Animal Anorexias

N. Mrosovsky and David F. Sherry

There are times when animals eat very little and lose weight, even when food is present. In many species this occurs when the animal is engaged in other important activities that compete with feeding. For example, bull seals go without feeding for several weeks while they defend their territory and harem (*1*); to feed would entail their going into the water and leaving their territory unprotected. Fasting also occurs in association with incubation, migration, molting, and hibernation, even though food is sometimes readily available. Such fasting can be distinguished at the outset from the fasting of sick animals because it occurs regularly, at specific stages of the life cycle.

For anyone who has experienced the sensation of hunger, or who has seen how food-deprived animals can be trained to make great efforts or to perform diverse responses to obtain food, refusal to eat, or failure to search for food for long periods, needs an explanation. Before discussing the mechanism and adaptive value of fasting in the examples mentioned above, we review the data obtained in studies of low food intake in hibernators over the winter season and of low food intake in incubating birds. Numerous less well studied instances of fasting that we review subsequently appear to have features in common with these. We argue that eating very little, even when plentiful food is provided, reflects an adaptation to predictable periods when food is unavailable in nature, either because it is in short supply, or because an activity of greater importance, which would be disrupted by feeding, is going on.

Summary. Eating very little in the presence of food or failure to search for food has been documented in various species during the hibernation season, incubation, molting, and defense of the territory or harem. At these times feeding competes with other, more important activities. One way to avoid conflicts between feeding and these other activities is to lower the programmed weight or set-point for body fat. Experiments on mammalian hibernators and incubating birds provide evidence that set-points are indeed lowered. Failure to eat in these two examples depends on anorexia, loss of appetite. A review of other examples suggests that conceptualization in terms of lowered set-points provides a unified and testable way of understanding many naturally occurring instances of fasting in the animal kingdom. Finally, spontaneous animal anorexias are contrasted with attempts by people to lose weight.

Fasting During the Hibernation Season

Hibernation is a strategy that permits some mammals to survive seasons of low food availability. Food shortage, however, is not a necessary precondition for hibernation. Obligate mammalian hibernators become torpid even when they have food available. For instance, ground squirrels eat only sparingly or not at all during their periodic arousals from hibernation (*2, 3*). In a laboratory setting where the animals have free access to food close by there is nothing obvious stopping their eating. During arousals golden-mantled ground squirrels (*Citellus lateralis*) spend much of the time curled up resting in their nests (*3*); since these arousals often last more than 10 hours, there is plenty of time to eat. Indeed food is sometimes eaten but meal size is decreased (*4*). Since the animal eats a little rather than nothing, it is evident that there are no compelling environmental limitations on eating. Moreover, the amount eaten increases when energy expenditure increases. This can be most readily demonstrated by keeping animals in a warm room over the winter and so preventing deep torpor; they then eat more than animals in a cold room (*5, 6*). Most ground squirrels in a cold room hibernate, but occasionally a few individuals remain active, and these also eat relatively more than animals displaying extensive torpor (*6*) (Fig. 1B). If animals that hibernate are repeatedly forced to arouse and rewarm themselves they eat more: in one experiment frequently handled thirteen-lined ground squirrels (*Citellus tridecemlineatus*) ate more than eight times as much as undisturbed control animals during the middle of the hibernation season (*7*).

An instructive feature of such studies is that, whether energy expenditure was high or low, the ground squirrels lost weight at fairly similar rates. This suggests that weight may be regulated about progressively decreasing values and that hibernators eat only as much food as is necessary to keep themselves at these decreasing values. This idea can be tested by depriving ground squirrels of food altogether for parts of the winter season. As expected, they lose weight more rapidly during deprivation. More telling is the fact that when food is returned they regain not their predeprivation weight but a weight that is appropriate for them at that time of year (Fig. 1A) (*7–9*). Ground squirrels appear to pass through a series of progressively decreasing values for weight, each value appropriate to a particular phase of the cycle. Such programmed weight changes appear to be a general phenomenon in hibernators, having been found not only in ground squirrels, but also in woodchucks (*Marmota monax*) and European hamsters (*Cricetus cricetus*) (*10*). Although food intake has not been as extensively studied as body weight in these experiments, there is some evidence that when food is returned after deprivation more is eaten than is usual for that time of year (*2, 7*).

All the findings on hibernators mentioned so far as well as several others (*7, 9, 11*) can be accounted for by a single assumption: that over the winter phase of their cycle hibernators show a programmed decrease, or falling set-point (*12*), for body weight. Since changes in body fat are responsible for most of the weight changes in hibernators (*13*), a falling set-point for body fat may be a more accurate description. With a progressive lowering of the set-point during the hibernation season the animals are rarely below the specified level for body fat and so loss of appetite, anorexia, ensues. In situations where energy expenditure is increased or the animals are forced off their normal weights, food intakes increase in defense of programmed levels of body fat.

N. Mrosovsky is a professor in the Departments of Zoology and Psychology, University of Toronto, Toronto, Ontario M5S 1A1, Canada. D. F. Sherry is a postdoctoral fellow in the Department of Zoology, Oxford University, Oxford, OX1 3PS, United Kingdom.

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Incubation Fasting

Turning to incubation, we have found that the female of the red junglefowl (*Gallus gallus*) eats little and loses 10 to 20 percent of her weight over the 20-day period of incubation (*14*). Food intake is not eliminated entirely but is reduced to about 20 percent of that of nonincubating females.

The junglefowl hen is highly attentive to the eggs, leaving the nest for less than 20 minutes per day. In one experiment we attempted to determine whether the hen's attachment to the nest and eggs effectively reduced access to food, thus producing a low level of intake. Food was placed in containers inside the nest box, such that the hen could feed without leaving the eggs unattended. Despite the fact that eating and incubating were no longer physically incompatible, food intake did not significantly increase.

Although resorption of the ovary and oviduct and expenditure of energy for heating the clutch may both contribute to weight loss during incubation, neither factor exerts as great an influence on weight as does the reduction in food intake. Resorption of the reproductive organs in the ring-necked pheasant (*Phasianus colchicus*), a galliform comparable in weight to the junglefowl, accounts for 20 percent of the total weight loss, but is complete by the eighth day of incubation (*15*). Whether incubation is a period of increased or reduced energy expenditure for birds is a matter of some debate (*16*). Whatever the cost of incubation, however, food intake is well below the level necessary to maintain a stable body weight.

If the hen fasts and continues to lose weight even when incubation need not be interrupted in order to feed, it suggests that some modifications in the regulatory systems occur. We therefore deprived incubating junglefowl hens of all food for a 6-day period, either early or late in incubation. In both conditions the rate of weight loss was accelerated during deprivation. Upon the return of food, intake increased to values above those of control animals. Weight also increased on the return of food, but returned not to predeprivation levels but to close to the level seen in control animals at the same stage of incubation. Animals deprived during the early part of incubation returned to midincubation weights; animals deprived late in incubation returned to weights seen in control animals at the end of incubation (Fig. 2).

These results suggest that regulation of weight or its correlates persists during incubation, but that the defended weight declines. A reduction in set-point accounts for reduced intake and weight loss occurring even in the presence of food. Provided that the rate of fall of the set-point is one that the hen can keep pace with by eating limited amounts of food during brief excursions away from the nest, there is no striking evidence that the regulatory machinery is still in action. But if the animal is forced below the set-point by total deprivation, then when food is again available, the corrective response of compensatory overeating occurs.

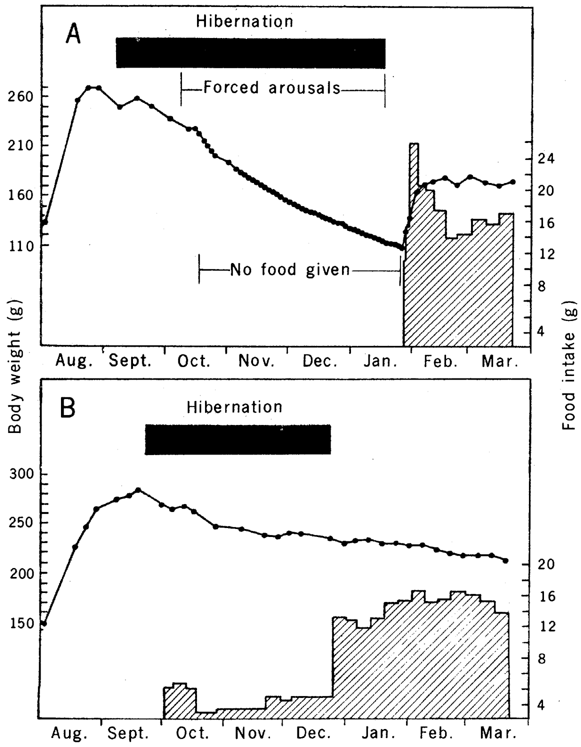

Fig. 1. Body weight (solid line), food intake (hatched area), and hibernation (solid horizontal bar) for two individual golden-mantled ground squirrels. Periodic arousals from hibernation are not shown. (A) An animal repeatedly aroused from torpor by frequent handling. When the animal was given food after a period of deprivation its weight increased to a level appropriate for the early spring rather than the fall. (B) An animal with an unusually short hibernation season. Its food intake increased after hibernation stopped but a gradual decline in weight persisted. [Adapted from Mrosovsky and Fisher (*7*)]

Survival Value of Anorexia and Regulated Weight Loss

Given the data on these two examples, we now must ask not only what is the survival value of the anorexia but also why weight loss should be regulated. The function of anorexias may be simply and broadly stated: they are adaptive when eating and maintenance of body fat would compete with more important activities (*14, 17, 18*). In the case of junglefowl the female does all the incubating; the male does not participate even to the extent of bringing food for its partner (*19*). Maintaining the eggs at the appropriate temperature or preventing predation may well be incompatible with finding and eating enough food to maintain body weight.

In the case of ground squirrels and some other hibernators, the adaptive value of anorexia is less obvious. However, there are plausible reasons stemming from the metabolic end-product theory of the periodic arousals from hibernation. According to this theory, arousals are necessary to permit clearance of metabolic end products from the bloodstream by the kidney, which does not function fully under conditions of hypothermia. It follows that if an animal has eaten large amounts of food just before becoming torpid, it will have to arouse relatively soon in order to clear the resulting end products from its system; indeed, food intake and the length of hibernation bouts are inversely related in golden-mantled squirrels (*2*). Although metabolic end products are not the only factors controlling the length of hibernation bouts, since toward the end of the hibernation season these shorten even in totally deprived animals, there is now considerable evidence that they play an important role (*17, 20*). This may explain why hibernators often spontaneously stop eating before hibernating. If the economy of long-lasting torpor, uninterrupted by thermogenically expensive arousals, is to be realized, then anorexia is essential.

Plausible reasons for the survival value of fasting exist therefore for both our examples. But why is this achieved by lowering of set-point? To obtain insight into this one has only to consider what would happen if methods not involving a lowering of defended value were adopted. It is well known that when animals lose weight after food deprivation their activity commonly increases (*21*) and they perform responses that earn them food. It has been shown that the strength of such responses, both in rats and chickens, is proportional to the weight loss (*22*). In behavioral studies with pigeons, motivation is often specified in terms of body weight loss. This does not mean that animals will not work for food without appreciable loss of weight (*23*), but that food restriction and weight reduction are effective motivators in many species.

If one keeps in mind the powerful and widespread effects of being below the usual body weight, it becomes easier to understand the lowering of set-point in the incubating junglefowl. Unless set-point is lowered, incubation will have to compete with and triumph over the behaviors that are usually set in motion by food deprivation. While it is presumably possible in theory that the hen is getting hungrier and hungrier as she sits on the nest, a much more elegant and safer solution to the problem would be to lower the set-point and avoid clashes between incubating and eating. Similarly, in the case of hibernators, the motivation to hibernate would have to be very strong to overcome the temptations of food lying right under the animal's nose.

Reasons why there must be anorexia, and why a lowering of set-point is a good mechanism for achieving it, have already been given. But is there any reason why the set-point should be lowered progressively as appears to be the case in both the examples discussed? To obtain insight into this point one may again start by considering the alternative, a sudden one-step lowering of set-point. This would leave the animal at the start of hibernation or start of incubation a long way above the set-point. When animals are a long way below the level they are defending, then compensatory responses such as extra eating, increased efficiency of utilization of food, searching for food, and working for food come into play. What happens when animals are above their set-points, are there also compensatory responses? This side of the coin has been much less studied for the obvious reason that this situation is much less likely to occur. There are, however, some relevant data here. In the Vermont studies on the physiological concomitants of obesity, subjects deliberately made themselves fat by eating large amounts of food. However, they experienced considerable difficulties in gaining large amounts of weight despite the fact that they were successful in greatly increasing their caloric intake (*24*). Evidently, some of the excess calories were not efficiently converted into fat but disposed of in some other way. Animal studies support the view that excess calories can be dissipated as heat (*25*). Of particular interest here is that during weight loss in rats that had been switched from a varied and palatable diet to standard laboratory diet, there was a greater negative energy balance than could be accounted for by reduced food intake (*26*).

Thus there is a possibility that animals above their set-points do not simply cut down their eating till their weight has fallen, but also bring calorie expending mechanisms into play in defense of appropriate weights. If the same were to occur in species where natural anorexia is needed, then a sudden lowering of set-point might be wasteful of fat gained before anorexia, fat that had been gained at some cost to the animal. To evaluate these speculations fully we would need more information on weight loss mechanisms and whether there is any hierarchy of responses (*27*).

Laboratory studies and detailed data are only available for a few instances of fasting animals, but the principles elaborated here probably have much wider application. Certainly there are many examples of feeding being incompatible with some other activity that can be understood in this framework (*28*), and we will now review some of them.

Incubation and Protection of Eggs and Young

Weight loss during incubation, comparable to that in junglefowl, has been reported for blue grouse (*Dendragopus obscurus*) (*29*), capercaillie (*Tetrao urogallus*) (*30*), California quail (*Lophortyx californicus*) (*31*), ring-necked pheasant (*Phasianus colchicus*) (*15*), and the domestic fowl (*Gallus gallus*) (*32*). Among nongalliforms an incubation weight loss is known to occur in female mallards (*Anas platyrhynchos*) (*33*), common eiders (*Somateria mollissima*) (*34*), and snow geese (*Chen caerulescens*) (*35*). Some, but not all, of these data come from records for individual birds over the course of incubation; other data are based on weights of different birds at different times in the reproductive season. In all of the species cited one parent completes incubation alone and is neither fed nor relieved on the nest by its mate.

Penguins undergo especially prolonged fasts during which their weight falls dramatically. Emperor penguins (*Aptenodytes forsteri*) breed during the austral winter on the sea ice along the Antarctic coast. Both the males and females fast while they walk up to 100 kilometers to the breeding site (*36*); at arrival there the males weigh 34 kilograms and are 26 percent fat and the females weigh 24.8 kg and are 18 percent fat (*37*). Short-

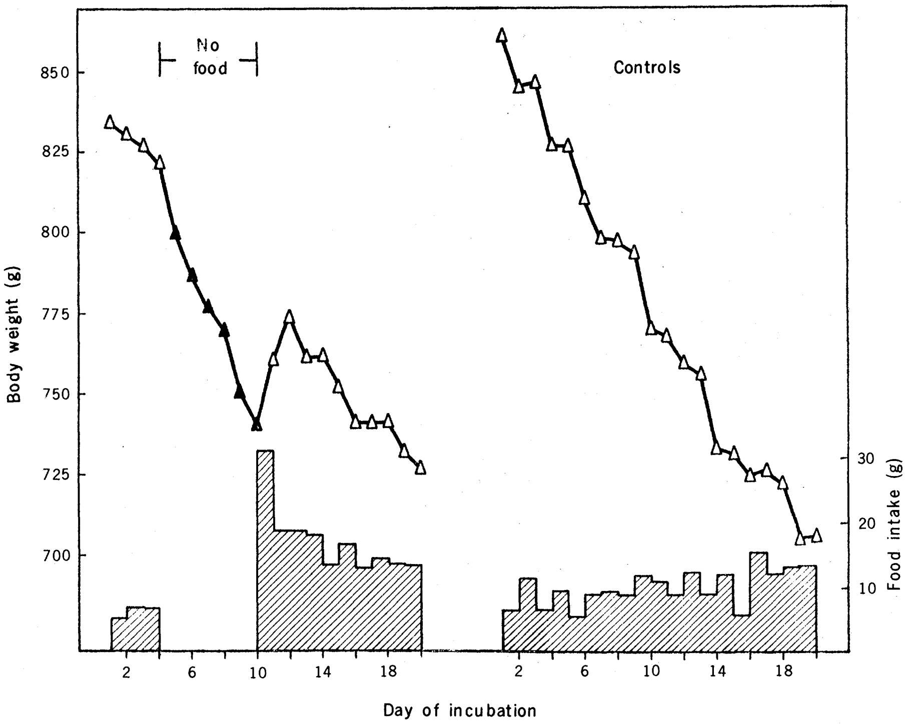

Fig. 2. Mean body weight and food intake for groups of incubating junglefowl (*14*). Open triangles show weight on days when the birds were given free access to food; solid triangles show weight on days when they were deprived of food.

ly after the single egg is laid the male assumes the incubation duties for the 62 to 64 days until hatching, and the female, who has been fasting for 40 to 50 days, goes to sea. By the time the female returns the male has not eaten for about 120 days, and has lost 40 percent of his body weight (*36*).

Above a critical weight of about 20 kg, lipid catabolism accounts for 55.5 percent of the weight loss, protein 9.2 percent, and water loss 35.3 percent (*38*). The 20-kg critical weight is the average weight at which fat reserves are exhausted and the rate of protein catabolism and the rate of weight loss increase. This is close to the critical weight at which the male will abandon the egg and leave for the sea (*36*). Evidently, defense of body weight is not abandoned in the male emperor penguin but the values of the weight defended are altered. Whether this alteration takes place in one step or gradually, as appears to be the case with incubating junglefowl, requires further study.

In the closely related king penguin (*Aptenodytes patagonicus*), both the male and female undergo courtship fasts of about 10 to 15 days which are followed by alternating incubation fasts, the first lasting about 18 days (*39*). King penguins begin breeding at weights between 10 and 15 kg, and lose 10 to 20 percent of their weight in the course of the first incubation fast.

Adelie penguins (*Pygoscelis adeliae*), establish small breeding territories during the austral spring, at which time they weigh from 4.5 to 5.0 kg (*40*). A period without food, during travel across the ice to the breeding site, precedes the incubation fast; this period varies according to the distance of the breeding site from the water. Once the eggs are laid the females end their first fast of about 20 days and return to the sea to feed. The males continue incubating for another 20 days, and are then relieved by the returning females. During this first fast the male and female lose 32 and 24 percent of their body weight, respectively (*40*). A second fast of shorter duration follows for each sex until the eggs hatch.

At the start of their first fast Adelie penguins are about 45 percent fat (*41*). About 93 to 97 percent of the weight lost during the first fast is estimated to be fat (*41*). However, in the remaining fat there is no increase in the proportion of unsaturated fatty acids, in contrast to other animals deprived of food or kept at cold temperatures (*42*). This suggests that fasting is physiologically different from starvation (*41*). This is consistent with the observation that Adelie penguins shun food for several weeks on end during the nesting season (*43*).

Animals that do not actually warm their eggs, but care for them in some other way, also fast. For instance, during brooding the female octopus reduces its food intake and dies after the young hatch. Although it sometimes leaves the eggs in order to catch crabs and snails, exposure of the eggs to predators is reduced. Moreover, the female's decreased appetite may lessen the chances of her eating her own eggs. The optic glands play a role in this inhibition of feeding (*18*).

Examination of the stomach contents of female Nile crocodiles (*Crocodylus niloticus*) shows that these crocodiles fast during the 3-month incubation period of their eggs. They spend much of their time lying in a comatose state on or close by the nest, yet there is at least some food about that they would normally include in their diet. For instance, they normally eat the monitor lizards (*Varanus niloticus*) that frequent the rookeries and plunder crocodile eggs (*44*). But hunting lizards or looking for other food is incompatible with guarding eggs; other lizards would soon appear and start digging if the crocodile moved away from the nest. Apparently lizards sometimes even cooperate in provoking female crocodiles into chase: one lizard then rapidly excavates the nest and the other returns to join in the spoils later (*45*).

Of all animals, the mouthbreeding cichlids epitomize incompatibility between feeding and raising young. Of course, it is conceivable that solutions other than anorexia might have occurred in so inventive a group; for instance, the cichlids might have developed a means of swallowing food without swallowing their eggs. But anorexia preceded by fattening seems to be the course adopted by at least some of the African cichlids. At courtship the female is "heavy with roe and stored body nutrients [probably fat, but possibly protein as well]" (*46*), and during the 3 to 5 weeks that she incubates the eggs in her mouth the female tends to reject food; indeed this is a way that aquarists can tell if their fish have spawned (*46*). "Such fasting indicates the efficacy of the physiological changes which take place at this time, particularly in the predacious species, for it is not difficult to imagine the fate of a small fish or an egg enclosed within the mouth of a non-brooding predatory fish" (*47*). But this phenomenon does not appear to have received detailed investigation. Comparative studies of feeding in cichlids with different brooding strategies and different division of labor between the sexes would be interesting (*48*).

Defense of Territory and Harem

For successful breeding, defense of territory may in some instances be as important as defense of the young or eggs. It is not surprising, therefore, that there are also examples of fasting in this context, and that there are associated sex differences in weight loss.

Red deer (*Cervus elephas*) stags lose a considerable amount of weight during the rut, from 14 to 17 percent of carcass weight (*49*). Although food is constantly available underfoot, feeding time is reduced in the males, probably as a result of the time committed to defense of the harem. Stags collected during the rut show reduced gut weights, and have lost most of their fat by the time rut is completed. Females of the red deer do not lose weight at this time (*50*). Annual cycles of weight have also been reported for deer of the genus *Odocoileus* (*51*). These changes in weight occur in captive animals given free access to food and are correlated with reproduction, with weight loss in males being associated with the rut.

The fur seal (*Callorhinus alascanus*) breeds on the shores of the Pribilof Islands. When the bulls haul themselves out of water at the start of the breeding season they are fat. During the next 6 weeks or so they go without feeding and become quite emaciated (*1*). This time is occupied with defending a territory and guarding the harem; returning to the sea to feed would jeopardize these activities. Dominant male elephant seals of the species *Miriounga angustirostris* also go without food during the breeding season; they rarely leave the harem for more than a few minutes (*52*).

Migration

Incompatibilities between migration and feeding arise when breeding and feeding grounds are far apart. The reduced feeding by certain whales and sea turtles provide examples in this category.

Gray whales of the species *Eschrichtius robustus* spend summer in the Bering Sea where they feed off benthic amphipods and other foods in areas of relatively shallow water. For calving in the winter they travel south to Baja California. Virtually no food is eaten during this migration or at the calving grounds or during the subsequent northward migration, as judged by stomach contents (*53*). Weight loss between the southward and northward migration is 11 to 29 percent, with females that give birth and lactate losing the greatest amounts. These whales thus appear to fast for about 6 months, despite the fact that at least some potential foods, red crabs for instance, are sometimes abundant near the calving grounds (*53*). Some benthic foods must also presumably be available during migration, because gray whales often travel relatively close inshore. However, swimming speeds are relatively constant; perhaps covering the huge distance from the Bering Sea to the nearest suitable calving grounds in Baja California is incompatible with searching for food. Several other whale species eat little or no food after periods of fattening in Antarctic waters (*54*).

Green turtles (*Chelonia mydas*) feed largely off pastures of sea grass in shallow, relatively protected areas. Their nesting grounds are often considerable distances away, in places where heavy seas throw up high sandy beaches. This situation tends to create spatial incompatibilities between feeding and egg laying. To take an extreme example, turtles nesting on Ascension Island would not be able to make the round trip of some 2800 miles (4480 km) to their feeding grounds off Brazil and back in the 14- to 15-day period between nesting, even if they sustained the very highest migratory speeds, about 90 km per day, recorded for this species (*55*). In the case of green turtle populations nesting at Tortuguero, Costa Rica, a visit to their principal feeding grounds some 400 km away at Miskito Cays, Nicaragua, would be conceivable in their 12-day internesting interval (*55*), but it would only allow them at most a few days for feeding and would not be profitable energetically. In this context it is interesting that green turtles nesting in captivity eat sparingly despite available food, and also that injections of estrogens, which cause hypertrophy of their oviducts, reduce eating (*56*). Putting these points together, one can see that it might be adaptive for nesting turtles to decrease their appetite, and that the high estrogen concentrations associated with reproduction might constitute part of a mechanism that lowers defended levels of weight, just as estrogens appear to lower the defended weight in the female rat (*57*). However, eating is not completely suppressed, because at Ascension Island turtles will eat greens dumped into the harbor, and at Tortuguero water hyacinths and even woodland debris drifting out to sea from lagoons are found in turtles' stomachs (*58*).

Molting

During the molting season penguin plumage is no longer watertight. Feeding and molting are therefore incompatible, if not physically at least economically, because much heat would be lost by a poorly insulated bird in cold water. Stonehouse (*39*) provides data on weight loss during the prenuptial molt in the king penguin. Molt lasts an average of 31 to 34 days during which weight loss occurs at a rate of 0.25 to 0.35 kg per day, for a total weight loss of around 50 percent.

Weight loss during molt in rock hopper (*Eudyptes chrysocome*) and macaroni (*Eudyptes chrysolophus*) penguins has also been studied (*59*). Both species fast during molt, losing about 40 percent of their weight, most of this being fat and water loss. Apparently both species also refuse food that is offered to them, at least until the last stages of molt (*60*). Since molt will take place in captivity, it should be feasible to determine experimentally if it is associated with decreased set-points for weight.

Animal Anorexias, Anorexia Nervosa, and Control of Obesity

Finally, it may be asked if any of these animal anorexias could be a useful model for anorexia nervosa. It would be valuable if an animal model for this baffling disorder could be found, but unfortunately the phenomena we have described do not seem appropriate. Although there may well be hypothalamic involvement both in animal anorexias (*61*) and in anorexia nervosa, for instance in the disturbed circadian patterns of luteinizing hormone secretion (*62*), there are prominent psychiatric features of the disorder such as distortions of body image (*63*), concern with control and being controlled, troubled family interactions, and preoccupation with food (*64*) that are not mirrored in animal anorexias. Nor are the binge eating and self-induced vomiting that sometimes occur. Moreover, amenorrhea and weight loss, resulting in death in an appreciable number of cases [15 to 21 percent (*65*)], often in young girls before they have children, is hardly adaptive, whereas the animal anorexias have important functions in ensuring the survival of their offspring.

But animal anorexias may be of some interest to those concerned with obesity. Attempts to control human obesity seem to be becoming more and more radical, including sewing the jaw shut (*66*), intestinal bypass surgery (*67*), vagotomy (*68*), and lateral hypothalamic lesions (*69*). These contrast with the physiological and adaptive way animals lose weight. In the case of hibernation anorexia, not only is there a loss of the weight put on in the course of normal prehibernation fattening, but there is also a marked attenuation of any additional weight that had been gained as a result of hypothalamic lesions (*61*). If the way these animal anorexias are controlled could be discovered, if something analogous to the secretion from the optic gland of the octopus (*18*) could be found in vertebrates, it might become possible to mimic the effortless way that animals lose weight, even with food close by, and by mechanisms that are part of their natural physiological repertoire.

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27. It is interesting that animals that have stabilized at low weights after receiving lesions in the lateral hypothalamus do not use food more efficiently than controls although they are capable of increasing efficiency if they are put on restricted rations [R. E. Keesey, P. C. Boyle, L. H. Storlien, *Physiol. Behav.* **21**, 265 (1978)]. Evidently adjustments in the efficiency with which food is used take place with reference to the regulated body weight, not some absolute weight. Rats with lateral hypothalamic lesions that are tube-fed shortly after the lesions are placed have elevated energy expenditures [S. D. Morrison, *J. Physiol. (London)* **197**, 325 (1968)].
28. Changes in set-points when maintenance of a given regulated level is incompatible with some more important activity may well be characteristic of regulated systems in general, not just those for body fat. For instance, camels and prairie dogs, animals inhabiting arid regions, become hyperthermic in the daytime [K. Schmidt-Nielson, *Sci. Am.* **201**, 140 (December 1959); L. N. Reinking, D. L. Kilgore, E. S. Fairbanks, J. D. Hamilton, *Comp. Biochem. Physiol. A* **57**, 161 (1977)]. This avoids having to use up valuable water in sweating, panting, or other forms of heat loss. For species where water conservation is at a great premium, it might be appropriate to raise set-points for temperature and avoid bringing thermoregulatory mechanisms into action. To what extent periodic high temperatures are defended against thermal challenges has not been thoroughly investigated, although it is known that in prairie dogs they occur even when the animals are kept all day in a constant temperature (see Reinking *et al.*, cited above). The temperature drops in hibernators are certainly precisely regulated and are not just passive declines occurring in cold surroundings [H. C. Heller, J. M. Walker, G. L. Florant, S. F. Glotzbach, R. J. Berger, in *Strategies in Cold: Natural Torpidity and Hibernation*, L. C. H. Wang and J. W. Hudson, Eds. (Academic Press, New York, 1978) pp. 225–265]. Obviously, maintenance of a normothermia of close to 37°C is incompatible with energy conservation and torpor. But to turn off the regulatory machinery altogether would entail the danger of freezing if the ambient temperature fell too low.
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48. For it to be plausible that the anorexias in these various examples stem from a lowering of set-points for weight or fat, it would be necessary to know if weight is normally defended. In the case of the octopus this can be questioned because food intake is so much dependent on how much food the animals are offered, and in experiments on *Octopus briareus*, with density of any food offered held constant, there were only small and generally insignificant compensatory increases in intake following up to 9 days deprivation [K. T. Borer, *J. Comp. Physiol. Psychol.* **75**, 171 (1971)]. However, this experiment was not conclusive because weight loss over this period was small, not exceeding 7 percent and, moreover, most of the animals in this experiment had already laid their eggs and therefore might have lost weight anyway. Moreover, J. J. Walker, N. Longo, and M. E. Bitterman [*Behav. Res. Methods Instrum.* **2**, 15 (1970)] have found that the number of crabs required to satiate *Octopus maya* is a function of the number of days of deprivation prior to this test, suggesting that (in the non-egg-laying octopus) it is indeed possible to motivate the animals by food deprivation. Similar experiments have been done with the African mouthbreeder *Talapia macrocephala:* the number of pellets required to satiate these fish increases as a function of deprivation, both when a simple instrumental response or a direct consummatory response is involved [M. E. Bitterman, *Am. J. Psychol.* **71**, 94 (1958)].
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