THE BIOLOGY OF THE PIG

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PREFACE

The domestic pig (*Sus domesticus*) is in great demand as an animal model for many types of biomedical research. Information on the biology of the pig is voluminous, but it is widely scattered in the literature. Our purpose has been to assemble the pertinent information on the pig under one cover, thus providing a useful reference source for animal scientists, veterinarians, biomedical researchers, and other biologists working with the pig or interested in the literature on the pig. This book is not intended as a complete reference source, but we hope that the references cited accurately represent the current knowledge in the field and provide a basis for developing a greater body of information.

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1. THE PIG AS A MODEL IN BIOMEDICAL RESEARCH

Introduction

Research with the pig falls into two categories: that directed toward production of pork to supply human food and that directed toward gaining basic knowledge applicable to human health. Much of the knowledge gained from efforts in production of pork for human food has found application in studies of problems related to human health. Bustad (1966), Bustad and McClellan (1965), Glauser (1966), Mount and Ingram (1971), and Book and Bustad (1974) have described the many uses of pigs in the laboratory, and a symposium devoted to an analysis of uses of the pig in biomedical research highlighted important contributions (Bustad et al. 1966). The use of miniature swine in fetal, neonatal (Book and Bustad 1974), gerontological (Bustad et al. 1968), and other biomedical research (Bustad and Crowder 1968) has become frequent and important.

The extent of the research effort with swine is indicated by the *Index of Current Research on Pigs* (Braude 1978), which includes about 5700 entries of active research projects and publications from more than 50 countries. A selected list of references on the use of swine in biomedical research has been published (Pekas and Bustad 1965); it includes more than 1500 entries of papers issued from 1960 to 1965. A two-volume compendium on growth and body composition of the pig also provides numerous references (Topel 1971). In this chapter the general characteristics, anatomical variations, and abnormalities of the pig are described, and several examples are given of human diseases for which the pig serves as a research model.

General Characteristics

The present-day domestic pig, *Sus domesticus* (phylum, Chordata; class, Mammalia; order, Artiodactyla; family, Suidae), is the result of thousands of years of evolution; natural selection and, more recently, application of Mendelian genetic principles by animal breeders have resulted in the pig becoming a valuable asset to humankind as food and as an animal model in biomedical research.

There are currently some 87 recognized breeds (Mason 1969) of domestic pigs in the world, most of them in Europe and North America. They originated from the European wild pig, *Sus scrofa*, and the Far Eastern pig, *Sus vittatus*. For purposes of this discussion, a breed represents a group of pigs that has certain characteristics (color, ear carriage, etc.) in common and is recognized by an organized breed association or by a governmental agency. In addition, there are another 225 or more groups of pigs not recognized as breeds but each having unique characteristics, appearance, or geographical location.

The domestic pig has 38 somatic chromosomes (19 pairs) (Jimenez-Martin et al. 1962). A karyotype is shown in Figure 1.1. Bone marrow cells from males and females have been used to classify chromosomes into seven groups in decreasing order of length (Bustad 1966). Establishment of karyotype can also be done using the blastocyst flushed from the uterus 10 days after mating (McFeely 1967), peripheral blood from pigs of any age (Stone 1963), or liquor folliculi and cells detached from the granulosa, cumulus, or corona radiata of the follicles of sows

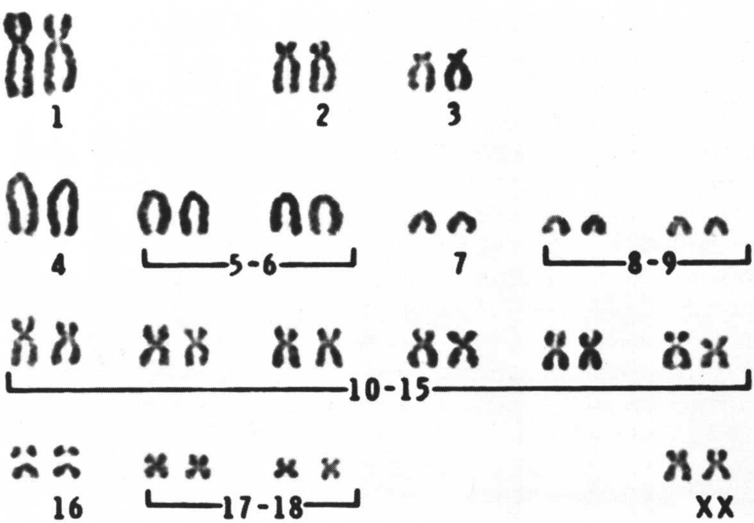

Figure 1.1. Karyotype of domesticated pig, with 38 chromosomes, arrayed here in four rows. (From McFee et al. 1966, *Cytogenetics* 5:75.)

(Paraipan 1969). Pace et al. (1975) described a simple, inexpensive, and reproducible G-banding technique that permits precise identification of individual swine chromosome pairs. This technique should help to clarify the karyotype terminology in swine used by different investigators. As in other mammals, the male determines the sex of the offspring by producing the Y sex chromosome. The European wild pig has 36 chromosomes. Mating of the domestic pig with the European wild pig produces a hybrid with 37 chromosomes (Fig. 1.2). McFee and Banner (1969) reported no evidence of reduced fertility or physical changes associated with different chromosome forms.

A high proportion (up to 10 percent) of blastocysts from normal pigs have grossly detectable chromosome defects (McFeely 1967). These abnormalities include: triploid XXX, tetraploid XXYY, triploid XYY, triploid XXY, and diploid XX/triploid XXX. The proportion of these defects associated with the high early embryonic mortality in pigs is not known. However, since they have not been reported in living adult pigs, some of these changes are probably lethal. Triploidy could arise by fertilization of an ovum with two spermatozoa and tetraploidy from failure of the first cleavage division. Each has alternative origins as well. A case of a male pig with a genotype 39, XXY/40, XXXY has also been described (Harvey 1968).

Much genetic variation exists among and within breeds in mature size and characteristics. This variation is exemplified by the contrast between the conventional breeds of swine in the United States and the miniature pig developed by the Hormel Institute at the University of Minnesota as a more suitably sized pig for use in laboratory studies. The average mature weights of the former and latter are approximately 175 and 80 kg, respectively. The existence of variation in size provides an opportunity for genetic selection. The expected mature weight of males and females of a few common breeds is given in Table 1.1.

An illustration of the diversity existing within the species has been made (Phillips and Hsu 1944) by a comparison of size and performance characteristics among native Chinese pigs and several modern U.S. breeds of pigs, which originated many generations ago from crosses between native Chinese and European pigs. The native Chinese pigs studied are smaller, reach sexual maturity earlier, and are more prolific than the modern U.S. pig. The U.S. breeds grow faster with greater efficiency of feed utilization and are leaner than the Chinese pigs. A notable difference in organ size between the two groups is the 40 percent longer small intestine of the U.S. pig as compared to the native

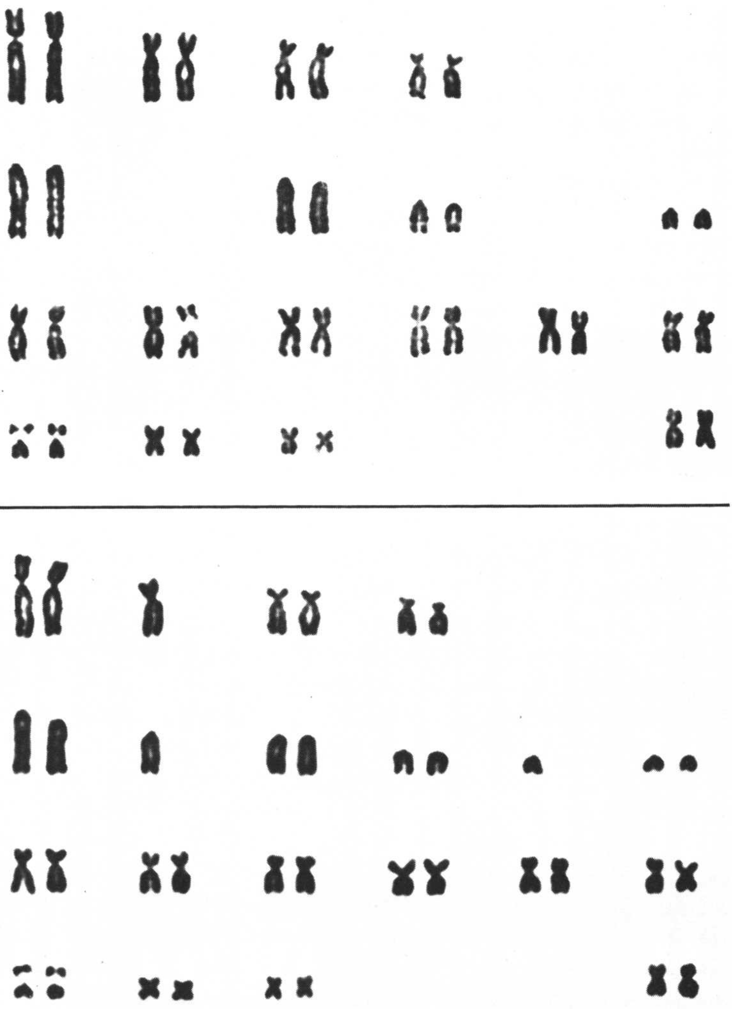

Figure 1.2. Other pig karyotypes. *Above*, European wild pig has only 36 chromosomes. One pair that the domestic animal lacks is in the first row; two pair present in the domestic are missing in the second row. *Below*, hybrid pig has 37 chromosomes. Single chromosomes occupy each of the three karyotype positions where either the domestic or the wild animal lacked a pair. (From McFee et al. 1966, *Cytogenetics* 5:75.)

Table 1.1. Mature weight of some representative breeds (kg)*

Breed	Female	Male
Chester White	150	195
Duroc	160	200
Labco†	70	70
Minipig‡	75	75
Poland China	180	205
Spot	160	200
Yorkshire	125	150

*Values are for weight in show-ring condition (except for miniature pigs). Weight in healthy breeding condition should be about 20 kg less than shown for both females and males. Mature weight is reached at about 3 years of age.

†Labco, Inc., 196th and Route 54, Homewood, Illinois.

‡Vita Vet Laboratories, Box 108, Marion, Indiana.

Chinese pig. A difference in intestinal length has also been noted between the improved Danish Landrace and the wild boar of Europe from which the Danish Landrace breed was developed (Clausen and Nielsen 1963).

The anatomy of the pig is thoroughly described by Sisson and Grossman (1953), St. Clair (1975), and Nickel et al. (1975). Description of anatomical details is therefore not included here.

There is considerable variation among pigs in the number of ribs and in the number of thoracic and lumbar vertebrae. Results of extensive X-ray studies of live animals and examination of carcasses (Shaw 1930, Berge 1948, Freeman 1939) show that cervical vertebrae almost always number 7; thoracic vertebrae vary according to the number of ribs present, 13–17; lumbar vertebrae usually number 6–7. Sacral vertebrae number 3–7; caudal vertebrae (tail), 21–26 (Donald 1949). True ribs are always attached to thoracic vertebrae. Floating or incomplete ribs or an unequal number of ribs on each side occur frequently. The number of ribs increases with the number of presacral vertebrae, thus averaging 28.6 (range 27–30). With an increase in number of ribs, the number of lumbar vertebrae decreases. The heritability of presacral vertebrae number has been estimated at 0.74 (Berge 1948). There are breed, but not sex, differences in average vertebrae number, additional ribs being generally associated with breeds of larger size. Selection for carcass length (distance from first cervical vertebra to aitchbone or from first rib to aitchbone) has probably resulted in an increase in the average number of vertebrae in selected strains.

A problem of practical importance in some strains of pigs is the tendency toward unequal development in the length and diameter of the members of digit pairs (toes) on the hoofs (Nordby 1939). In this con-