Feeding Birds for Optimal Health

Janine Perlman, Ph.D.
Wildlife Nutrition Consultants
14817 Willy Lane
Alexander, AR 72002
501-847-5581
jpandjf@swbell.net

Avian veterinarians and caregivers continually confront questions about how to feed their charges in ways that best support the birds' physiologic and psychologic health. Although companion parrots comprise the majority of patients in most practices, veterinarians may, over time, see many avian orders. This paper will attempt to place issues of diets for psittacines in a larger context, one that includes principles basic to feeding all birds (and other animals), and that permits species-specific factors to be understood and addressed as well.

There is general agreement that much remains to be known about the natural diets and nutritional requirements of exotic animals. Out of understandable fears of malnutrition resulting from incomplete seed-based diets, practitioners often resort to "psittacine formulations" - i.e., pellets or crumbles. These formulations attempt to include optimal levels of the known indispensable, or essential, nutrients (those that are necessary to life and can't be synthesized by the animal), and some of which are often missing from limited seed-based diets (Ullrey, et al., 1991).

In addition to nutrients that are essential for all vertebrates, some are taxon-specific. There are also "conditionally essential" nutrients required by animals of particular ages or physiologic states. Taxon-specific and conditionally-essential nutrients, and optimal levels of most other nutrients are not well characterized for many species, including psittacines. But identified indispensable nutrients, though not sufficient, obviously comprise a *sine qua non* of successfully feeding birds. Koutsos, et al. (2001) review many of them in relation to companion parrots.

Formulations are touted as "complete and balanced" (a description which, as we'll see, is questionable at best). These products do not remotely resemble the wide variety of diets natural to the various parrot species, and birds generally find them unpalatable. There are many problems inherent in the manufacture and storage of formulations (Harrison and McDonald, 2005) and, assuming that birds can be persuaded or forced to eat them, even the most reputable formulations do not prove reliably salutary.

On the other hand, many breeders with decades of experience feed and swear by naturalistic diets offering a wide range of foods that may include fruits, vegetables, nuts, seeds, grains, animal-sourced foods, and more from which their birds can choose. Their

practices may be quite sound or, if their offerings or the birds' intake are nutritionally incomplete, they may have been courting (or periodically encountering) disaster. In any case, even successful bird breeders rarely have the scientific understanding needed for productive troubleshooting or making fully informed dietary decisions.
Pet owners who attempt to feed naturalistically often lack knowledge and experience, and are perhaps more prone than bird breeders to offer incomplete and unbalanced diets that result in malnutrition (Harrison and McDonald, 2005).

Disagreements about what kinds of diets to offer psittacines echo a long-standing debate about how to feed captive animals generally. Of course, many people offer their parrots (and other pets) some combination of formulated and naturalistic diets. But without an understanding of what all animals and birds specifically require, there is no guarantee that they will receive and consume what they need.

As typically presented, neither approach addresses all relevant aspects of optimal feeding and health. Dietary recommendations cannot be assessed without an understanding of relevant biologic principles. Those who feed birds and those who advise about feeding are probably more in need of information about how to *think* about feeding and nutrition than of a prescriptive list of nutrients or foods.

Three nutrients are generally felt to be most problematic and difficult to optimize in feeding companion birds: Vitamins A and D, and calcium. Levels of vitamins A and D can cause life-threatening syndromes in both excesses and deficiencies.

The feeding approach I propose here solves the A, D and calcium problems easily, with no guesswork required. Over many years, birds, and taxa this dietary regimen has proved to provide abundant but safe levels of vitamins A and D while the bird chooses how much calcium it consumes, just as it evolved to choose in nature. The approach also offers much more, including nutritional and psychologic enrichment that greatly enhances the well-being of the bird and the satisfaction of the caregiver.

This way of feeding incorporates essential features of both naturalistic and formulated-diet perspectives. It also integrates crucial recent and not-so-recent information from a number of disciplines including, but not limited to, nutritional ecology, biochemistry, physiology and epidemiology.

In part, this paper presents the scientific and experiential path that led me to this approach. The scientific literature in relevant fields is vast. I include only a few references from several of them. They serve to illustrate that findings in apparently far-flung fields can bear directly on improving the feeding and nutrition of captive birds. The nutritional needs of some species have been considerably better studied than those of psittacines. I present principles and specifics regarding a few of them that may be usefully applied to companion birds.

I will also describe practices that have resulted in both failure and success among thousands of patients - my own and those on which I have advised clients. It is my hope that the parallel discussion of scientific principles underlying those outcomes will help provide a basis for readers to critically consider the ideas offered herein.

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My current understanding of nutrition developed in an unlikely setting, the practice of wildlife rehabilitation. As it turned out, the hand-rearing of orphaned wild passerine nestlings permitted insights that could be obtained in few other venues.

Blind Nestlings Opened My Eyes

Not all readers may be familiar with what is required to hand-rear songbird nestlings that are highly altricial and very demanding. As is true for all nestlings, hand-rearing passerines must closely hew to what occurs in nature. In the first three days after hatching, the blind, naked bird must be fed every 5-10 minutes, from dawn to dark. That schedule is quite inflexible; even a few longer intervals result in increased mortality.
As the bird matures, the time between feedings gradually increases, so that by fledging at about 3 weeks of age, a typical songbird is eating every 30 minutes. Fledglings are entirely reliant on hand-feeding for another week or so. After that, self-feeding and independence are acquired gradually in the next 3-6 weeks, during which hand-feeding is still required, if at increasingly greater intervals.

Almost all species of songbird parents feed their nestlings exclusively arthropods, mainly larval and adult insects, but also spiders and, depending on the bird species, other invertebrates. Calcium is generally supplied in the form of snail shell, eggshell, or calciferous grit.

Between hatch and fledge, songbird rates of growth and development are unsurpassed in the animal kingdom. It appears that, in contrast to slower-growing birds, passerines' growth rates are limited by the ability of the gastrointestinal tract to digest and absorb food (Caviedes-Vidal and Karasov, 2001; Konarzewski and Starck, 2000).
Because the great majority of non-water weight gain is comprised of protein, and because normal growth rates require the maximum amount of food that can be digested and absorbed, it follows that nestlings' diets must be very high in high-quality (fauna-derived) protein whose indispensable amino acids profile closely matches the proteins that the bird is accreting.
This inference is supported by the fact that parents expend the effort necessary to find and capture invertebrates (as opposed to easily procured, lower-quality plant-based foods) and by studies showing that nestlings whose parent-fed insect diets are nutritionally diluted are developmentally delayed and stunted (e.g., Johnston, 1993).
Rehabilitators have also consistently observed that nestling survival correlates closely with the dietary fraction of animal-sourced protein (Duerr, 2007).

If observation and experience had stopped there, nestlings would not have offered many surprises. Indeed, a continuing source of surprise and dismay is that with few exceptions, and despite the fact that psittacine nestlings are not faunivorous, manufacturers of psittacine hand-rearing formulations still promote their plant-based products as suitable for songbird nestlings. Products based on soy protein also fail as diets for both young and adult insectivores (Elliston and Perlman, 2002; pers. comm. with numerous rehabilitators). The lack of basic understanding of nutritional requirements and trophic categories (below) among these commercial concerns is both astonishing and disheartening.

When I began rehabilitating songbird nestlings in the early 1990's, I followed the local protocol of feeding a "premium" prescription canned feline food. The reasoning was that if a food could support a carnivore, it could support an insectivore. And birds did generally survive on that diet, as they rarely did on plant-based hand-rearing foods. The advent of the Internet allowed avian rehabilitators, like other groups, to begin to communicate with each other as never before. Based on rehabilitators' experience, there was unanimity on passerine nestlings' requirement for high levels of animal-sourced protein. Basic principles and recommendations for feeding nestling songbirds were described (MacLeod and Perlman, 2000).

Each summer, rehabilitators are presented with overwhelming numbers of orphaned nestlings which require the extremely demanding care described above. For ease and affordability, many rehabilitators have chosen to syringe-feed formulations that are generally based on feline kibble. Most such kibbles are about 35% protein (all figures on a dry matter basis). Arthropods generally consist of 50-60% protein, so more recent hand-rearing formulations use higher-protein kibble and/or additional ingredients such as egg white that raise the overall level to about 50%. All-meat canned pet foods are about 40% protein.

Unfortunately, these foods, and others such as egg-based formulations (unpublished data), though possessing excellent amino acids profiles, are often not well-digested by nestlings, especially in the critical few days after they are introduced. This is evident in the feces that look and smell similar to the food. In severe but not uncommon cases, weight gain ceases and birds succumb. The younger the bird, the more negative is the response.

Even in the absence of evident maldigestion, observant rehabilitators have long noted that, although higher dietary protein levels improve outcomes, formulations based largely on feline (or ferret) foods - canned or kibble - almost universally produce hand-reared birds that are small, with noticeably dull and keratin-deficient plumage compared to same-age parent-reared conspecifics. With these diets, birds are difficult to sate for normal intervals between feedings, and are often described as always hungry.

Many studies show that early malnutrition, both generally and in songbirds, is detrimental to fitness in nature (e.g., Nowicki, et al., 2002; Monaghan, 2007). The great majority of malnourished passerines would not even have the opportunity to experience negative effects in later life. Juvenile passerines that have suffered stunting have a much-reduced chance of surviving to breed (Tinbergen and Boerlijst, 1990). Any diet that results in visible developmental deficits almost certainly wastes the time, effort and financial resources of rehabilitators, and the lives of the birds.

The solution to the problem of captive diets for nestling songbirds turned out to be elegantly simple. In our ongoing multi-year feeding trials, the best formulated diets are being compared side-by-side with diets comprised of insects. In contrast to formula-fed birds, those who are fed insects (mainly mealworms, crickets and waxworms) exhibit growth, development and plumage that compare favorably with wild-reared conspecifics. Interestingly, even very young nestlings noticeably **prefer** insects over formulations. Nutritional wisdom appears to be present from birds' earliest days.

Nutritional secondary hyperparathyroidism has long been observed in hand-reared birds fed inadequate diets. This problem is never observed in songbirds reared on insects supplemented with approximately 2% elemental calcium, which is easily quantitated using a paste of powdered calcium carbonate in vegetable oil. This paste is available as human calcium supplements in convenient 1.2-gram capsules. These can be open, and the contents squeezed out. The appropriate fraction---calculated on the basis of the bird's daily caloric requirement converted to dry matter of food---can be dabbed onto an insect and fed, thus reliably meeting the bird's daily calcium requirement.

To more fully understand, *inter alia*, the superiority of insects over apparently iso-nutritional formulations, a brief review of some principles of comparative nutrition will be helpful.

Basic Principles of Optimal Nutrition

Trophic Categories: What Animals Evolved to Eat

The first principle of optimal feeding is ascertaining the type(s) of foods that comprise the animal's dietary mainstay(s) in nature; i.e., what it evolved to eat and need - its trophic category. Does it eat solely or mostly plants (making it a florivore); animal prey (faunivore); or significant amounts of both (omnivore)? Does it eat a few kinds of foods (oligovore); or specialize in fruit (frugivore), insects (insectivore), seeds (granivore), leaves (folivore), or vertebrate prey (carnivore)? The types of foods that can be utilized are constrained by the animal's ability to recognize and ingest them, and then digest and use them to meet its physiologic requirements. Klasing (1999) presents an admirable description of avian trophic groups.

Seeds are of course fed in large amounts by many pet bird owners, sometimes exclusively or nearly so. Formulated foods are also comprised of seeds. These foods are easily purchased and very convenient for the owner. As we will see, diets comprised solely of seeds - whether whole or processed into pellets - are inadequate for optimal health.

Some parrot species are true granivores. The term “granivore” has come to mean “eater of any of many kinds of seeds”, but there should arguably be divisions within the category. For example, grain seeds are typically high in starch and their (often modest level of) oil is high in unsaturated fatty acids. Other kinds of seeds may be higher in protein and/or oil; and tropical seed oils are high in saturated fatty acids.
Animals that consume different types of seeds also have distinct nutritional requirements. Thus, grains and legumes may not be the ideal dietary base for parrots that, in the wild, largely eat oily palm seeds.

The gastrointestinal tract (GIT) reflects and dictates what its owner consumes in nature. Avian nectarivores (e.g., hummingbirds) and mammalian carnivores tend to possess relatively short, simple GITs because nectar and meat are easily digested; once the foods are swallowed, endogenous enzymatic digestion and absorption occur with little or no pre-processing. Even among carnivorous birds, GIT physiology is exquisitely evolved for the diet. For example, after a meal, gastric pH is much lower (more acidic) in vultures (*Gyps africanus*; Houston and Cooper, 1975) than owls (*Tyto alba*; Smith and Richmond, 1972), presumably as a defense against pathogens in carrion.

In contrast to anatomically simple GITs, columbids need their muscular gizzard to grind the seeds they swallow whole before they are digested.   Darwin's rheas (*Pterocnemia pennata*) and ruffed grouse (*Bonasa umbellus*) possess large ceca in which are fermented otherwise indigestible carbohydrates in their browse diets.

A large and important set of trophic groups consists of animals that eat almost exclusively leaves, grasses, or fibrous plant parts. These animals rely on microorganisms residing in the fore- or hindgut to degrade the cellulose from those foods and to supply energy via fermentation products (volatile fatty acids). Examples of such animals include ruminants, rabbits, horses, beavers, and, yes, a bird; the Hoatzin, *Opisthocomus hoazin,* ferments its diet of leaves in a notably large crop and aborad esophagus. In such animals, vitamins and essential amino acids are also provided by gut microbes. The microbial community on which the animal utterly depends is in turn fully dependent for its composition and health on the animal’s natural, high-fiber diet. Gut microbiota are no less vital to other animals regardless of trophic category. We are just beginning to understand the requirements and complex, life-permitting functions of those microbial communities which are immense in numbers, complexity, and importance. As is the case for fermenters, the composition of gut flora in other trophic groups is significantly influenced by diet.

I am not aware of detailed comparisons of the gastrointestinal tracts of Psittaciformes, an order comprised of a wide array of trophic groups with their vastly different natural diets. However, it is safe to assume that parrots are as exquisitely evolved to their natural diets as are all other animals.

Trophic Categories in Practice

A solid understanding of an animal's trophic group is crucial, as may be illustrated by a few poignant examples. One of my clients was a young woman who had recently come into possession of two budgerigars (*Melopsittacus undulata*) that were not hand-tame. She had an idea that seed diets were unhealthful for them. For a few days she fed them nothing but raw grated greens and carrots. She was soon impressed by how tame they became. She contacted me after one had died and the other was moribund.

In another case, an emaciated Canada goose (*Branta canadensis*) was presented to a novice rehabilitator. Canada geese are herbivorous in the summer and, depending on food availability, facultatively granivorous/herbivorous in the winter. The rehabilitator took the bird to an avian veterinarian, who prescribed tube-feeding with a commonly used canned "prescription diet" for undernourished cats and dogs. I advised instead a food that matched the bird's actual needs based on what it had been eating in the wild and to which it was, at that time, physiologically adapted. Rates of recovery from emaciation markedly improve using a protocol that incorporates the imperatives of GIT physiology and trophic category (Perlman and MacLeod, 2003). The veterinarian's advice was followed. Predictably, the goose was unable to digest the food and it succumbed.

Correcting feeding practices can allow a dramatic return to health in non-emergency situations as well. Once animals are offered only a full range of foods appropriate to their trophic category and natural diet, chronic, life-threatening disease typical in zoos can resolve. The case of a siamang (*Hylobates syndactylus*) is described in MacLeod, et al. (2003).

These examples serve as reminders of the crucial importance of trophic category in feeding animals. Knowledge of the animal's trophic category is crucial, but it is neither prescriptive nor sufficiently informative to dictate in detail a captive animal's optimal diet.

Trophic Categories Do Not Dictate Specific Foods

One reason the trophic category is not prescriptive is that an animal's dietary requirements depend in part on its age and stage. To take obvious examples, neonates generally require foods quite different from adults: Tigers (*Panthera tigris)* are carnivores, but tiger cubs are of course lactovores. Ruby-throated hummingbirds (*Archilochus colubris*) are nectarivores, but hummingbird nestlings are insectivores. As we will see, this example extends to all species of nestlings whose parents feed them arthropods.

Trophic categories can change with the season, too. Northern chickadees (*Poecile atricapilla*) are granivorous in winter and insectivorous in summer. This species, Canada geese and many others are facultative -vores. As their diets seasonally change depending on food-type availability, their digestive tracts change accordingly. Gizzards become larger and more muscular and contain more grit to macerate seeds. Ceca enlarge when more fibrous diets require more fermentation. The physiology, biochemistry and mechanical capabilities of the gastrointestinal tract change significantly over time and determine what foods the animal needs and can utilize.

Other physiologic variables can necessitate dramatic changes in intake as well. Any experienced avian caregiver knows that laying hens eat voraciously and require increases in protein, calcium and other nutrients as well as energy. Molting birds also require more protein (e.g., Heitmeyer, 1988). Ill and injured non-faunivores often crave and require more protein than their usual diet may provide. In one such case, a gun-shot gadwall (*Anas strepera*) was presented to me for rehabilitation. In the wild, adult gadwalls are almost purely florivorous, but for the five months he was in my care, the duck would eat nothing but live prey or premium feline kibble.

Trophic categories are often only rough descriptors for animals that don't actually fit nicely within their borders. Even classic examples of a given trophic category occasionally eat, and assuredly require - if only in very limited amounts - foods that dramatically violate the rules. For example, white-tailed deer (*Odocoileus virginianus*; browsers) and horses (*Equus caballus*; grazers) occasionally seek and eat small vertebrates such as nestlings or frogs, almost certainly for essential minerals that are scarce in the usual foods of herbivores.

Knowledge of trophic category is insufficient because the foods that an animal needs are typically quite specific. Southern flying squirrels (*Glaucomys volans)* and American crows (*Corvus brachyrhynchos*) are both omnivorous, but *G. volans* rely on considerable amounts of fungi, lichen and cambium---items at which any self-respecting crow would turn up its *brachyrhynchos*.

Animals Require Foods, Not Just Nutrients

How do these principles pertain to the hundreds of thousands of nestlings that other rehabilitators and I hand-reared to become stunted, dull-plumaged, doomed fledglings? Once birds were provided insect-based hand-rearing diets, both process and outcomes were dramatically different. On an insect diet, hand-fed nestlings were much more easily sated, and their droppings were normal throughout their time in care. As fledglings, they were noticeably larger, their developmental pace and plumage were normal, and they compared favorably in every observable parameter to parent-reared same-age conspecifics. Quantitative side-by-side comparisons (Birch, et al., in preparation) of the best syringe-delivered formulations with insect diets confirm this consensus impression.

It appears that there are as-yet-unidentified nutrients or properties of insects that cannot be replaced by formulations, even one formulated to be a stand-alone insect substitute (Winn and Finke, 2008).

Among other crucial factors, the physicochemical properties of insects - the specifics of arthropod anatomy - may be crucial to normal digestion by neonate passerines. For example, chitinous exoskeletons may provide benefits analogous to those of soluble fiber in human enteral diets (Rushdi, et al., 2004). Muscle may be muscle, more or less, but could there be under-appreciated features of hemolymph that are not found in cat kibble?

Physicochemical properties that are "all of a family" can work in favor of captive feeding programs, too. As noted above, egg-based formulations do not work well for passerine nestlings. They are, however, good substitutes for crop milk of columbids (MacLeod and Perlman, 2002) and flamingos (*Phoenicopterus spp*.; Dierenfeld et al., 2009). It is possible that since both crop milk and egg are avian secretions, they share crucial properties which neonate columbids and flamingo chicks have evolved to need and utilize.

Our findings in nestlings translate directly to feeding other birds and to feeding animals generally. There is much evidence that all animals need the kinds of whole foods they evolved to eat - not just the relatively few nutrients that have thus far been identified in those foods.

What is an essential nutrient? As mentioned previously, beyond the two or three dozen nutrients that all vertebrates require, there are "conditionally essential" nutrients that cannot be endogenously synthesized in sufficient levels at all ages and stages of an animal's life. Most would agree that beyond those is a *vast and largely unknown array of nutrients that are essential to fully realized development, health and longevity* (Jacobs and Tapsell, 2007).

One example is taurine. This amino acid is needed not only by felines, but also by nestling songbirds for normal behavioral development (Arnold et al., 2007). Taurine is supplied by spiders that parent birds preferentially feed to their chicks (Ramsay and Houston, 2003).

Most animal nutritionists have been trained in Animal Science Departments, where the emphasis is on feeding livestock as efficiently and inexpensively as possible. In such programs there is typically little or no focus on nutritional ecology, optimal health, or longevity. But until recently human nutrition scientists, too, have held dear the maxim "Nutrients; not food." I submit that the reality is quite different. Animals need **food, not just** (known) **nutrients.**

Neonates of all vertebrate taxa provide clear examples of this principle. Their gastrointestinal tracts and entire physiologies require very specific **foods**, and their rates of growth and development make it starkly evident when those requirements are not met.
Mammals may provide a more familiar case than songbirds. The major nutrients of mammal milk have been very well characterized; precise amounts of water, protein, fat, carbohydrate, minerals and vitamins are known for milks of many species (Oftedal and Iverson, 1995). A formulation containing all those nutrients in the exact proportions can easily be made---from water, chicken, sucrose, and micronutrient supplements. Yet few if any mammal neonates would survive on such a diet. They require nutrients in the form of milk.

We know some of the reasons why; the three-dimensional form of milk proteins and micelles - again, the physicochemical matrix - is crucial. Compounds not previously recognized as essential, such as docosahexaenoic acid (DHA), are emerging as possibly necessary for normal neonate development (McCann and Ames, 2005). Other factors essential factors of milk remain mysterious at present.

Avian "milk" drinking neonates exhibit similar stage-specific food requirements. In the first week after hatch, rock pigeons (*Columba livia*) and other columbids require fat and protein found in crop milk. Hatchlings do not survive on plant-based hand-rearing foods (MacLeod and Perlman, 2002). In the second week, parents gradually add grain to the regurgitant. Even before they fledge, pigeons require grain, and they fail to thrive in that period if fed crop milk replacer.

The principle of "Food, not just nutrients" applies to birds - and other animals - generally. At some level, most of us are aware of that. Few raptor caretakers, for example, would consider arguing that formulated diets are superior to whole prey. Nor, I suspect, would many veterinarians consider feeding their families solely or mainly primate biscuits.

The necessity for feeding real foods is an ineluctable conclusion of the history of nutritional science and practice.

One Hundred Years of Feeding Captive and Domestic Animals

For thousands of years prior to the 20th century, domestic animals (livestock, dogs and cats) were fed by time-honored and -tested traditions. In many cases, they largely fended for themselves in environments that forced - and permitted - them to scrounge feedstuffs that corresponded relatively well to their evolved diets. Wild and exotic animals in captivity were relatively uncommon, and most of them did not survive for long. The best feeding strategy their captors could manage was to try to simulate the animal's natural diet. Unfortunately, ignorance of both evolved diet and nutritional needs led to the inability to provide either and resulted in far more failures than successes. This might be considered the first generation of comparative nutrition - the Very Bad Old Days.

Research into the identity and chemistry of essential nutrients began in the 18th century, but the first half of the 20th century was surely a golden age of discovery when the identities of many essential vitamins, minerals, amino acids and more were established in an astonishingly short time. In humans, rickets, scurvy and beri-beri were mysteries solved. Indeed, around mid-century, it was commonly believed that no significant unknowns remained in nutritional biochemistry.

As these discoveries unfolded, formulated foods became increasingly popular for dogs (and more recently, cats). Perhaps tellingly, these canned, dry and semi-moist foods were not sold on the basis of supposedly being more healthful than table scraps, but rather for their convenience and affordability.

For caregivers of wild and exotic species, however, formulated foods quickly became the apparent answer to what had ailed and greatly foreshortened the lives of their captives. Animals including companion parrots that, on limited "naturalistic" diets (such as all-seed), had previously lived truncated lives of illness did dramatically better on formulated foods that provided sufficient nutrients such as vitamin A and calcium.

Some fast-growing species, for example cranes, storks, ratites, bustards, and some waterfowl species, remain vulnerable to metabolic bone disease when captive-reared. Thorough investigation of their natural diets may prove helpful. For example, lesser adjutants (storks; *Leptoptilos javanicus)* are fed by their parents almost exclusively frogs, which are up to 5% Ca (Schairer, et al., 1998). Based on these data, Fidgett and Dierenfeld (2007) used corresponding amounts of calcium in hand-rearing diets, and eliminated previously common rickets.

So much better were the results when animals received essential nutrients that animal science departments everywhere began teaching the above-mentioned mantra of "Nutrients; not food." It was believed that food was simply a vehicle for calories and the few dozen identified essential chemicals required by all vertebrate life. At the same time, feed manufacturers became very active participants in this nutrition revolution. Baked or extruded formulations, ranging in unit size from crumble to pellets to biscuits became mainstays of feeding animals of almost every major taxon in settings ranging from homes to zoos to livestock operations.

As we examine the results of that development and look back with the benefit of hindsight, we might say that formulated foods ushered in the second generation, or Less-Bad Days, of animal nutrition.

Feeds Then to Now: Grain-based Formulations for All

Regardless of species designation, the compositions of formulated "balanced and complete" products are very similar. Corn, a subsidized commodity in the U.S., is usually the main ingredient. Products typically include various amounts of soy, wheat, soybean hulls, and animal-sourced meal that alter, to some extent, fiber and protein levels. Fat or oil and a micronutrient mix complete most of these feeds.

Zoo Animals
Skipping the step of putting different labels on essentially identical products, a prominent zoo feed manufacturer promotes a single product as a diet for a breathtaking array of animals that includes carnivores, omnivores, frugivore/florivores, and hind-gut fermenting herbivores. In addition to the unsuitability of the basic ingredients in such commercial formulations for most trophic groups, the wheat they contain is highly allergenic to a wide range of species.

Is it any wonder that (largely unbeknownst to the public) zoos and other animal collections are plagued by exceedingly high rates of nutrition-related morbidity and mortality?

Livestock
Of course, such feeds are not restricted to use in collections of exotic animals. The livestock industry determined that grain, primarily corn, could form the dietary base for chickens, pigs and cattle (to which antibiotics are routinely administered to reduce problems described above). None of the wild forebears of these animals evolved to eat significant amounts of grain. Some of the negative results are obvious. As veterinarians or merely informed citizens, readers are likely aware of the nearly-inevitable gastrointestinal infections resulting from grain-based feed in cattle (and rabbits, and other herbivorous fore- and hindgut fermenters). These infections cause severe suffering and, if untreated, are often fatal.

Faunivorous Pets
On the other end of the trophic spectrum lie faunivores, including pet ferrets, cats and dogs. (At this point, it should be noted that Association of American Feed Control Officials (AAFCO) standards for pet foods do not incorporate measures of optimal health or longevity.) Dry and many canned foods for carnivorous pets contain large amounts of starch. The starch typically derives from grain, usually including wheat, which, again, is an exceedingly poor choice for daily feeding of most taxa, but particularly those prone to gastroenteritis or other manifestations of food allergy.

Ferrets exhibit high rates of refractory gastrointestinal illness. Dietary grain is also plausibly linked to other common diseases in ferrets including insulinomas and lymphomas (which may result from gluten-induced enteropathy).

Veterinarians are also aware that **cats** suffer high rates of diabetes, gastrointestinal disease, renal failure, urinary tract disorders, cardiomyopathy and congestive heart failure, and hyperthyroidism. These maladies have plausible or proven links to nutrition. It would be very interesting to see if cats fed more naturalistic diets experienced fewer such problems.

Dogs are often mistakenly characterized as omnivores. Their recent ancestors are carnivorous wolves (they still interbreed with ease). A number of biochemical and GIT characteristics suggest that, like their forebears, dogs are carnivores. And obviously, like ferrets and cats, they did not evolve eating grains. Indeed, dogs provide some of the clearest evidence that grain-based formulations are not healthful for carnivores.

Typical canine foods are grain based and contain only about 20% protein, much of which is of plant origin. By contrast, whole vertebrate prey offers three times as much protein, of very high quality. While some consequences of grain-based canine foods, such as intolerance/allergy, are familiar to veterinarians, other evidence of malnutrition is less obvious. Overweight takes a large toll on dogs' (and cats') health and longevity (German, 2006). It is plausible that dietary protein insufficiency contributes to canine (and feline) overeating, since even in omnivorous species, hyperphagia can result from protein deficiency (White, et al., 1994).

Direct support for canine carnivory comes from studies in which middle-aged and older dogs were fed diets of 34-46% protein over multi-year periods. These dogs had half the death rate from all causes as control dogs fed conventional foods (Finco, et al., 1994; Kealy, 1988). Furthermore, there is no evidence for the common belief that high dietary protein causes renal failure in dogs (Finco, et al., 1994), Rigorous attempts to initiate (Robertson et al, 1986) or cause progression of (Bovee, 1992) renal pathology with high (up to 56%) dietary protein have failed.

Other nutrients found in meat and whole prey and lacking in typical canine formulations are associated with preventing and reversing age-related cognitive decline in dogs (Cotman, et al., 2002). Dietary mitochondrial cofactors plentiful in whole prey including coenzyme Q10, taurine (Fascetti, et al., 2003), carnitine and lipoic acid are also likely to reduce the incidence of dilated cardiomyopathy (Aliev, et al., 2009) and other age-related diseases (Sethumadhavan and Chinnakannu, 2006).

There is ample evidence to suggest that feeding dogs as the carnivores they are would significantly improve their average health and lifespan.

Clearly neither herbivores nor carnivores thrive on diets based on food types (grains) or components (starch) that are outside their evolved trophic category. This may be a surprise to few people other than those employed by feed companies.

But what about florivore/omnivores - specifically, animals whose evolved diets are more similar to those of parrots such as Amazons (*Amazona spp.*), macaws (various) and African greys (*Psittacus erithacus*) - who are also often fed high-grain formulations?

Much about these parrots' natural diets and nutritional requirements is unknown at present. Fortunately, however, a species that evolved in the tropics, to eat broadly similarly to them, has been much studied indeed. That species is, of course, *Homo sapiens*.

Humans: The Best-Studied Species

Humans evolved to eat fruits, nuts, other plant parts, and lean meat - minimally processed whole foods that could be foraged, gathered, or hunted. Archaeological studies show that, as is true for all other animals, humans who ate their evolved diet enjoyed optimal health. Injuries and infections put an early end to lives, but risk factors for and incidence of cardiovascular disease, cancer, and diabetes were exceedingly low compared to too-well-fed-humans of the present or of earlier agricultural civilizations (Allam, et al., 2009).
Indeed, physiologic and metabolic measures of human health have unequivocally deteriorated in the past 10,000 years as a result of the grain-based diets that are the products of agriculture (Eaton and Konner, 1985; Cordain, et al., 2005).

Controlled human studies and epidemiology have made our nutritional needs the best understood of any species. Although confounders and correlation (as opposed to cause-and-effect) plague the analysis of many studies, health effects of some nutritional regimens are clear:

- Consumption of fruits and vegetables reduces disease (Beliveau and Gingras, 2007) and promotes health in a dose-dependent fashion (Amiot, 2009). A vast array of phytochemicals available only from whole foods appears to be largely responsible (Liu, 2003). If ingested in purified form, even phytochemicals do not improve cardiovascular disease biomarkers (Curtis, et al., 2009). To exert their health-promoting effects, they apparently must be consumed in their whole, natural food matrix.
- A short-term switch from a typical American diet (high in grain, fat, sugars, meat and dairy) to a "Paleolithic" diet rich in a variety of whole plant foods, with lean animal-sourced protein, and free of grain, legumes, dairy and processed foods, results in significantly improved levels of markers for cardiovascular disease (Frassetto, et al., 2009).

As described in Cordain et al. (2005), when grains become a significant part of a non-granivore's diet, they dilute essential nutrients. However, addition of purified standard micronutrients to a grain-based diet does not confer health benefits (e.g., Gaziano, et al., 2009; Lin, et al., 2009, Martí-Carvajal, 2009). Thus, known micronutrients are necessary but insufficient components of the whole foods we need for optimal health. In fact, a recent review is titled **Food, Not Nutrients, Is the Fundamental Unit in Nutrition** (Jacobs and Tapsell, 2007).

There are numerous differences in compounds and characteristics between current U.S. fare and more natural diets. Many of those differences appear to hold considerable significance for human physiology. In addition to the paucity of flavonoids, carotenoids, and other phytochemicals in American diets, there are large differences in features ranging from fiber to fatty acids to effects on pH equilibrium (Cordain, et al., 2005).

Factors determining optimal diets continue to be identified. Indeed, despite the complacency of the mid-20th century, subsequent decades have seen an increasing rate in the discovery and identification of novel essential nutrients (e.g., Andlauer, et al., 1998).

The situation for humans is clear and, given basic principles of comparative nutrition, unsurprising. For maximal health and longevity, humans, like all other animals, need the foods they evolved to eat. This is emerging as the most fundamental principle of improving nutrition to reverse increases in potentially life-shortening diseases (Olshanksy, et al., 2005). A recent and highly influential editorial (Eaton, et al., 2010) states:

> …[T]he process [of basing nutritional recommendations on our evolved diet] might be accelerated, and its investigative expense reduced, if the health research community came to organize its terms, concepts, observations, and arguments in accord with paleoanthropologic insights. To achieve a paradigm shift of this magnitude will require the mental agility to integrate ideas and data from widely separate disciplines—heretofore an uncommon characteristic of our much-fragmented academic community.

From People to Parrots

The generalization of these principles to companion birds, many of whose evolved diet is very similar to our own, seems more than defensible. Pellets are ground-up seeds; a small number of grains, oily seeds, and legumes, with micronutrients added. Differences between these seed-based formulations and natural psittacine diets are manifold and large.

Pellets are Deficient

Formulations contain few or none of the thousands of phytochemicals that parrots evolved to eat and need. They provide little other than calories and the standard set of essential nutrients which were missing from the justifiably maligned "seed-based diet" of Ullrey, et al. (1991). Can cultivated fruits and vegetables provide panoplies of compounds identical to those in native diets---which themselves differ enormously among psittacine species? No. But it is very likely that, as is true for humans, phytochemicals in fruits and vegetables that *are* currently available are significantly health-promoting compared to a diet comprised of ground-up seeds.

Pellets are Homogeneous; Birds' Needs and Natural Diets Are Not

There is an additional, very important problem with formulated diets. No human would willingly eat primate biscuits as a sole or primary food, day after day, year after year. We crave various foods at different times and, if we avail ourselves of a healthful array of choices that comport with our evolved diet, we easily meet our nutritional needs. As mentioned previously, birds' needs change significantly over time. In nature and in captivity when offered a complete selection of natural foods, birds also choose what they need. Formulated foods cannot provide the range of nutrient levels that is needed over time. For one physiological state, the formulation may be deficient in a given nutrient; for another physiological state, a nutrient may be present at levels that are toxic.

This is not merely a theoretical possibility. Ironically, two of the most strictly granivorous psittacines, budgerigars and cockatiels, fare notoriously badly on pellets. Possible reasons are as numerous as there are substances that are, under various physiologic circumstances, needed by or toxic to these and other species; vitamin D and calcium are among the suspects (Echols, 2005). Whatever the reason(s), grain-based formulations do not meet the needs of these "easy" and granivorous (*stricto sensu;* see above discussion on oily/proteinaceous seeds vs. grains) birds. When other, non-granivorous, parrots are forced to eat mainly pellets, they may or may not display problems as quickly as do the smaller, shorter-lived granivores, but it's hard to imagine that such products better meet the needs of these birds, which, collectively, evolved to eat a vast array of whole plant parts and modest amounts of animal food.

In this connection, fast-growing passerine nestlings represent a serendipitous model system for the study of nutrition. The demands of those tiny bodies allow us dramatic and rapid insight into what happens when the diet does not meet requirements. For birds that are no longer growing, similar physiologic and biochemical constraints surely still apply, but in these birds, suboptimal diets reveal themselves in more subtle ways and over longer times. As noted above, formulated diets are often less than optimal for small granivorous psittacines (Echols, 2005). It is possible that larger parrots, with their longer life spans, also lose potential longevity to formulated diets. Opportunistic infections, neoplasms, metabolic disease, and/or organ failure may claim birds (and other animals) that have experienced long-term subtle malnutrition.

Alex, the famous African grey parrot, was reportedly fed a formulated diet and may have been a very public example of this phenomenon. According to The Alex Foundation website http://www.alexfoundation.org/alex_the_parrot.html, the veterinarian who performed a necropsy attributed his death to atherosclerotic processes. His veterinarian is reported to have stated that "she has seen similar events in young (<10 year old) birds who also were on healthful diets." One does, perforce, wonder how healthful those diets actually are.

This is, of course, only one anecdote. Cause and effect are not established for Alex, for the other presumably large parrots to which the veterinarian referred, or for other anecdotes and case reports. Clearly, studies are needed to compare formulations to whole-food diets. But because Alex was familiar to so many, perhaps his death can be a springboard for candid discussions, and even a catalyst for such studies. And as a hypothesis, since atherosclerosis in humans is strongly associated with diet (above), it is surely reasonable to wonder whether, as is the case for humans, a more naturalistic diet for parrots might greatly reduce the incidence of this common, life-shortening disease.

Nutritional Wisdom: Bird Brains vs. Limited Human Knowledge

There is no doubt that a seed-based diet with only limited fresh fruits or vegetables is nutritionally inferior to formulated foods (Ullrey, et al., 1991). Such a diet is almost certainly deficient in a number of standard essential micronutrients. However, from the principles and human studies described above, there is an obvious alternative that is likely (and in my experience has proved) to be superior to formulations. A diet that includes a wide variety of fruits and vegetables with non-grain seeds and nuts for birds that evolved to eat oily seeds or a grain mix for granivores, and animal-sourced foods, offers complete nutrition by all known criteria. It also provides the psychological enrichment and nutrient-level flexibility that are requirements for optimal health.

The "nutrients, not food" canard has a fraternal twin: "Animals don't possess nutritional wisdom." That assertion begs the question of how they've managed in the wild for millions of years without the benevolent dietary advice of humans. Laboratory studies on nutrient cravings and taste discrimination are conducted in exceedingly unnatural and often very stressful conditions, with choices that are also extremely limited and unnatural. The data that result, whether positive or negative, should be interpreted with considerable caution.

When birds are offered only a complete array of whole foods that are natural to their species, in an environment in which they feel relatively secure, they assuredly do possess nutritional wisdom. They use it liberally and very much to their benefit. However, if animals are presented with an incomplete array of choices or with unnatural foods that are extremely palatable, they clearly can't or won't choose wisely. Some parrots assuredly would eat high-calorie seeds and nuts in excess, an issue exacerbated by sedentariness, and such foods may have to be limited. Critical periods of learning and taste acquisition, and later neophobia, are also real phenomena. Birds that have been allowed to develop tastes exclusively for less-healthful foods and/or are neophobic toward novel healthful offerings can be gently, consistently encouraged and guided. Techniques include social eating times (with avian or human company) and judicious limiting of old favorites combined with artful encouragement to try more healthful options. Perseverance and patience may be needed. Much literature confirms that environmental enrichment - psychological and physical challenges such as hiding foods - can add considerably to the enjoyment of eating and to contentment levels generally. A happier bird, of course, results in a happier caregiver, a stronger bird-human bond, and better care for the bird - a positive feedback loop. Eating should never be a power struggle. Instead, it can and should be viewed as an opportunity for learning, entertainment, and interaction, for the person and their parrot.

Recommendations for Feeding

Before addressing specific diets, it will be useful to address a few fundamental details of nutrition and feeding that are generalizable to many taxa.

Every day is D-Day

The quality, intensity, and schedule of light to which birds are exposed are of immense importance. Light regimens of captive birds greatly influence many aspects of their physiology and behavior, and almost certainly have a large impact on their subjective contentment. Natural light, on a schedule similar to that found in a bird's native latitude, is obviously ideal. For many captive situations, though, this may not be possible.

A general discussion of light sources and regimens is beyond the scope of this article (and of the author's expertise). However, one specific aspect of light exposure is particularly relevant to the nutritional status of birds. For most species in the wild, UV-B irradiation from sunlight is the major or sole source of vitamin D. In captive situations, even when housing is lit naturally, many caregivers find it impossible to provide their birds access to sunlight (which must be unfiltered through glass or plastic) sufficient to prevent vitamin D deficiency. One option may be an artificial light source that emits UV light of the correct wavelengths and intensity. In this context, Stanford (summarized in Stanford, 2006) has studied the needs of parrots, mainly African greys. Unfortunately, UV-emitting bulbs available to many caregivers are notoriously unreliable. Their output is difficult to ensure. Even when bulbs are new, their emitted light may not correspond well to the manufacturer's characterization. UV emissions decrease rapidly with use, so bulbs must be replaced frequently. In addition to the possibility of insufficient UV, in many setups there may be danger of overexposure.

It is therefore usually necessary to provide vitamin D in the diet. Happily, it is also possible, safe, and easy. Recent findings in humans reveal that prior recommendations for vitamin D blood levels and daily intake have been far too low, as reviewed by Vieth, et al. (2007). Many diseases appear to be caused or exacerbated by inadequate vitamin D blood levels that are well above those causing obvious deficiency syndromes such as osteomalacia (Holick, 2007). Domestic and companion animals suffer many of the same, very wide-ranging, types of disease that are now being associated with vitamin D deficiencies in humans. Since prevention of syndromes has comprised criteria for recommended dietary vitamin D levels in both humans and non-human animals, it appears indicated to increase vitamin D levels in the diets of both. Optimal human blood levels require intakes of at least 4,000 IU vitamin D per kg food (dry matter) and possibly more (Vieth, 1999; Hollis, 2005). Until recently, this level was considered excessive for humans. Now it is believed to be at the lower end of the optimal range.

The challenge of fat-soluble vitamin supplementation is made much easier (even approaching fool-proof) with one crucial, and oddly overlooked, piece of information. Hypervitaminoses D and A need be of little concern because the two vitamins compete with each other. Metz, et al. (1985) showed in turkey poults that if the ratio of the two is kept at approximately 0.5 to 1 [IU vitA : IU vitD_3] – far below the ratio in standard recommendations - the absolute dietary amounts of these vitamins can be increased by orders of magnitude above recommended levels and far above levels at which either vitamin alone is toxic, with no resultant sign of pathology.

This is consistent with my own experience. In the past, I have observed and consulted on cases of vitamin A deficiency and vitamin D toxicity (both confirmed by expert pathologists), and apparent vitamin D deficiency. In the past several years I have continuously supplemented avian diets with the vitamins at a ratio of 2 to 1 [IU A to IU D_3] that synthesized the findings of Metz, et al. (1985), the long tradition of more dietary vitamin A than D, and the recent findings on vitamin D in humans. I have provided the two vitamins at various, but high, absolute levels. Over that period, numerous birds of several orders, including nestlings, laying hens, and adults at maintenance into senescence have exhibited vibrant health, with no signs or symptoms of hypo- or hypervitaminosis A or D. These vitamins are mixed with appropriate amounts of vitamin E in a solution of omega-3-rich oil (recipe below). This ratio of A to D is considerably smaller---and apparently more salutary and safer---than in foods formulated for an array of taxa. Without this altered ratio, typically low vitamin D levels in these products could easily result in excessive levels of vitamin A described by Koutsos, et al. (2003).

Several vexing problems have apparently been easily solved. By supplementing a whole-foods diet with a 2:1 ratio of vitamin A to D, and a vitamin D level of at least 4,000 IU/kg, both vitamins appear to be safely supplied at adequate levels.

(Note: Carotenoids are plentiful in a whole-foods florivorous diet and should easily meet vitamin A requirements. The vitamin A in the above mix acts as “insurance” and to buffer vitamin D so that, as described, the latter can safely be given over a wide range of absolute levels. Dietary water-soluble vitamins (B-complex and C) are more than adequate and need not be supplemented if a complete array of foods is offered and consumed.)

Florivores are surprisingly faunivorous

Breeders and owners often report that among other foods, Amazons and African grey parrots enjoy such foods as cooked chicken with bone, cooked egg, cheese, and yogurt. My own African grey would not eat mealworms with exoskeleton, but, at times, ate dozens of mealworm innards squeezed from beheaded exoskeletons. Animal-sourced foods are likely to be minor but crucial parts of the natural diet. To whatever extent that is true, they clearly serve a purpose and are relished in captivity. They may provide the types (or analogs) of biochemicals described above for dogs. Premium feline-growth kibble should be available ad libitum. It is a concentrated source of protein and micronutrients and parrots often choose it as a small but regular part of their diets. Probiotics in yogurt appears to be salubrious across taxa (e.g., Patterson and Burkholder, 2003).

It is sometimes assumed that, because birds develop atherosclerosis and because they are often fed oily seeds high in unsaturated fatty acids, saturated fats in animal-sourced foods are a concern. This is countered by the long-established fact that tropical seed oils are highly saturated compared to those of higher-latitude plants (Pearson and Raper, 1927). Parrots who eat tropical oily seeds are presumably adapted to eat and need saturated fats along with the other aspects of their native diets. If this is not sufficiently reassuring, animal-sourced foods provide only a small portion of total intake.

Captive diets contain insufficient omega-3 polyunsaturated fatty acids

Compared to diets comprised of wild foods, grains (and the animals fed grain that themselves become food) are high in omega-6 and low in omega-3 polyunsaturated fatty acids (PUFA) (Cordain, et al., 2005). While it may not be possible to bring the ratio of these two classes of PUFA to that of a wild diet, the base of the supplemental oil mix (below) containing vitamins A, D and E is comprised of concentrated omega-3 marine oils and supplies a source of these nutrients.

Foods must be offered separately

Individual foods supply different and unique sets of nutrients. Animals require various levels of specific nutrients at any given time and must be allowed to choose what they need. An obvious example is that of calcium and laying hens. Some other nutrients and physiologic states may be less obvious, but are no less crucial to the animal's optimal health and contentment. Regarding the latter, doubters need only allow a formulation-fed animal to begin choosing its fare. Food-associated levels of happiness and gratification increase dramatically. Home-made breads fall into the category of formulations and should be offered only in addition to the recommendations below.

Dishing dirt

Few species in the wild do not have access to dirt or do not take advantage of it. They eat dirt, they dig in dirt, they "bathe" in dirt. Rehabilitators routinely note that when hand-reared juveniles of many species (including avian) are first given access to dirt, they enthusiastically avail themselves of it in any or all of these ways. For many species it has nutritional and/or medicinal effects (Engel, 2002), including inoculation with beneficial microbes. Dirt should be a standard feature of captive housing.

Feeding Parrots

When asked to advise on the nutrition and feeding of a parrot (or any animal), I research its natural history and natural diet as thoroughly as possible. I "key out" its diet in a schematic tree, beginning with trophic category. Most parrots are mainly florivorous. Within that broad category, they may eat mainly one or two categories of food (e.g., fruit) or they may eat widely. If they consume foods from a small number of categories, they may eat narrowly (e.g., figs) or widely. Their diets may be fairly constant through the year or they may change seasonally. Most or all undoubtedly also consume some fauna.

With luck, there are detailed and reliable accounts of wild feeding habits, such as Galetti's (1993) for scaly-headed parrots (*Pionus maximiliana*). Multiple independent accounts are very helpful. Reports of scarlet macaw (*Ara macao*) diets by Vaughan et al. (2006) and by Renton (2006) differ in both the content and breadth of foods consumed. This may reflect seasonal, life-stage, locale, or even reliability differences among other possibilities. But they suggest that these birds might be relatively omni-florivorous, able to flexibly meet their nutritional needs and finding numerous foods palatable. Other species such as cape parrots (*Poicephalus robustus*) may have much more narrow diets (Wirminghaus, et al., 2002).

In feeding captive psittacines, some limitations must be acknowledged and reasonable inferences made:

- Knowledge of natural diets for all species is, to various extents, incomplete.
- Captive birds cannot be provided diets identical to those in the wild.
- As is the case for humans, cultivated foods can provide nutrients that extensively replace those found in a wild diet.
- Stipulating that standard nutrient requirements must be met, birds' optimal nutritional status and psychologic health require a wide variety of whole foods.

Specific Food and Feeding Recommendations

Foods should be rotated often. An item that was ignored for months may suddenly come into strong favor. In nature, most foods wax and wane in availability. Like other animals, birds have evolved to incorporate that reality into their physiology, requirements and cravings.

While rotation is very important, always allow a bird to have some amount (even if limited) of foods it likes, every day. The proportion of foods needed and consumed from the categories below will be species-specific. For example, parrots that eat mainly fruit and oily seeds should be expected to favor those over other groups, and every effort should be made to provide a wide variety of foods in those categories each day.

In my experience, it is rare that a bird absolutely refuses all but a favorite single food. If that occurs, several approaches are possible. The new foods can be presented more attractively than the favorite by, for example, being accessible only through enrichment activities as in treat toys. The favorite food can be gradually "contaminated" with other foods. A mix of the favorite and one or two new foods can be shredded and offered as small pieces. (In using tactics such as these latter, care must be taken not to allow the diet to devolve to yet another formulation.)

If other tactics do not work, the bird's favored food (likely high-calorie seeds or nuts) may be *regularly, intermittently, and very judiciously* withheld, so that the bird is sufficiently hungry to try other foods. As with other methods, when the alternative foods are offered, they should be made as attractive as possible by, for example, having them consumed with gusto by the caregiver or avian companions, as the bird watches. To repeat, food deprivation should be used judiciously, with great care and much thought. And, as necessary in either direction (again, in my experience, it rarely is), amounts of particular foods should be regulated to maintain ideal body condition.

Regardless of the bird's trophic group, daily fare should include at least two choices (preferably more) from **each** of the following categories:

- **Fruits:** Grapes, figs, apples, oranges, pears, melons, papayas, mangos, pineapple, berries, cherries, peaches, plums, bananas, tomatoes, etc. Depending on availability, the possibilities are almost endless. Most fruits may be either fresh or frozen/thawed.
- **Non-starchy vegetables, raw or cooked:** Peppers; leafy dark lettuce-type greens (including dandelion); pea pods; crucifers - if consumed in large amounts, should be cooked - (cabbage, broccoli, cauliflower, collard greens, mustard greens, turnips, etc.); carrots; squashes; beets; etc.
- **Legumes:** Beans, peas, peanuts - all items except green peas (*P. sativum*) should be **cooked/roasted** due to anti-nutrient compounds.
- **Starchy vegetables:** Sweet potato, occasional white potato - both **cooked** with skin.
- **Oily Seeds:** Pumpkin, sunflower, safflower, etc. and **tree nuts**
- **Whole Grains:** Cooked, raw, or dried, depending on the bird's preference; corn, brown rice, oats, quinoa, millet, buckwheat, etc.; wheat/pasta, barley and rye only occasionally, due to possible allergenicity. High-quality seed mixes for cereal-granivores.
- **Animal-based foods:** Cooked egg, yogurt, cheese, cultivated insects, cooked lean poultry including bone. Premium-quality feline kibble should be available at all times.
- (Nectarivores additionally require a separate, pure-nectar substitute - not a formulation.)

Additional Requirements

- **Oil-vitamin mix*:** Minimum dose: Give one drop (0.05 cc) per 50 Kcal food per day. See Harper (2000) for estimates of daily energy requirements. I have used multiples of this dose over multi-year periods with no signs of toxicities (or deficiencies). Most birds find the mix palatable. It can be added to any food that will assure its consumption. May be given weekly; to calculate dose, multiply daily energy needs by 7.
- **Free-choice calcium:** Cuttlebone, high-quality non-flavored mineral block, eggshell, *and* oystershell grit. These should be supplied in sizes and forms that the bird finds recognizable, manipulable and ingestible. Birds unambiguously have evolved and exhibit "calcium wisdom" and, given the opportunity, regulate intake according to need.
- **Pan of Dirt:** Despite their potentially beneficial microscopic residents, higher-latitude dirts may not contain biological communities that are native to, or safe for, tropical species. Caution should be exercised and caregivers may want to offer parrots sterile dirts. Sterilized topsoil can be purchased or it can be made by baking pesticide- and other-chemical-free dirt in an oven at 400^{o}F for 1 hour.

*__Oil-vitamin mix:__

5 cc omega-3 marine (fish) oil
5,000 IU vit D_3
10,000 IU vit A
400 IU vit E

Mix thoroughly, minimizing oxygenation; store refrigerated, in the absence of air, for up to 2 weeks. Each vitamin can be bought as oil-based solution in gelatin capules from manufacturers such as NOW™ http://www.nowfoods.com/.

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Those who promote formulated foods may express various objections to the knowledgeably-offered-whole-foods approach. The real question is surely which of the two approaches actually works better for birds. Whatever your current practices and perspectives may be, readers interested in collaborating on feeding studies are warmly invited to contact the author.

In my experience and that of my colleagues and clients, the happy result of giving birds informed, naturalistic diets is that they will live longer and in better health. But there are arguably greater rewards than even those. In nature, birds spend most of their waking hours foraging, often in the company of others, and in many cases roosting together nightly. Compared to the activity, dynamism, interactions and challenges they have evolved to experience in the wild, caged birds possessing, as they do, astounding intelligence and extremely strong and complex social needs have life sentences of tragic barrenness in small jails. To the greatest extent possible, we must enrich all aspects of their circumscribed lives. When it comes to all-important diet, the least we can do for them is to provide a variety of interesting, palatable and healthful foods.

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