Cats are unique among mammals with respect to metabolism of fatty acids. Except for some ruminants, all other mammals, including cats, are able to synthesize nonessential saturated and monounsaturated fatty acids de novo from glucose or amino acids via a common precursor, acetyl CoA. The products of this synthesis are 16- and 18-carbon saturated fatty acids that can subsequently be desaturated to monounsaturated fatty acids of the n-7 and n-9 fatty acid families (eg, 16:1n-7 and 18:1n-9). These acids are the result of the introduction of a single double bond between carbons Δ-9 and Δ-10 of the respective saturated acids. Enzymes regulating these reactions are active when high-carbohydrate, low-fat diets are fed but have low activity when high-fat diets are fed. Consequently, animals fed relatively high-fat diets will only synthesize limited amounts of the needed fatty acids. Instead, they directly use the dietary supply of fatty acids.

When low-fat diets that are devoid of essential omega-6 and omega-3 fatty acids are fed, mammals will further elongate and desaturate 18:1n-9, which results in the production of 20:3n-9 (ie, 5,8,11-eicosatrienoic acid). Measurable quantities of the latter fatty acid are a hallmark of EFA deficiency (Figure 1), which leads to classical signs of this disorder, such as poor growth, scaly dermatoses, and scruffy hair as well as numerous other metabolic consequences. Of necessity, mammalian diets must include EFAs (both n-6 and n-3 fatty acids) that animals are incapable of synthesizing.

By contrast, plants can manufacture all of the aforementioned fatty acids, including saturated, monounsaturated, and polyunsaturated omega-6 and omega-3 fatty acids. Synthesis of polyunsaturated fatty acids is accomplished via enzymes not found in mammalian tissues that result in the insertion of additional carbon-carbon double bonds in distinct locations into a less unsaturated precursor. This process typically happens at a carbon atom located some distance away from the carboxyl carbon and is a unique characteristic of the enzyme involved. For example, insertion of a double bond between carbon atoms 9 and 10 is performed by stearoyl-Co-A desaturase (a Δ-9 desaturase), whereas insertion between carbon atoms 6 and 7 is performed by a Δ-6 desaturase.

Mammals have both stearoyl-Co-A and Δ-6 desaturases. Plants have additional desaturases, including a Δ-12 desaturase that generates linoleic acid (18:2n-6) from the monounsaturated precursor, oleic acid (18:1n-9), and a Δ-15 desaturase that inserts a double bond into 18:2n-6 to generate α-linolenic acid (18:3n-3). In this way, terrestrial plants synthesize n-6 and n-3 fatty acids. Furthermore, marine plants are able to insert additional double bonds into 18:3n-3 and subsequently elongate the carbon chain, which accounts for the formation of the omega-3 LCPUFAs and their abundance in marine plants. Terrestrial plants, however, do not analogously insert additional double bonds into 18:2n-6. Thus, arachidonic acid (20:4n-6) is not found in plant tissues.

The inability of animals to synthesize n-6 and n-3 fatty acids via Δ-12 and Δ-15 desaturases is the fundamental basis of the essential nature of these fatty acids and the need for a dietary supply. Once ingested in most mammals, except for felids, these dietary essen-
tials are actively converted to longer chain derivatives through regulation by Δ-6 desaturases (Figure 2). In cats, these conversions are greatly limited because of low Δ-6 desaturase activity. This latter fact distinguishes the EFA requirements of cats because without Δ-6 desaturase, EFAs are not converted to other physiologically important LCPUFAs, such as arachidonic acid and DHA, to the extent necessary for certain life stages or processes. Thus, the derived omega-6 and omega-3 LCPUFA products may be conditionally essential in felids. For that matter, there is evidence that omega-3 LCPUFAs may also be conditionally essential for dogs and animals of several other species, even though adults of those species have substantial Δ-6 desaturase activity.

Finally, it should be mentioned that mammals are not capable of inserting double bonds into the Δ-12 and Δ-15 positions of precursor fatty acids. Thus, there are no conversions among the n-3, n-6, n-7, and n-9 families.

**Fatty Acid Metabolism in Adult Cats During Maintenance**

Omega-6 fatty acids—Early studies on EFA metabolism in cats revealed that domestic cats could not convert linoleic acid to arachidonate, which led to speculation that cats do not possess the necessary Δ-6 desaturase to perform this conversion (Figure 2). Other investigators confirmed and extended those observations and concluded that cats possess both Δ-5 and Δ-8 desaturases, which led to the suggestion that an alternative pathway of arachidonate acid synthesis may exist in cats (Figure 3). Indeed, subsequent studies revealed that when cats were fed diets rich in linoleic acid, plasma and liver concentrations of arachidonic acid were similar to those for cats fed diets containing arachidonate. On the basis of these data, it appeared that cats were able to synthesize arachidonate acid from linoleic acid, although evidence was not provided for an alternate route of synthesis.

Evidence of limited Δ-6 desaturase activity in the liver and brain of cats has been confirmed by use of stable isotope techniques combined with gas chromatography and mass spectrometry. The limited Δ-6 desaturase activity in these tissues was detected when cats were fed a diet completely devoid of arachidonate. However, neither that study nor any of the aforementioned studies were designed to investigate the existence of an alternate pathway for arachidonate synthesis in tissues of felids.

Omega-3 fatty acids—In another study, other investigators evaluated conversion of vegetable-based omega-3 fatty acids to longer chain forms. Similar to the results for linoleic acid, adult cats converted small amounts of α-linolenic acid, which yielded eicosapentaenoic acid (20:5n-3) and docosapentaenoic acid (22:5n-3) in hepatic tissues and plasma. In addition, DHA (22:6n-3) and the omega-6 form of docosapentaenoic acid (22:5n-6) were detected in brain tissues. These findings were of particular interest because the final conversion of DHA was detected only in neural tissues but not hepatic tissues, which lends support to the possibility that omega-3 docosapentaenoic acid that accumulates in plasma phospholipid fractions when cats are fed α-linolenic acid is then transported to the brain and nervous tissues for DHA synthesis.

**Fatty Acid Metabolism in Adult Cats During Reproduction**

Omega-6 fatty acids—Male cats fed a diet deficient in linoleic acid developed tubular degeneration of the testes. However, when linoleic acid was provided, fatty acid patterns of testicular phospholipids revealed higher arachidonate concentrations, compared with arachidonate concentrations in the deficient, unsupplemented cats. Queens did not bear live kittens when fed a diet deficient in linoleic acid. Thus, it was con-
cluded that linoleic acid appears to meet the require-
ments for spermatogenesis but that arachidonic acid is necessary for reproduction in females.

The requirement for dietary arachidonic acid for reproduction in queens was evaluated in 1 study by feeding cats 1 of 3 diets that contained 1% corn oil, 3% corn oil, or 1% corn oil plus 0.02% arachidonic acid. Queens were fed the assigned diet beginning at the time of mating, and all became pregnant. A high incidence of congenital defects and low viability was found in fetuses of queens fed the diet that contained 1% corn oil. By contrast, the diet that contained 3% corn oil or 1% corn oil plus 0.02% arachidonic acid supported normal reproduction. Queens did not have effective reproduction when fed the diet low in linoleic acid unless that diet was supplemented with small amounts of arachidonic acid. However, because the diet that contained 3% corn oil without supplemental arachidonic acid also supported effective reproduction, it was concluded that other dietary factors may be involved.

Of additional interest is the fact that neonatal kit-
tens from queens fed arachidonic acid in that study were used in another study. The neonatal kittens were able to synthesize arachidonic acid from a labeled linoleic acid precursor.

In another study, investigators reported the effects of arachidonate-depleted diets on reproduction in male and female cats. Investigators in that study confirmed an earlier finding that males were fertile when fed diets containing linoleic acid but not arachidonic acid. In that study, 5 male cats fed diets consisting of hydrogenated vegetable oil that was devoid of arachidonic acid were allowed to mate with queens maintained on commercially available dry-type diets. Twelve of 13 queens conceived, with litter size ranging from 3 to 8 kittens. Sixty-seven kittens were born and were clinically normal, although 4 kittens from 3 litters died after 1 day of age for unspecified reasons. Nonetheless, litter size of those 12 queens exceeded the mean litter size for the colony, which consisted of cats fed commercially available dry-type diets. Therefore, the study confirms that arachidonic acid is not an EFA for reproduction in queens. However, because the diet that contained 3% corn oil without supplemental arachidonic acid also supported effective reproduction, it was concluded that other dietary factors may be involved.

Independent of the site of tissue synthesis, the important clinical concern is whether the synthetic capacities for long-chain omega-3 fatty acids in cats are adequate for reproduction. In another study, investigators fed diets that contained various amounts of corn oil and hydrogenated coconut oil to cats before mating, during pregnancy, and throughout the subsequent lactation. Two reference diets that contained arachidonic acid and DHA were also evaluated. Diets that contained corn oil were capable of maintaining arachidonic acid concentra-
tions in the developing retinas and brain of kittens, but only those diets that contained DHA could support the high concentrations of DHA generally found in these tissues. Low concentrations of an omega-6 fatty acid, 22:5n-6, were also detected, which suggested that kittens have a low capacity to generate either 22:5n-6 or DHA.

Differences in electroretinograms, an index of neu-
ral development, were observed in the kittens whose queens were fed diets deficient in LCPUFAs, compared with electroretinograms for control kittens. It was concluded that the LCPUFA-deficient diets in that study did not provide kittens with an adequate supply of n-3 fatty acids for proper accumulation of neural and retinal DHA during development and thus were inadequate for support of optimal visual function. There may have been insufficient conversion of the n-6 or n-3 18-carbon pre-
cursors needed for developing or immature kittens.

**Clinical Summary**

Similar to the case in other mammals, cats do not synthesize linoleic acid and require a dietary supply. Also, cats have a limited capacity to synthesize arachidonic acid, but it is unknown whether some alternative pathway, other than that defined by limited Δ-6 desaturase activities, may exist for synthesis of arachidonic acid. Regardless, the limited amount of arachidonate synthesized from linoleic acid may be sufficient for maintenance needs of adult cats, especially when linoleic acid is in abundant supply, which is in many current commercial diets formulated for cats.
With regard to reproduction, male cats are able to synthesize sufficient amounts of arachidonate from linoleate to enable spermatogenesis. However, queens require an exogenous source of arachidonate for successful outcomes for pregnancies and normal litters, although queens can conceive when linoleic acid is provided in the diet without arachidonate.

Finally, for omega-3 fatty acids, high dietary amounts of α-linolenic acid, relative to the dietary amount of linoleic acid, may be contraindicated and lead to signs of EFA deficiency. The reason for this phenomenon may be the known competition of linoleic and α-linolenic acids for limited Δ-6 desaturases. Similar to the synthesis of omega-6 fatty acids, adult cats can synthesize small amounts of long-chain omega-3 fatty acids from precursors. Nonetheless, to support the high concentrations of DHA in the retinal and neural tissues needed for development, kittens may require an exogenous source of DHA (such as a diet supplemented with DHA) because conversion of precursors may be insufficient to meet this need.

References