adult penguin with depth sensor attached to back feeds chick in breeding colony.*

fewer than 10 percent of their dives. Kooyman says that this result would have been more surprising if they were not finding a similarly high food capture failure rate in a study of fur seals.

How energetically a penguin forages for the squid differs among individuals. One bird averaged 304 dives per day for 4 days; another averaged 111 dives per day for 8 days. Differences also are apparent in the metabolic rate. One bird expended energy at half the rate of another, but it stayed at sea more than twice as long. "It looks like some animals work more intensively when they are out," Kooyman says. "It would seem that at times birds go to sea for less time but work harder."

Kooyman hopes to be able to go back to South Georgia Island in a couple of years to do a larger study of the diving birds. He would like to attach depth sensors to more penguins and measure several thousand dives. He is particularly interested in exploring shallow dives, which were the most frequently recorded in the current study. Whereas dives of more than 50 meters require a serious swimming effort and are considered foraging dives, those of less than 30 meters are difficult to interpret because it takes the penguins so little effort.

—J.A. Miller