

# Behavioral and Nutritional Aspects of the Virginian Opossum (*Didelphis virginiana*)

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## KEYWORDS

- Virginia opossum • Behavior • Nutrition • Disease • Captive
- Management

## OPOSSUMS IN THE CLINICAL SETTING

Injured Virginia opossums (*Didelphis virginiana*) traditionally have been treated by wild-life rehabilitators. Over the past 20 years, however, private practitioners have been examining opossums more often for various medical conditions. Opossums typically present because of receiving impact injuries from vehicles or trauma from domestic animal attacks, being orphaned joeys from an injured jill, receiving injuries from being trapped accidentally, or being a nuisance species. In other cases, opossums are presented as “pets” or part of zoologic collections or are from environmental education facilities and have clinical symptoms associated with poor husbandry and diet.

Despite certain anatomic, behavioral, and nutritional differences, opossums can be examined and approached diagnostically in a similar manner to companion animals. As with domestic and feral cats, opossums may display a wide variety of behaviors depending on whether they are captive-raised and habituated to people or wild, injured, and displaying defensive prey responses. Clinicians who handle opossums should be aware of these behaviors to minimize stress, promote healing, and keep staff members safe. This article addresses wild and captive opossum behaviors, husbandry, and nutritional requirements.

## ***Behavioral Considerations in the Management and Treatment of Captive and Owned Virginia Opossums***

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### ***Captive opossums***

**Treating captive opossums** Any wild opossum that is trapped, caught, or taken from the wild is considered a captive animal. Although any veterinarian is capable of treating

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captive opossums, these species cannot be treated successfully without familiarizing oneself with normal opossum behaviors. Regardless of how healthy wild opossums may initially appear, many have pre-existing problems that require a complete examination to diagnose. Like other wild animals, opossums mask their illnesses with defensive posturing and appear unhealthy only when their energy reserves fail and they can no longer compensate. Clinicians who are unfamiliar with normal opossum behavior are likely to mistake these defensive actions for good health and miss medical problems. Unless veterinarians can recognize normal behavior and correct underlying problems, many sick captive opossums continue to deteriorate.<sup>1</sup>

**Evaluating captive opossums** Evaluating a captive opossum's condition begins by obtaining an accurate history and determining the circumstances under which the opossum was found. Healthy opossums often arrive in feral cat traps (**Fig. 1**), and many are injured or deceased. Many good Samaritans arrive at the clinic with infants taken off an injured or deceased jill. These are critical cases, and treatment, ongoing care, and prognosis often depend on the accuracy and extent of the history obtained.

When presented with a captive opossum, the practitioner must determine the client's intentions for the animal, which will guide the practitioner's advice to the client. Many veterinarians work closely with wildlife rehabilitators to try to release these animals back into the wild. These animals should have minimal interaction with humans to avoid habituation. Opossums that have become habituated to people can be used in educational settings. Owners of these captive animals are often knowledgeable regarding opossum husbandry and natural history; captivity-induced medical problems are rare in this group. Finally, well-meaning citizens who find injured opossums often wish to obtain medical treatment to eventually release the animals back into the wild or keep the animals as captive pets. This group of opossums frequently develops problems associated with poor nutrition.

**Behavioral response of trapped captive opossums** Healthy captive opossums are often fearful, defensive, and difficult to handle. The degree of their behavioral response depends on the circumstance of their capture, severity of injury, and degree of illness.



**Fig. 1.** Opossum in a live trap.

When approached, a trapped opossum lowers its lip, pulls its lips back, and begins to drool. It hisses, spits, growls, opens its mouth as wide as possible, and bares its teeth, expanding its palatine pouches while attempting to frighten you away. If unsuccessful, the opossum increases the intensity of its hissing and growling and then strikes and snaps. When caught, opossums continue to growl with open mouths, defecate, urinate, and express their anal scent glands. Opossums do not use their claws as weapons, but they are sharp and can scratch when they struggle to get away.

Opossums can deliver a painful bite, so handlers should be cautious. Although more resistant to rabies than other mammals, they are not immune. In California, there have been five confirmed cases of rabies in opossums in the last 10 years.<sup>2</sup> Opossums likely contract rabies by eating dead bats. All opossum bites are reportable to state public health agencies, and protection of all individuals exposed to potentially rabid animals is paramount.

**Restraining captive opossums** Always use gloves or a towel when attempting to restrain a captive opossum. The restraint method used depends on the size, age, and condition of the opossum. Even when using gloves, the restrainer can use a towel not only to distract the opossum from biting the handler by covering its head but also to add an extra layer of protection against flea bites. Opossums carry the cat flea, *Ctenocephalides felis*, which is known to transmit murine typhus, *Rickettsia typhi*.<sup>3</sup> Whenever handling any wildlife, anyone coming in contact with the animal should wear protective latex/vinyl gloves and thoroughly wash his or her hands. Once restrained, an opossum may give up and relax, clasping its paws together as in a prayer-like pose. All age groups may demonstrate this pose, which does not mean the opossum has given up. It still bites if given the chance.

To examine an infant opossum, place a towel over its head and wrap it around its body. With the opossum wrapped in a towel, hold the animal vertically and extend the tail downward, allowing the body to hang. This gives the animal a sense of security and it struggles less.<sup>4</sup> Juvenile and adult opossums can be restrained on a flat surface by holding a towel over their heads with one hand while grasping the base of their tail with the other hand. This manner of restraint makes the animals feel more secure, so they are less apt to cling to surrounding surfaces or attempt to escape. They can be grabbed around their neck with gloved hands to control their head while avoiding their teeth. Holding them by the scruff of their neck (as one would a cat) is difficult, however, because the neck is short and there is limited skin in this region. Although the opossum is restrained by the tail, it may be turned over for a cursory examination of the head, mouth, and body. Move slowly, because opossums are sensitive to sudden movements, loud noises, and bright lights. Be quiet and handle them gently and securely. When an opossum is restrained excessively, it struggles to try to get away; sometimes, less restraint is better.

If a captive opossum is too uncooperative or fractious, it should be anesthetized with an inhalant anesthetic agent for a complete examination and any diagnostic or therapeutic procedures (**Fig. 2**).

**Examining captive opossums** On initial examination, determine the opossum's gender, check for presence of young in the pouch if it is a female, and record weight and temperature. Injured opossums found on roadsides often are hyperthermic and should be treated immediately. The average body temperature of Virginia opossums is approximately 35.2°C. Estimate the patient's age based on size and weight. The Virginia opossum moves to the pouch after only 13 days' gestation, at which point it weighs only several grams and is approximately the size of a bumblebee. The infant's eyes open between 9 and 11 weeks of age, while they are still suckling and weigh



Fig. 2. Anesthetized opossum.

approximately 55 to 75 g. Juvenile opossums live on their own when they weigh approximately 400 to 500 g and are approximately 15 weeks of age. They should be checked for external parasites, wounds, abscesses, cuts, and injuries. Juvenile and adult opossums are often covered with fleas, ticks, and dirt. Scars and abrasions on the head from past trauma are common, as are torn ears, broken and chipped teeth, and sores or scabs on the feet, tail, and nose.

**Appearance of a healthy opossum** A healthy opossum has clear, bright eyes, intact, shiny, white teeth, a slightly pink gum line, and clean ear canals. Its anus should be dry, clean, and closed, with no signs of diarrhea or anal prolapse. The hair coat should be smooth and cool to the touch. The lungs and heart should auscult clearly and steadily. The kidneys and liver are not palpable. The spine should be smooth and free of deviations, and the tail, joints, and hands should be flexible and grip well.<sup>1</sup>

Captive opossums in trauma situations should be initially stabilized, which includes supporting fractures, cleaning abscesses, preventing blood loss, and treating all wounds. These patients should be treated for shock, administered fluids, given antibiotics, and supported thermodynamically by adjusting the surrounding temperature. Once animals are stabilized, diagnostic tests, including blood and urine samples, radiographs, and fecal examination, may be conducted. All opossums also should be treated for internal and external parasites.<sup>5</sup>

**Housing captive opossums** Two or more juvenile or adult captive opossums should not be housed together in the same enclosure if they have not grown up together. Wild opossums are solitary animals by nature, and fighting ensues if they are housed in close quarters. Opossums raised together from infancy may get along. Observations of captive opossums kept in large outdoor enclosures show that some females may form stable, noncombative hierarchical social relationships. Extreme antagonistic behavior has been observed between males. When males and females are housed together, females are more dominant.<sup>6</sup>

Cannibalism has been reported in captive opossums. This behavior has been attributed to poor husbandry, overcrowding, stress, improper diet, mixing different sized animals, mixing litters, and placing sick or injured opossums in cages with healthy opossums. Placing different sized infants on a surrogate mother also may lead to injured ears, bite wounds, and missing toes. Hand-raised females that are accustomed to other opossums have been known to take on and nurse infants of different sizes from other litters.<sup>1,6,7</sup>

Healthy opossums from different litters that weigh less than 400 g each but are approximately the same weight can be housed together. Housing these opossums together reinforces normal wild behavior. Habituated opossums quickly lose their ability to discriminate between friend and foe and their natural survival instinct to find food in the wild. Captive opossums must be returned to the wild as soon as possible. Providing proper long-term care is not practical, unless they are being housed in established educational or zoologic facilities operated by trained staff. Preparing correct diets, monitoring appetite and health, and providing appropriate enclosures for different life stages is an involved and time-consuming process. Individuals considering long-term opossum management must be made aware of these requirements and the repercussions to the animal's health if these needs are not met.

**Behavioral response to confinement** Wild opossums do not exhibit typical wild behaviors in a hospital setting and do not adjust well to being confined. These patients can be sensitive to the sights, smells, and sounds of normal hospital activity and, as a result, can become stressed and have delayed recovery from injury. In the hospital, the opossum's cage must be secure to prevent escape. Opossums are nocturnal animals that become active in the early morning, exploring their cages and looking for ways to break out.<sup>8</sup> They can squeeze through bars, turn handles and latches, climb anything, and hide everywhere.

When housed in a cage, opossums must be provided with fresh food and water daily. Every morning, their bowls must be checked to see how much and what kind of food has been eaten. Being nocturnal, opossums sleep up to 16 hours a day and likely are not active during peak hospital working hours. Captive opossums spend most of their time hiding in a den box or sleeping under a towel or blanket. Captive opossums should be kept in a quiet, dark location away from dogs or cats. Caged opossums demand regular and consistent daily monitoring. Captive opossums may not eat when brought to the hospital, although most healthy captive animals begin eating in a few days. If an opossum does not begin to eat within 72 hours of hospitalization, look for an underlying problem; a healthy opossum lives to eat!

**Case management of captive opossums** Marsupial case management and treatment follow standard protocols for nonmarsupial companion mammals. Most practitioners who work with opossums associate management of this species with that of management of cats. Allometric scaling techniques show that opossums have lower basal metabolic rates when compared with placental mammals, however; they require lower medication dosing regimens.<sup>9,10</sup> Opossums may appear normal despite an underlying illness, or they may have clinical symptoms that take time to manifest. Clinical signs may wax and wane from day to day, so continued monitoring is imperative.

#### **BEHAVIORAL MANIFESTATIONS OF DISEASE**

Trauma is the most common problem in opossums that present to veterinary practices. Common signs include paralysis, paresis, fractures, labored breathing, shock, and bleeding. Pacing, hyperactivity, and pawing at the mouth are often associated with head injuries. Immediate care is required in most cases, and maintenance of body temperature and cardiovascular support is essential. Radiographs should be performed in every trauma case after stabilization, unless life-threatening injuries that require immediate diagnosis are suspected. If the opossum cannot eat after being stabilized, a pharyngostomy tube may be placed for nutritional support.<sup>11</sup>

Abandoned infants are commonly seen and require immediate attention and supportive care. These patients need to be kept warm and rehydrated and should

be fed frequently to provide the greatest chance for survival. A young opossum that weighs less than 100 g is truly an orphan, not a victim of kidnapping by well-meaning individuals, as is common in many other wildlife species. For these orphans, care must be provided.

If an opossum does not eat after 72 hours in the hospital, underlying medical conditions must be sought. Anorexia is always a sign for concern. Check for broken teeth, fractured jaws, and other signs of head trauma. Look for indications of abdominal or back pain, bruising, ruptured bladder, or anemia. Perform a fecal examination, and treat intestinal parasites. Obtain radiographs to diagnose intestinal blockage, intestinal stasis, or other signs of internal trauma. Complete blood cell counts, serum biochemistry analysis results, and urinalysis results should be collected as part of a minimal database to investigate ongoing problems. Provide nutritional and fluid support while diagnostic test results are pending and until causes for anorexia can be addressed. If the opossum is anemic, an injection of iron dextran and vitamin supplements, such as Hi Vites (EVSCO Pharmaceuticals, Buena, NJ) or Liqui-Tinic 4X (PRN Pharmacal, Pensacola, FL), can be administered. In general, blood transfusions in opossums are impractical.

Weakness, staggering, falling over, and circling are all signs of neurologic disease. Neurologic signs may be temporary or permanent and may be static or progressive. Concussion from head trauma, migrating parasites, muscle myopathy, spinal myelopathy, and chronic nutritional deficiency can result in generalized weakness and should be considered as differential diagnoses for neurologic disease. A standard neurologic examination to assess proprioception, motor function, and superficial and deep pain can be conducted on opossums as in companion animals. Assess for the ability to grasp, hang, and climb and check for circling, pacing, and stereotypic behavior. Atonic bladder, along with concurrent bladder infections, is commonly found with spinal damage.

Labored and open-mouthed breathing, flail chest, and cyanotic mucous membranes are signs of trauma or underlying respiratory disease. Many opossums develop verminous pneumonia and protozoal lung disease in the wild and may present to practitioners with end-stage infection. Inhaling noxious substances and particulate matter also can lead to lung disease. Fungal, bacterial, and mycoplasmal infections can cause serious lung damage.<sup>4,5</sup> If radiographic changes are present, tracheal and bronchial lavage should be performed to obtain cultures for a more accurate diagnosis. Puncture wounds, fractured ribs, and flail chest occur commonly from cat and dog bites. Radiographs should be taken, antibiotics should be administered, and oxygen supplementation and nebulization should be considered.

Parenteral fluids should be given in cases of shock, dehydration, and cardiovascular collapse. Cardiovascular signs include pale mucous membranes, low core body temperature, and cold extremities. Determine the state of dehydration by checking the degree of skin tenting over the shoulder region. Warm a hypothermic opossum by placing it on a warm water heating pad or forced air heating device. Administer fluids via the lateral or ventral tail vein. If catheterization is not possible, give fluids subcutaneously or use an intraosseous catheter. Tube feeding with warm blended food can be administered for support.

Skin disease is common but usually not life-threatening, unless it reflects internal circulatory problems. Opossums can develop chronic, nonhealing abscesses that can take longer than 3 months to heal. These wounds may get progressively worse no matter what the treatment regimen, and euthanasia may be the only option in the end. Dermal septic necrosis and “crusty ear syndrome” have been described.<sup>1</sup> These skin conditions can be caused by systemic yeast or bacterial infections or

the development of peripheral microabscesses that affect capillary filling. Anemia from severe ectoparasitic infection is common and must be treated with appropriate antiparasitic drugs and supportive care.

Opossums also may present with gastrointestinal problems resulting from trauma-induced nerve damage, foreign body ingestion with obstruction, dietary mismanagement, or endoparasites. A prolapsed rectum is also common in this species and is usually associated with chronic diarrhea, constipation, or trauma. Surgical repair can be performed, but prolapses often reoccur. In all cases of gastrointestinal problems, a complete nutritional history should be obtained and a standard evaluation that includes radiographs, fecal examination, and treatment for helminths should be performed.

### ***Pain Response and Treatment***

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Opossums are tough animals, and in the wild they can withstand considerable abuse and pain. Recovered opossum skeletons have showed healed bone fractures that equivalent-sized placental mammals could never have survived. Opossums are generally more stoic than other mammals when it comes to experiencing pain. Opossums exhibit different kinds of pain responses.<sup>12</sup>

#### ***Acute pain***

This is a reflexive, instinctive, and immediate response to an acute injury, and it is the response most easily observed. Opossums show a startle response that includes a quick squeal or cry and a quick snap while they move away from their source of discomfort.<sup>13</sup> Opossums in pain may become aggressive and attack when approached. When faced with anticipation of overwhelming pain, they appear fearful, crouch and become immobile, and freeze or “play dead.”

#### ***Chronic pain***

Chronic pain is more subtle and is most often manifested by anorexia, sitting or sleeping in a hunched position, pacing, and crawling in circles. This response is more difficult to evaluate.

#### ***Postoperative pain***

This response in opossums depends on the type of surgery and the resultant pain elicited. Pain is best evaluated postoperatively when the opossum is awake and aware of its surroundings. Opossums seem to respond favorably to most analgesics. An array of pain responses has been observed, from stoic calmness, to chewing or pawing at the surgical site, to aggressive behavior that makes postoperative care difficult. Nonsteroidal anti-inflammatory medications, such as meloxicam (Metacam, Boehringer Ingelheim, St. Joseph, MO), are commonly used for mild pain and inflammation, whereas narcotics such as butorphanol tartrate (Equanox, Vedco, St. Joseph, MO) and buprenorphine hydrochloride (Buprenex, Reckitt Benckiser Pharmaceuticals, Inc., Hull, England) can be used to control more severe pain.<sup>13</sup>

### ***Euthanasia***

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When an injured or ill captive opossum comes to the hospital, the goal is to reintroduce it back into the wild as soon as possible. The longer it remains in the hospital, the more it loses its instinct for survival upon release. Some captive opossums regain their health quickly, whereas others never seem to completely recover; injuries may be too great or the illness too severe. Evaluating quality of life may be a subjective decision, and being familiar with normal opossum behavior may help the clinician with this

difficult evaluation. The Wildlife Center of Virginia uses the following protocols to help assess whether the opossum should be returned to the wild:

1. The animal has recovered from its initial problem and it will not recur.
2. The animal is able to avoid predators.
3. The animal is able to find food in the wild.
4. The animal has been cured of any secondary problems.
5. The animal is expected to function reasonably within a population.
6. The animal displays normal behavior and is not habituated to humans.
7. The animal does not pose a risk to the wild population or to the environment and it is not likely to spread pathogens or contribute to disease processes.
8. The animal is not carrying a potentially zoonotic infection.

Animals that fail to meet any one of these criteria should not be released. If alternative placement options are not available or the opossum's disposition is not suited to captivity, the animal should be euthanized. The more one works with injured and sick opossums, the better one can recognize the right time for euthanasia. Humane euthanasia for opossums should be performed under general inhalant anesthesia, followed with an intracardiac or intravenous injection of euthanasia solution.

#### OPOSSUMS AS PETS

The longer a captive opossum spends in the hospital, the more it loses its instinct to survive in the wild. Opossums tend to bond and habituate to human contact, especially younger animals. Animals that cannot be rehabilitated and released back to the wild may be considered for euthanasia or permanent captive placement. Captive opossums ideally should not be kept as pets, but some caretakers feel responsible for long-term care and adopt captive or infant opossums. Often there are legal restrictions associated with the placement or owning of captive opossums, and clinicians should consult local wildlife laws in their area before practicing on these animals. Adopting opossums as pets is illegal in many states. Regardless of the legalities, many people feel they make good pets.

#### *Behavior in Pet Opossums*

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Pet opossums are responsive, often vocal, cuddly, docile, and responsive to human touch. Many pet opossums adjust their nocturnal schedule to fit their owners' schedule; they are more apt to eat and be active during the day. Pet opossums are more comfortable and less stressed in a hospital environment than captive wild opossums, which makes them easier to handle and treat.

Pet opossums must be kept indoors. Opossums can escape easily, and once outside, they are practically impossible to find. Opossums are not destructive, but they are curious and are excellent climbers. Lock all doors, secure all windows, and shut all toilet lids. Everything on shelves must be put away and all cabinets locked. Pet opossums need to be given as much exercise as possible to prevent obesity and the development of neuroses. An enriched environment reduces stress and boredom, encourages activity, and increases circulation, strength, and lifespan. Five- to six-month-old pet opossums should be given the full run of a room. Adopted opossums need lots of space to roam, climb, and explore for at least 2 hours a night. Confined opossums require cages that are at least 6 sq ft and large enough for wheels, ramps, branches, and nest boxes. Pet opossums may pace when confined.<sup>8</sup> A few pet opossums become used to wearing collars or harnesses and are happy walking outside on leashes (**Fig. 3**).



Fig. 3. Pet opossum with collar, leash, and harness.

### ***Lifespan***

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Captive opossums live approximately twice as long as wild opossums. Wild opossums have an average lifespan of approximately 1.5 years, whereas captive opossums have an average lifespan of 3 to 4 years. Occasionally, a pet opossum may live up to 8 to 10 years.<sup>2,14</sup>

### ***Socialization***

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The optimal age to obtain an opossum that is to be kept as a pet is 5 to 8 weeks of age; the optimal weight is 85 to 115 g. This age is the critical period for human socialization. Imprinting on caretakers occurs by encouraging as much contact as possible between animals and caretakers and by having caretakers hand feed early and often. The more time the caretakers spend with them, the better they respond. They must get used to being touched around the face and muzzle, which can be facilitated by frequent brushing and combing. These animals are sensitive and become fearful with teasing, cage rattling, sudden movement, and noises. Opossums can bond to members of the family and respond to clicking noises made by human lips.

It is more difficult to adopt an older opossum. Their natural instincts are too engrained, and they do not adjust to captivity. Older opossums hiss, growl, show its teeth, and bite if disciplined. Opossums startle easily, so caretakers must speak quietly and move slowly. Individual opossums develop their own unique, often temperamental personalities.

### ***Grooming***

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Opossums are clean and do not have a body odor. They groom themselves and do not require bathing. Their nails need trimming approximately every 4 weeks.<sup>4</sup> They wash themselves after eating and lick themselves to maintain their body temperature. Opossums do not tolerate dry, hot environments; they need adequate shade and fresh air circulation. Fresh water must be available at all times.

### ***Litter Training***

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Opossums can be litter trained similarly to cats and use litter boxes. A small tray should be placed in their nesting area, and additional trays should be available in rooms where they spend time. Placing a litter pan in these areas reinforces the continual use of these spots. Some opossums choose their own spots and sometimes prefer to use a water bowl as their toilet area.

***Spaying and neutering pet opossums***

Spaying female opossums prevents endometritis and a Cushing's-like syndrome associated with partially paralyzed, unspayed opossums (**Fig. 4**). This syndrome is often associated with urine retention, urinary tract infections, and obesity. Nonreleasable females should be spayed and not bred.<sup>1,3</sup> Neutering male opossums is neither desirable nor necessary. An unneutered male opossum does not become aggressive with age or develop body odor. Neutering a paralyzed opossum prevents trauma caused by increased genital contact with the ground, and neutering may reduce anxiety around intact females. Castrated opossums stop vocalizing and instead respond with lip smacking noises.

***Diseases of pet opossums***

Secondary nutritional hyperparathyroidism, obesity, and dental disease are the most common nutritional disorders in pet opossums. Obesity occurs in opossums because of lack of exercise and overfeeding.

**NUTRITIONAL CONSIDERATIONS IN THE MANAGEMENT AND TREATMENT OF CAPTIVE AND HOSPITALIZED VIRGINIA OPOSSUMS*****Oral and Gastrointestinal Morphology***

The gastrointestinal morphology of the Virginia opossum is consistent with that of many other mammalian omnivores. The dental formula is 5/4, 1/1, 3/3, 4/4, and the salivary glands include large mandibular and smaller parotid and sublingual glands. The distal esophagus has raised, transverse rugae and is comprised of smooth muscle fibers. The opossum's distal esophagus, pylorus, and ileocecal junction have been studied extensively, because the smooth muscle arrangements in these areas closely resembles that of humans.<sup>15</sup>

Virginia opossums have a simple, globular stomach; most of the gastric mucosa is comprised of fundic glands. Pyloric glands and a narrow ridge of cardiac glands exist near the esophageal-gastric border.<sup>16</sup> Like most placental mammals (also known as Eutherian mammals), opossums have enteroendocrine cells lining portions of their gastrointestinal tract. These cells, in addition to endocrine cells in the pancreas, aid in secreting peptides that control various digestive functions such as gastric acid secretion, pancreatic secretion of electrolytes and enzymes, and contraction of the gall bladder.<sup>17</sup> In the stomach, 90% of the enteroendocrine cells are located in the pyloric region and secrete a variety of hormones, such as gastrin, gastric-inhibitory peptide, secretin, cholecystokinin, and pancreaticozym.<sup>18</sup>



**Fig. 4.** Obese female opossum with Cushing's-like syndrome.

In opossums, the Brunner's glands secrete their products into mucosal depressions located on the duodenal wall. Virginia opossums possess a cecum that is simple, conical, and approximately 20% to 40% of the total body length. Distal to the cecum, the colon is mobile because of its simple, loose mesenteric attachment.<sup>19</sup> A more detailed summary of the Virginia opossum's gastrointestinal anatomy is available for interested readers.<sup>15</sup>

### General Diet Information

Many captive diets exist for the Virginia opossum, and the veterinarian or wildlife rehabilitator must take care in choosing which one to use. Many diets are designed for laboratory research opossums or are deficient in nutrients essential for growing or adult opossums to thrive. Captive diet information (see later discussion) has been developed and used successfully at the Wildlife Center of Virginia to rehabilitate and release wild opossums. A summary of the feeding schedule for Virginia opossums can be found in **Table 1**. Alternative reliable diet information can be found by contacting the National Opossum Society.<sup>20</sup>

| Approximate Weight (g) | Physical Characteristics  | Amount per Feeding (mL)                                      | No. Feedings per Day                       |
|------------------------|---|--|--|
| < 10                   | Body is pink and nested; oral membrane present over mouth               | .25-.50  | Round the clock; difficult to rehabilitate |
| 10-20                  | Eyes closed; skin turning gray; fur beginning to grow in                | .50  | 5+   |
| 21-30                  | Eyes closed; fur is smooth and sleek                                    | .50-1  | 4  |
| 31-54                  | Eyes closed or just opened; oral membrane is completely gone            | 1.25-2 (begin to offer mash)                                 | 3  |
| 55-74                  | Eyes open; fully furred; look like opossums; approximately 9-11 wk old  | 2.5-3.5 (add soft foods and dish of fresh water)             | 2  |
| 75-100                 | Beginning to run around; eating on its own                              | 4-5 (introduce small mouse pieces)                           | 1  |
| 101-200                | Climbing, active, and using tail  | Juvenile meal (see menu) and a mouse                         | None                                       |
| 200+                   | Aggressive defense behavior; becoming more nocturnal; eating whole mice | Gradually change to adult meal over a 2-wk transition period | None                                       |
| 500                    | Aggressive, nocturnal   | Release  |  |

Opossums are born after 12 to 13 days' gestation. The naked young climb to the pouch, where they attach for 60 days. Eyes begin to open around 63 days after birth, and weaning begins around 87 to 104 days after birth. Because the actual birth date is often unknown, feeding is often based the animal's weight.

### ***Neonatal Opossum Nutrition***

Lactation in the average female opossum lasts for 15 weeks.<sup>21</sup> The nutrient composition of the milk changes over the course of lactation. When rearing captive infant Virginian opossums, caretakers should try to replicate the type, amount, and relative percentage of nutrients found in the jill's milk. The milk is initially comprised of 9% total solids, peaking at 34% at week 11. There is then a decrease to 27% at week 13, which is maintained until the end of lactation.<sup>22</sup> Carbohydrate, protein, and fat content of the milk fluctuates at different times in the lactation cycle. Hexose seems to be the most abundant carbohydrate in opossum milk; it reaches a peak concentration of 7% at week 7.<sup>22</sup> Although opossums are frequently reported as being lactose intolerant, the jill's milk contains lactose. Lactose concentrations are higher during the initial weeks of lactation and taper off to almost undetectable amounts by week 15.<sup>23</sup>

The total protein concentration of opossum milk mirrors that of the total solids, peaking at 10% at week 11 of lactation. The milk fat concentration is stable at 8% up to week 9; it increases to 17% at week 11 and then declines to 11% by week 13 of lactation.<sup>22</sup> Magnesium, sodium, and potassium concentrations in milk remain constant throughout lactation (mean concentrations of  $9.2 \pm 1.2$  mmol,  $41 \pm 4$  mmol, and  $35 \pm 11$  mmol, respectively). Calcium concentration increases from 13 mmol during the beginning of lactation to 100 mmol by week 7 and remains at this level until week 10.<sup>22</sup> The estimated energy content of milk at the beginning of lactation is just over 500 kJ per 100 mL and then peaks at week 11 to 966 kJ per 100 mL. This increase in energy concentration coincides with significant growth periods in young joeys.<sup>22</sup>

Until their eyes are open, joeys can be tube fed formula that consists of two parts Esbilac powder (PetAg, Inc., Hampshire, IL), one part Zoologic Milk Matrix 30/55 powder (PetAg, Inc., Hampshire, IL), four parts warm water, and a half teaspoon of dicalcium phosphate (28:18.5) powder (UPCO, St. Joseph, MO). After joeys have opened their eyes, the formula should be changed to one part Esbilac powder, two parts warm water, and a half teaspoon of calcium/phosphorus powder. Tube feeding young opossums is the fastest and surest way to ensure that milk is delivered into the stomach. Animals that weigh less than 20 g can be fed through 2.8- to 3.5-Fr tubes, whereas opossums that weigh 20 to 100 g may be fed through 5.0-Fr tubes. A tube whose length equals the distance from the opossum's nose to just proximal to the sternum should be passed gently down the esophagus. Care must be taken not to administer too much formula because of the risk of aspiration. If aspiration occurs, the opossum should be treated with appropriate antibiotics (broad spectrum and good systemic penetration into respiratory tissues) for a minimum of 5 days. Other methods of feeding infant opossums, such as syringe or pipette feeding, may be used successfully but tend to be more time intensive, especially when large numbers of animals must be fed.

The volume of formula per feeding and the number of feedings per day depend on the animal's age and size. A retrospective analysis from archived Wildlife Center of Virginia records indicated that the success rate of rearing orphaned young opossums decreases significantly if joeys weigh less than 24 g on admission. These smaller animals require round-the-clock feeding and often have concurrent bacterial infections from suckling on contaminated milk from dead jills. Unless orphaned opossums are removed from their mothers immediately after they are killed, they should be treated with antibiotics upon entering the hospital to decrease the likelihood of developing bacterial infections.

### ***Juvenile Opossum Nutrition***

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Weaning commences in juvenile wild opossums at 12 weeks' postpartum, when joeys weigh approximately 165 g;<sup>24</sup> however, joeys that weigh as little as 100 g can be weaned successfully. A juvenile mash that consists of 2 tbsp of infant opossum tube feeding formula (recipe listed above), 1 tbsp of baby rice cereal, and 2 tbsp high-quality puppy kibble can be introduced when the opossum weighs 31 to 54 g and can be given concurrently with tube feeding. This soft appetizing diet encourages young opossums to sample solid food and can be given until they weigh 100 g. When joeys weigh 55 to 75 g, they can be fed small pieces of soft food and offered fresh water in a separate bowl. When the joeys weigh 75 to 100 g, they can be offered small pieces of cut-up mice.

When they weigh more than 100 g, joeys require only a juvenile opossum diet that can be prepared in bulk if several joeys are being fed. The daily juvenile diet consists of approximately 4 tbsp soaked puppy chow, 1 tbsp meat-based baby food, 2 tbsp canned puppy food, 1 tbsp cat chow, several small chunks of soft vegetables (ie, broccoli, carrots, cauliflower, sweet potato, squash), one to two pieces of fruit just large enough for the opossum to handle and manipulate, and one fifth of a dead mouse cut up with the bones included. Only high-quality meat, non-soy-based dog and cat food should be offered. This juvenile diet may be given until the opossums weigh approximately 200 g, at which point they should be switched to an adult diet.

### ***Adult Opossum Nutrition***

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The Virginia opossum is an omnivore.<sup>25</sup> Dietary studies of wild adult opossums indicate that opossums eat a variety of insects, small vertebrates, fruits, nuts, seeds, and vegetation that vary geographically and seasonally. In a study of opossums in New York, analysis of the stomach contents of 187 road-killed Virginia opossums showed that the average opossum diet consists of 18% fruit, 17.2% amphibians, 14.2% mammals, 13.4% insects, 6.6% grass, 5.4% worms, 5.3% reptiles, 5% birds, 4.8% carrion, and 6.7% other items.<sup>26</sup> Another study showed that stomach contents of road-killed opossums in Portland, Oregon consist of 27% mammals, 11% leaf litter, 10% fruits, seeds, and bulbs, 10% gastropods, 9% garbage, 9% earthworms, 9% pet food, 8% grass and green leaves, 3% insects, 3% birds, and 1% unidentified animal tissue.<sup>27</sup> Both studies examined stomach rather than fecal content because fecal analysis reveals food items that readily pass through the gastrointestinal system and may not account for more digestible food items. One study showed that of 39 food items typically found in opossums' diets in eastern Texas, 36 appeared in the stomach contents, whereas only 10 could be identified in fecal contents.<sup>28</sup>

Like infant and juvenile diets, many adult diet variations exist, and maintaining the proper Ca:P ratio and avoiding high fat meals should be a priority. A well-balanced diet includes 6 tbsp of dry, high-quality cat food, a half cup of small vegetable chunks, two to three small pieces of fruit, 7 tbsp of high-quality, canned dog food, several earthworms, one hard-boiled egg with shell, and one whole mouse (approximately 30 g). This diet can be given once a day with unlimited amounts of fresh water.

### ***Vitamins***

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If given an appropriately balanced diet, healthy opossums do not need vitamin supplementation. When appropriate diets are given, vitamin deficiencies are uncommon, and the risk of health problems associated with oversupplementation can be avoided. Vitamin D deficiencies are uncommon in opossums because they, like other crepuscular mammals, are highly efficient at producing vitamin D<sub>3</sub> (cholecalciferol, the active

form of vitamin D) in the skin, compared with diurnal mammals that require exposure to sunlight to activate vitamin D.<sup>29</sup> If vitamin D must be supplemented, only products that contain cholecalciferol should be given. Many products manufactured for humans, dogs, cats, horses, and cattle contain only vitamin D<sub>2</sub>, or ergocalciferol, the inactive form vitamin D, which is converted in the skin in response to sunlight to active vitamin D<sub>3</sub>. Oversupplementation with vitamin D can lead to demineralization of bone and mineralization of soft tissues and should be avoided. A single dose of vitamin D<sub>3</sub> may be stored in the body for as long as 6 months.<sup>29</sup>

Opossums do not usually need to be supplemented with vitamin B if they are fed appropriate diets. Oversupplementation of vitamin B in humans can lead to high blood pressure, nausea, vomiting, fatigue, dermatitis, muscle pains, and weight loss. The same signs may be possible with oversupplementation in opossums, although no specific studies of vitamin B oversupplementation in this species have been conducted.

Vitamin A is fat soluble and is derived from carotenoids found in plants. It is formed in the intestinal epithelium of most animals and stored in the liver. Vitamin A is essential for maintenance and growth of surface epithelium, eye pigmentation, and bones. Oversupplementation with vitamin A can prevent bone formation and stimulate bone resorption.<sup>30</sup> Supplemental vitamin A should be given only when deficiencies are suspected, and doses should be carefully monitored, because hypervitaminosis A can contribute to metabolic bone disease.

### ***Nutritional Diseases***

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#### ***Nutritional secondary hyperparathyroidism***

The most common nutritional disorder that affects captive Virginia opossums is nutritional secondary hyperparathyroidism or metabolic bone disease. This syndrome is also referred to as osteoporosis, osteomalacia, rickets, osteogenesis imperfecta, cage paralysis, bone atrophy, juvenile osteoporosis, paper-bone disease, fibrous osteodystrophy, and osteitis fibrosa cystica. All of these terms refer to metabolic defects that affect bone morphology and function of bones, however.<sup>29</sup> This disease is most commonly caused by the feeding of inappropriate diets to opossums and is most commonly a result of either a deficiency of calcium or an improper dietary Ca:P ratio. In other species, vitamin D deficiency also can cause metabolic bone disease, but this situation is less likely in Virginia opossums because of their increased ability to synthesize vitamin D<sub>3</sub>.

Calcium homeostasis is tightly controlled by parathyroid hormone (PTH), calcitonin, and 1,25-dihydroxycholecalciferol (the biologically active metabolite of vitamin D) and involves reactions within the intestine, liver, kidney, parathyroid gland, thyroid gland, and bone. When serum calcium concentrations are low, the PTH is released from the parathyroid glands. PTH increases serum calcium concentrations by stimulating renal tubular calcium resorption, bone osteoclastic activity, and renal vitamin D formation. Vitamin D, in turn, augments the actions of PTH by increasing intestinal calcium and phosphorus absorption. When calcium concentrations return to normal, calcitonin is released from C-cells of the thyroid. Calcitonin decreases serum calcium concentrations by increasing renal calcium excretion and decreasing PTH-induced osteoblastic activity and renal vitamin D formation. In this way, calcium homeostasis is achieved.

Phosphorus homeostasis is directly tied to calcium homeostasis and is essential for maintaining acid-base balance. Phosphorus is also an essential component of bone. The ideal body Ca:P ratio is roughly 2:1, and the ideal Ca:P ratio in the adult opossum diet is 1:1 to 2:1. Excessive dietary phosphorus binds with dietary calcium to form insoluble calcium phosphate. The remaining unbound phosphorus may continue to be absorbed, leading to hyperphosphatemia and resultant hypocalcemia.

When captive opossums are fed diets too low in calcium or too high in phosphorus, excessive PTH production occurs from hypertrophied parathyroid glands, which results in calcium resorption from bone. Chronic dietary calcium deficiency results in osteomalacia in adults, with bone softening and decreased bone density caused by demineralization of bone's osteoid matrix. In young, growing animals, the osteoid matrix fails to mineralize. Early clinical signs are mild but may progress with continued dietary calcium deficiency. Initially, the opossum does not grip strongly with its hands, feet, and tail. Activity levels progressively decline, and opossums show reluctance to ambulate and climb. When the opossum walks, its strides become shorter, and foot placement becomes more tentative, as if it were walking on eggshells.

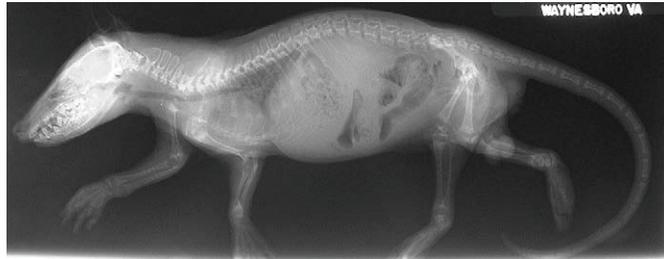
As the syndrome progresses, systemic changes, such as polyuria, polydypsia, hyposthenuria, and folding fractures in the digits, long bones, and spine, may occur. Long bones become painful when palpated, and the opossum develops a crouching posture in which its elbows or knees or both hit the ground, its hands and feet spread, it cannot fully ambulate, and its hind limbs are tucked up underneath its body. These symptoms often progress to hind limb paresis (**Fig. 5**). With time, skull changes also may occur, such as classic "rubber jaw" symptoms that result from osteoclastic resorption and replacement of osteoid by highly cellular connective tissue.<sup>31</sup> The clinician should suspect this syndrome when opossums have difficulty chewing. Muscle tetany, which results from decreased serum calcium concentrations (<8 mg/dL) may be present; however, because serum calcium concentrations are not always decreased, this measurement is not a reliable indicator of nutritional secondary hyperparathyroidism.<sup>29</sup>

Radiographic findings consistent with nutritional secondary hyperparathyroidism include an overall decrease in bone opacity and cortical thinning (**Fig. 6**). Changes are most apparent in the long bones and may be accompanied by multiple, incomplete folding fractures. Angular limb deformities and spinal changes may occur secondary to fracture (**Fig. 7**). These signs do not arise until at least 40% of the bone mineral has been absorbed and disease is chronic.<sup>29</sup>

Treatment for nutritional secondary hyperparathyroidism may or may not correct clinical signs, depending on the extent of the skeletal abnormality and chronicity of malnutrition. Once hind limb paresis occurs, recovery is rare.<sup>32</sup> For optimal therapeutic results, dietary changes must be instituted early in the course of disease. First, the patient must be switched to a diet with the correct Ca:P ratio. A careful dietary history



**Fig. 5.** Juvenile Virginia opossum showing advanced signs of secondary nutritional hyperparathyroidism. Note the clutched front paw, thickened forelimb, and permanent hind limb paresis.



**Fig. 6.** Radiographic lesions typical of secondary nutritional hyperparathyroidism in a growing juvenile opossum, including decreased cortical opacity (especially in digits), enlarged, nonmineralized physes in carpal and tarsal joints, and degenerative changes in elbow and stifle joints.

is essential, because opossums with metabolic bone disease are commonly fed high-protein, low-calcium meals, infant milk formulas, or excessive fruits and vegetables. Although calcium supplementation is often required in treatment of metabolic bone disease, Ca:P ratios vary between sources, and supplements must be selected carefully. For example, calcium gluconate administration may be appropriate for animals that exhibit signs of hypocalcemic tetany; however, the calcium concentration in calcium gluconate is not high enough to overcome clinical signs and radiographic changes associated with long-term effects of dietary Ca:P imbalance. Appropriate supplements may be chosen from a review of relative Ca:P content of various supplements.<sup>29</sup> Calcitonin may be administered to severely affected animals; however, it should be given only if plasma calcium concentrations are within reference ranges. Calcitonin decreases circulating plasma calcium levels by inhibiting PTH-induced osteoclastic activity. Calcitonin also decreases serum calcium and phosphorus levels, however, and if adequate calcium is not supplemented when calcitonin is administered, further hypocalcemia may occur.<sup>33</sup>

### **Obesity**

Obesity is a common problem in adult Virginia opossums. Obesity can lead to cardiac, hepatic, and pancreatic disease<sup>33</sup> and often shortens their lifespan. Signs of obesity



**Fig. 7.** Radiographic findings of chronic secondary nutritional hyperparathyroidism in an adult opossum. This animal was on a poor diet deficient in calcium during neonatal and juvenile growth phases but managed to survive. Note persistent degenerative changes in elbows and stifles, folding fractures in long bones and caudal vertebrae, and decreased cortical opacity in digits. Most other bones are well calcified at this time.

include weight gain and fat deposition throughout the body; fat deposits are most noticeable in the tail and around the eyes. Buphthalmia may occur secondary to fat deposition in the retrobulbar fat pads. In general, obesity is caused by a lack of exercise and a diet too high in fat and protein. The clinician must control body weight and still provide a nutritious, balanced diet. The metabolic rate in marsupials is 30% that of similar sized placental mammals.<sup>34</sup> To avoid obesity, captive opossums should be fed portions based on metabolism rather than size.<sup>35</sup>

The number of calories in the diet should be reduced at the end of the juvenile growth phase—approximately 9 months of age. At this time, the proportion of cat or dog chow in the diet should be reduced so that by 1 year of age, only 45 to 60 mL are given per day.<sup>32</sup> If the opossum is still gaining weight, cat or dog senior or weight-control formula should be used to lower the dietary fat and total kilocalories. In addition to caloric restriction, exercise is also important for weight maintenance of captive opossums. They should be provided with a large enclosure with vertical space to allow climbing. Opossums can be trained to walk on leashes attached to a body harness and run in exercise wheels. The Opossum Society of the United States has published instructions on how to build an exercise wheel appropriate for opossums.<sup>36</sup>

#### **Dental Disease**

Virginia opossums commonly have broken teeth and periodontal disease from collisions with vehicles. With car accidents, if opossums survive the impact, wounds may make them more susceptible to development of systemic infection, such as endocarditis, a common cause of opossum death. In captivity, periodontal disease is often seen in marsupial omnivores as a result of sugary, moist diets.<sup>37</sup> To prevent



**Fig. 8.** Opossums are in. (THE FLYING MCCOYS © 2007 Glenn and Gary McCoy. Distributed by Universal Press Syndicate. Reprinted with permission. All rights reserved.)

dental disease in opossums, regular brushing and prophylactic cleaning is essential.<sup>38</sup>

#### SUMMARY

Virginia opossums are widely distributed throughout the United States, except in the most arid regions, and wild individuals are commonly brought to practitioners for medical attention. It has been estimated that there are 100,000 or more opossums in the state of California (W. Sakai, personal communication, 2008). Opossums' popularity as pets seems to be growing, and it is likely that pet opossums will be more common in veterinary practice (Fig. 8). Clinicians must be aware of natural opossum behaviors so that thorough physical examination and diagnostic procedures can be performed on injured patients. For animals kept captive long-term or as pets, veterinarians must understand proper nutrition and nutritional disorders, such as secondary nutritional hyperparathyroidism, obesity, and dental disease, to properly treat this species.

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