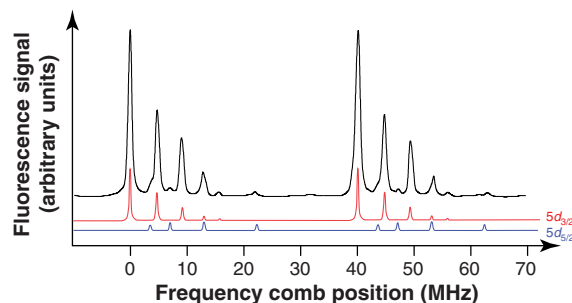


precise clock operating in the radio frequency domain).

In principle, it should be possible to apply many pulses in series to an atom or molecule, because a typical mode-locked laser emits ~70 million pulses per second. However, at room temperature, atoms or molecules tend to move out of the laser focus before they can be hit by a large number of pulses. This becomes even more of a problem if a harmonic of a laser is used, because these harmonics are usually of low power and must therefore be focused to a small spot size to obtain a reasonable intensity.

To date, spectroscopy with frequency combs has not reached the resolution of single-mode lasers. In an early experiment, Eckstein *et al.* reached a resolution of 4 MHz for the sodium 4s-4d transition (natural linewidth 1.6 MHz) (5). More recently, Marian *et al.* (6) and Snadden *et al.* (7) have performed comb spectroscopy on the two-photon 5s-5d transition of rubidium. The latter authors laser-cooled and trapped the atoms to keep them within the laser focus. The resulting linewidth approached the natural linewidth of 300 kHz (see the second figure). In contrast to Witte *et al.*, all these authors



Probing the resonance frequencies with a frequency comb.

The two-photon 5s-5d transition in ^{85}Rb breaks up into several components: For the 5s state, only the $F = 3$ hyperfine state is used. The 5d state first breaks up into two fine structure states, $5d_{3/2}$ and $5d_{5/2}$, which in turn break up into hyperfine components (red and blue curves). The black curve is the resonance fluorescence (shifted up for clarity) that is recorded as the frequency comb is scanned across the line. The two-photon excitation becomes possible whenever the frequency of two modes or twice the frequency of one mode coincides with the atomic transition. As a consequence, the two-photon absorption spectrum repeats at an interval of half the laser repetition rate (80.3 MHz in this experiment). Figure adapted from (7).

used the fundamental, not a harmonic, of a frequency comb.

Despite these advances, single-mode lasers remain more suitable than frequency combs for spectroscopy—unless one uses harmonics of frequency combs where single-mode lasers are not readily available. This is what Witte *et al.* have now demonstrated with a train of three pulses of the fourth harmonic of a Ti:sapphire mode-locked laser (rather than with the femtosec-

ond laser pulses themselves). Hopefully, we can expect the application of much higher harmonics with many more pulses to interesting atomic or molecular species. A whole new window for high-resolution spectroscopy thus opens. It might even become possible to use a single laser system to cover all wavelengths from the near-infrared to soft x-rays; this possibility is out of reach for single-mode lasers.

High-resolution spectroscopy in the extreme-ultraviolet regime would be very useful for investigating hydrogen-like ions. For these ions, the quantum electrodynamic contributions to the energy levels (Lamb shifts) become more important and can be determined more precisely. It might even be possible to create an optical clock that operates in the extreme ultraviolet regime. The stability of such a clock is proportional to the transition frequency in use, and would thus be very high.

References

1. E. Peik *et al.*, *Phys. Rev. Lett.* **93**, 170801 (2004).
2. R. J. Rafac *et al.*, *Phys. Rev. Lett.* **85**, 2462 (2000).
3. S. Witte, R. Th. Zinkstok, W. Ubachs, W. Hogervorst, K. S. E. Eikema, *Science* **307**, 400 (2005).
4. Ye. V. Baklanov, V. P. Chebotayev, *Appl. Phys.* **12**, 97 (1997).
5. J. N. Eckstein, A. I. Ferguson, T. W. Hänsch, *Phys. Rev. Lett.* **40**, 847 (1977).
6. A. Marian, M. C. Stowe, J. R. Lawall, D. Felinto, J. Ye, *Science* **306**, 2063 (2004); published online 18 November 2004 (10.1126/science.1105660).
7. M. J. Snadden, A. S. Bell, E. Riis, A. I. Ferguson, *Opt. Commun.* **125**, 70 (1996).

10.1126/science.1108159

ECOLOGY

A Leap for Lion Populations

Esa Ranta and Veijo Kaitala

There are substantial populations of lions in Africa and Asia. Despite being known as “the king of the jungle,” the African lion is principally found on open savannas, with smaller numbers in woodland areas. Since the 1960s, the ecology of lions has been intensively studied in the Serengeti National Park of Tanzania in East Africa (1–3) (see the figure). Lions live in family groups known as prides. Both woodlands and plains prides of the Serengeti are typically composed of six related females, their cubs, and a few unrelated males who mate with the adult females. The females do most of the hunting for the pride (1), and they must hunt in

groups to be successful. Most of the daily activity of males concerns maintenance of territory. Packer *et al.* (4) have completed a detailed analysis of long-term records of lion populations in a 2000-km² area of the Serengeti National Park. As they report on page 390 of this issue, lion population size has remained remarkably stable for long periods (10 to 20 years) punctuated by sudden increases that do not seem to reflect numbers of available prey.

The population dynamics (changes in the population size) of animals obey several

key rules (5, 6). Population increases are due to births of new individuals and arrival of immigrants from nearby populations, whereas any decreases are due to individuals dying or leaving their natal population. Often births and deaths are dependent on each other either directly or with an intervening time lag. Population increases also depend on the amount of resources that mature females are able to monopolize. However, Packer *et al.*

now reveal an unusual feature of the population dynamics of Serengeti lions (4). They discovered that lion numbers, both in the woodlands and on the plains, undergo long periods of stability interrupted by abrupt changes. This is intriguing because no such saltatory changes in population dynamics are reported for lion prey such as wildebeest, Cape buffalo, and gazelle (4).



Rather, the populations of these Serengeti prey species have changed without evidence of the dramatic leaps characterizing lion populations since the 1960s, when quantitative censuses began.

A straightforward expectation of predator-prey population dynamics is that a gradual change in resources (prey) would support a corresponding smooth change in predator population size (6). However, in Serengeti lions, the population increases have been abrupt often constituting an increase of 20 to 50% of the extant population size. The population records since the end of the 1960s include three saltatory changes (1973, 1983, and 1999) for lions inhabiting Serengeti woodlands and one (1997) for lions inhabiting the plains. In between these leaps, the lion population remained stable, hovering around the number reached during the previous increase.

Packer and his research team (4) now provide an explanation for these jerky dynamics by incorporating into their simulation model the social grouping behavior of lions within their prides. Serengeti lion prides have an optimal size: In the smallest prides, females have very low reproductive success, because hunting of their major ungulate prey calls for the cooperation of several individuals. In contrast, in the largest prides, females suffer from intense competition for the prey they have subdued jointly. When resources increase sufficiently to support more offspring and when the size of an extant pride is sufficiently large, the pride splits; several related females disperse together to form a new pride. Packer *et al.* suggest that it is optimal from an evolutionarily standpoint for a group of females to leave their pride and to establish a new pride with a different territory because this behavior ensures greater breeding potential. In this way, a gradual increase in prey population size supports a sequence of continued stability interrupted by abrupt increases in the abundance of lion populations.

The only major decrease (since the 1960s) in the population size of Serengeti lions occurred in 1994. The rapid decline (to 50% of the pre-1994 level) of woodland lions coincided with a decrease in the numbers of wildebeest and Cape buffalo due to a severe drought in that habitat. It is tempting to suggest that the collapse in lion numbers represented a reversal of the social mechanisms that result in punctuated increases in lion population size. A decrease in resources could have affected lion population size by reducing the number of prides in the overall population. However, this possibility cannot be verified because the 1994 decline in lion numbers was in fact due to an epidemic of canine distemper (4).

It is worth contrasting the population dynamics of Serengeti lions with the known dynamics of other species where long-term data are available (6). Whereas Serengeti lion population dynamics show saltatory changes in size, all other known predator-prey populations follow—with a time lag—a model in which smooth increases in prey availability result in smooth increases in predator population size. The best documented predator-prey populations display characteristic periodic fluctuations (5–7) that obey the standard models found in any population ecology textbook (6, 7). One feature shared by traditional predator-prey models (6, 7) and the Serengeti lion model of Packer *et al.* (4) is the presence of a time lag between changes in the population size of prey and that of predator.

The new data about Serengeti lion population dynamics (4) enriches our existing palette of predator-prey population patterns. One recent theory takes as a starting point the idea that individual behavior eventually has repercussions on long-term population ecology (8). The findings of Packer and colleagues support this view, although traditional population theories (5–7) have yet to incorporate the notion of social behavior into their models. The population dynamics of woodland and plains Serengeti lions are largely driven by the social structure of prides: To breed successfully, lionesses must belong to a pride that is suf-

ficiently large (but not too large). Once a pride exceeds the optimal size, it splits with several females leaving to form a new pride. This leads to an increase in the lion population, presuming that sufficient resources are available to support the increase in offspring. We anticipate that behavior-based population models examining social behavior within populations and how these behaviors influence population growth will ultimately find their way into the analytical toolbox of population ecologists. The use of such models will help ecologists to better understand the dynamics of focal animal populations, and to provide more sophisticated management of threatened animal populations such as those of the Serengeti.

References

1. G. B. Schaller, *The Serengeti Lion* (Univ. of Chicago Press, Chicago, 1972).
2. A. R. E. Sinclair, P. Arcese, Eds., *Serengeti Past and Present. Serengeti II: Research, Management and Conservation of an Ecosystem* (Univ. of Chicago Press, Chicago, 1995).
3. Serengeti Park (www.serengeti.org).
4. C. Packer *et al.*, *Science* **307**, 390 (2005).
5. T. Royama, *Analytical Population Dynamics* (Chapman & Hall, London, 1992).
6. P. Turchin, *Complex Population Dynamics: A Theoretical/Empirical Synthesis* (Princeton Univ. Press, Princeton, NJ, 2003).
7. A. Berryman, Ed., *Population Cycles: The Case for Trophic Interactions* (Oxford Univ. Press, Oxford, 2002).
8. W. J. Sutherland, *From Individual Behaviour to Population Ecology* (Oxford Univ. Press, Oxford, 1996).

10.1126/science.1108599

MEDICINE

Visfatin: A New Adipokine

Christopher Hug and Harvey F. Lodish

The developed world has been engulfed by a rapid rise in the incidence of obesity and diabetes. One hypothesis for the marked prevalence of obesity posits that selective evolutionary pressure favored those of our ancestors who were able to store excess food in the form of triglycerides, the primary component of adipose (fat) tissue. Unfortunately, what may have been an advantage eons ago is now manifest as a rapidly expanding waistline. The increased incidence of obesity and diabetes carry many sequelae, collectively known as the metabolic syndrome or syndrome X. Such sequelae include an increased risk of cardiovascular and kidney disorders as well as breast cancer, hepatocellular carcinoma,

The authors are at the Whitehead Institute for Biomedical Research, Cambridge, MA 02142, USA, and the Department of Biology, Massachusetts Institute of Technology, Cambridge, MA 02142, USA. C. Hug is also in the Division of Respiratory Disease, Children's Hospital, Boston, MA 02115, USA.

and Alzheimer's disease. How these and other conditions are related to the multiple defects in energy metabolism associated with diabetes and obesity is a major focus of current research efforts. An emerging theme is that adipose tissue, found in several locations throughout the body and long thought to be primarily a repository for triglycerides, is also important for regulating homeostasis and metabolism. Fat is an endocrine tissue and, indeed, may constitute the largest endocrine organ in the body (1, 2). Several hormones, called adipokines or adipocytokines, are synthesized by adipose tissue. These include adiponectin, tumor necrosis factor- α (TNF- α), leptin, resistin, and adipisin (see the figure). To be added to the list, as Fukuhara *et al.* report on page 426 of this week's issue (3), is a presumed new member of the adipokine family, visfatin.

Certain attributes of visceral fat, the adipose tissue surrounding abdominal organs,