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• Acknowledgements
• Introduction
• How to Use This Document
• Comparative Anatomy and Physiology of the Pig
• Bibliography
• Web Resources on Swine

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We would also like to thank the editors of the Scandinavian Journal of Laboratory Animal Science for permission to load the previously published article Comparative Anatomy and Physiology of the Pig authored by M. M. Swindle, D.V.M. and A. C. Smith, D.V.M., to this online resource.

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**Introduction**

Swine have increasingly become utilized as biomedical research models in the last two decades. This increased use as an animal model is not only a result of regulatory pressure on other large animal species, but also because swine are recognized as a suitable animal model for human disease based upon their comparative anatomy and physiology. Swine are used as general surgical models of most organs and systems, for cardiovascular research including atherosclerosis, for digestive system models, and in recent years in transplantation and xenografic research.

They are being explored as models in many other systems because of the widespread availability of both domestic and miniature breeds. Hand-in-hand with this increase in the number of swine in research, have come technical developments in surgery, anesthesia, husbandry and handling techniques. These technical advancements have made it easier to use this species in research and have also improved the humane care and use of swine by research institutions worldwide.

This resource was developed to provide investigators, laboratory animal veterinarians, technicians, and others, using swine for biomedical purposes with access to baseline literature on common models and procedures. As the resources available on laboratory swine continues to expand, investigators are encouraged to review multiple publications and to find information that supports their particular research needs.

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**How to Use This Document**

This document is divided into three major sections: Comparative Anatomy and Physiology of the Pig; Bibliography; and Web Resources on Swine.

**Comparative Anatomy and Physiology of the Pig**

This article provides information on the comparative anatomy and physiology of the porcine cardiovascular, digestive, dermal and urinary system. Differences between farm and miniature breeds are discussed. Comparisons and similarities between swine and human anatomy and physiology are also reviewed. The article is followed by a list of reference citations.

**Bibliography**

The bibliographic section of this document is divided into 29 subsections. Subsections range in topic from anatomy, anesthesia, surgical procedures, body systems, common biomedical models, and husbandry of laboratory swine. Citations in each subsection were compiled from a variety of medical, agricultural, and biological databases and other resources.
Abstract

Swine, *Sus scrofa domestica*, are widely used in research and testing. Most of the animals are small domestic farm breeds, but miniature swine such as the Yucatan, Hanford and Gottingen are widely used for chronic studies where the significant growth of the domestic breeds would be an issue. They share anatomic and physiologic characteristics with humans that make them a unique and viable model for biomedical research. The cardiovascular anatomy, physiology and response to atherogenic diets have made them a universally standard model for the study of atherosclerosis, myocardial infarction and general cardiovascular studies. Their gastrointestinal anatomy has some significant differences from that of humans, however, the physiology of their digestive processes has made them a valuable model for digestive diseases. The urinary system of swine is similar to humans in many ways, especially in the anatomy and function of the kidneys. Swine are also a standard model for skin and plastic surgical procedures and have been developed as models of transdermal toxicity. The anatomy and physiology of organs such as the liver, pancreas, kidney and heart have also made this species the primary species of interest as organ donors for xenograftic procedures. This manuscript reviews the anatomy and physiology of swine as it relates to biomedical research.

Introduction

Swine have been used extensively in biomedical research and the most relevant models have been reviewed in a series of technical proceedings and books in the last two decades (*Stanton & Mersmann, 1986; Swindle, 1983; Swindle, 1992; Swindle, 1998; Swindle & Adams, 1988; Tumbleson, 1986; Tumbleson & Schook, 1996*).

All swine commonly used in research and testing are *Sus scrofa domestica*, whether they are farm or miniature breeds. The main difference between breeds is size at sexual maturity. Domestic breeds typically reach 100 kg by 4 months of age and miniature breeds typically range from 25-50 kg at the same age. The predominant breeds of miniature swine used in research are the Yucatan, Hanford, Göttingen and Sinclair Hormel, although dozens of other breeds have been utilized in the scientific literature (*Swindle et al., 1994*).

The predominant porcine systems studied in biomedical research are cardiovascular, digestive, dermal and urinary. However, a smaller number of models have utilized other systems. This manuscript reviews the relevant anatomy and physiology of the pig as it applies to biomedical research. The discussion is organized by systems with the glandular and endocrine structures discussed with the anatomically associated organs.
Cardiovascular and Pulmonary Systems

The heart of the pig is anatomically similar to humans with a notable exception being the presence of the left azygous (hemiazygous) vein, which drains the intercostal system into the coronary sinus (Swindle et al. 1986). The coronary system is similar to 90% of the human population in anatomy and function. There are no preexisting collateral vessels in the myocardium (Bloor et al. 1992). The heart of a 40-50 kg miniature pig is approximately the same size as an adult human heart. The heart is approximately 0.5% of the body weight at sexual maturity in miniature swine, however, the heart decreases as a percentage of body weight in domestic swine as the animal grows and is approximately 0.3% at the same age as the miniature swine. Differences in heart weight between species of miniature swine have been noted with the Yucatan having a significantly larger heart than the Hanford at the same age (Smith et al. 1990; Swindle et al. 1988). The blood supply to the conduction system is from the posterior septal artery and thus is predominantly right side dominant like the human (Gardner & Johnson, 1988). There are large numbers of adrenergic cholinergic fibers in the AV node and right and left bundle branches. However, nerve cells are sparse in the fibers. The endocardium and epicardium are activated simultaneously because of differences in the distribution of the conduction system. The Purkinje system has large subendocardial fibers. These characteristics give the pig a more neuromyogenic conduction system than the human. However, other species used in cardiac electrophysiology also have anatomic and functional differences in the conduction system from humans as well. Conduction system rates decrease as the animal matures, but in general are more rapid than for humans of equivalent maturity (Gardner & Johnson, 1988; Stanton & Mersmann, 1986).

The aorta of swine contains a vaso vasorum like humans. It also has a comparable histologic anatomy. However, blood vessels and the atria in swine tend to be more friable than other species, especially in neonates. The blood vessels are also more prone to vasospasm during manipulation. The external jugular vein and sheath are at approximately the same depth as the ventral surface of the cervical vertebrae. The jugular furrow may be visualized running from the ramus of the mandible to the point of the shoulder by pulling the forelimb caudally while the pig is in dorsal recumbency. Many of the peripheral blood vessels are located relatively deep in the tissues compared to other species, however, vascular access may be readily obtained with standard sized needles from the cephalic, external and internal jugular, auricular, anterior abdominal, saphenous and femoral veins with practice. All of these vessels as well as internal abdominal and thoracic vessels may be chronically catheterized surgically (Swindle, 1983; Swindle, 1998; Swindle et al. 1986; Swindle et al. 1988).

Hemodynamically, swine have been demonstrated to be similar in cardiac function to humans. There are variations between breed and age of swine that need to be taken into consideration. For instance, the Yucatan micropig has a significantly higher pulmonary vascular resistance at the same age as the Yucatan and Hanford miniature breeds. The Hanford has a higher systolic blood pressure than either Yucatan under equivalent conditions. When reproducing studies between laboratories, caution should be taken in comparing hemodynamics between different breeds. Animals should be age and weight matched (Smith et al. 1990; Swindle, 1998). The development of atherosclerosis occurs both spontaneously and by experimental induction in swine feed an atherogenetic diet. The metabolism of lipoproteins is similar to humans. Endothelial damage with balloon catheters can be utilized to localize the site of development of the atherosclerotic plaque, however, the distribution of the atherosclerotic plaques will be similar to humans if allowed to develop spontaneously over time. The histology and pathogenesis of the plaques appears to be similar to humans as well (Gal & Isner, 1992; White et al. 1992).

Swine do have congenital cardiovascular anomalies including ventricular septal defect (VSD), atrial septal defect, patent foramen ovale, patent ductus arteriosus and tricuspid dysplasia. Hypertrophic cardiomyopathy also has a spontaneous occurrence in some breeds of domestic and miniature swine (Swindle et al. 1992). The model of VSD has been developed as a genetically reproducible model which has been shown to be analogous to human infants with VSD and failure to thrive syndrome. It consistently develops the various morphologies of high membranous defects and may be useful for the study of interventional closure of the defects. Congenital shunts may also be created by use of angioplasty balloon techniques. If shunts are reopened in neonates with balloon catheters they will remain open and develop volume overload hypertrophy. They also develop pressure overload hypertrophy following banding of the great vessels of the heart like other species (Swindle, 1998).
Most of the cardiovascular models in swine (Stanton & Mersmann, 1986; Swindle, 1998) are related to testing of interventional catheter devices (Gal & Isner, 1992; Swindle, 1998), atherosclerosis (White et al., 1992), myocardial infarction (Bloor et al., 1992; Gardner & Johnson, 1988), coronary blood flow (Bloor et al., 1992; Gardner & Johnson, 1988), intracardiac electrophysiology (Brownlee et al.; Smith et al., 1997) and cardiovascular surgery (Swindle, 1998; Swindle et al., 1986), predominantly with the implantation of biomechanical devices (Gal & Isner, 1992; Mehran et al., 1991).

The characteristics that have led to the use of swine over other species for these models are related to the anatomic and physiologic characteristics described above. The porcine model develops an infarction pattern like the human and develops arrhythmogenic activity with reperfusion. The canine model of infarction already has an existing collateral blood supply, but may represent the portion of the human population which has slowly developed collateral circulation due to gradual occlusion of a coronary artery. Gradual occlusion may be created in swine by causing endothelial damage with an angioplasty balloon and feeding an atherogenic diet of 2% cholesterol. The pattern of infarction and healing of the myocardium is almost identical to humans (Bloor et al., 1992; Gal & Isner, 1992; Gardner & Johnson, 1988; Stanton & Mersmann, 1986; Swindle, 1998; White et al., 1992).

Likewise, the wound healing characteristics in the cardiovascular system mimic these in man following implantation of some devices, such as intracoronary stents. Unlike other models they develop coronary restenosis syndrome (Swindle, 1998; White et al., 1992). For intravascular healing, investigators may be required to use multiple models since no single species is exactly analogous to humans. The pig has the advantages of predictable size and platelet function, unlike the dog. Even the primate models are not exactly analogous. Wound healing in the myocardium has typically used swine, dogs and sheep. The myocardial wound healing characteristics of swine are more analogous to humans than sheep models since ruminants healing is characterized by the formation of collagenous scars (Mehran et al., 1991; National Institutes of Health, 1985; Von Recum, 1986).

The lungs are composed of apical, middle and diaphragmatic lobes with an additional accessory lobe for the right lung. The interlobular fissures are incomplete. The larynx is prominent with a large vestibule and lateral and middle ventricles that create a caudal narrowing of the structure. The trachea courses from approximately C3-4 into the thorax. The apical lobe of the right lung has a bronchus that stems from the trachea cranial to the tracheal bifurcation which supplies the other lobes of the lung. The bronchial tree divisions are typical of other species (Swindle, 1998). Functional studies of the airway, including neurochemical anatomy and smooth muscle function, make them useful in models of acute respiratory distress syndrome and asthma. The neonatal development of the lungs and airways is useful for extrapolation to humans (Brown & Terris, 1996). The thyroid gland is located on the ventral surface of the trachea at the thoracic inlet rather than near the larynx. The thymus gl and is located in the cranial thorax and neck coursing along the trachea. The paired parathyroid glands are located near the cranial thymus rather than the thyroid (Swindle, 1983; Swindle, 1998).

**Digestive System**

The digestive system of swine has anatomic differences from humans (fig. 2, fig. 3, fig. 4), however, the physiology of digestion remains similar to humans. Swine are true omnivores.

The dental formula for swine is 2(I 3/3, C 1/1, P 4/4)=32 for deciduous teeth. For permanent teeth it is 2(I 3/3, C 1/1, P 4/4, M 3/3)=44. A full set of permanent teeth is usually present by 18 months of age (Swindle, 1998).

The salivary glands of the pig are large and consist of paired parotid, mandibular and sublingual glands. The parotid duct enters the oral cavity opposite the juncture of the premolars and molars. The mandibular and sublingual glandular ducts enter the floor of the mouth near the frenulum. Buccal glands are located opposite the cheek teeth. The parotid gland is serous, the sublingual glands are mucous and the rest are mixed for glandular secretions. The tonsils are embedded in the oropharynx (Schantz et al., 1996).

There is a pharyngeal diverticulum dorsal to the larynx in the caudal portion of the nasopharynx. The muscular layers of the esophagus are mainly composed of smooth muscle until its termination cranial to the esophageal sphincter when it becomes partially striated muscle. The stomach is typical of monogastric animals with the exception of the torus pyloricus, which is a muscular outpouching near the pyloric sphincter. The small intestine is long and located mainly in
the right side of the abdomen. The mesenteric vessels form a vascular arcade in the subserosa rather than in the mesentery as in other species. Mesenteric lymph nodes are prominent. The majority of the large intestine is located in the spiral colon in the left upper quadrant of the abdomen. It consists of the cecum, ascending, transverse and a portion of the descending colon coiled tightly into a series of centripetal and centrifugal coils. The outer coil contains two tenia. The descending colon passes caudally along the left abdominal wall to the rectum and anal sphincter. Neither a true sigmoid flexure nor an appendix are present. The pigs intestinal length is approximately 30 times its body length (Schantz et al., 1996).

The liver contains six lobes and a gall bladder. The lobules of the liver are separated by fibrous septae. The common bile duct enters the duodenum separately from the pancreatic duct caudal to the pylorus. The pancreas is extensive and the tail follows the lesser curvature of the stomach from the spleen to the proximal duodenum. The body encircles the superior mesenteric vein and extends dorsally to the left kidney. The pancreatic ducts in the tail and body join at the juncture of the two lobes to enter the duodenum distal from the bile duct. The islet cells are relatively indistinct histologically. Functionally, both the liver and pancreas are similar to humans (Mullen et al., 1992; Pennington & Sarr, 1988; Schantz et al., 1996).

In spite of the anatomic differences, the pig has been used extensively as a gastrointestinal model. Most of the classical models involving the digestive system have been related to nutritional studies to study digestion of the pig and for studying human digestive phenomena. They will readily ingest such test substances as alcohol in its various forms. The metabolic functions, intestinal transport times, and characteristics of absorption of nutrients have made them useful in basic nutritional research. Other specific functional characteristics of swine that relate directly to humans include ion transport and motility, neonatal development of the gastrointestinal tract and splanchnic blood flow characteristics. Development of host defenses and endotoxin shock studies have made them useful as biomedical models in these areas. Like the human, these physiologic characteristics of the gastrointestinal tract are probably due to the omnivorous diet that they consume, unlike that of carnivores, ruminants, rabbits and rodents (Brown & Terris, 1996; Reeds & Odle, 1996; Tumbleson, 1986; Tumbleson & Schook, 1996).

More recently endoscopic and laparoscopic surgical models have been developed and used extensively in the pig. The size and function of structures such as the biliary system and pancreatic duct make them amenable for studying human sized equipment and biomaterial implants. Surgical modifications have made the intestinal tract amenable to the study of surgical and chronic fistulation procedures (Swindle, 1998; Swindle & Adams, 1988).

Swine have a similar cytochrome P450 system to humans except for the absence of CYP2C19 and CYP2D6 (Skaanild & Friis, 1997). However, metabolically the liver functions similar to humans and has been used for xenoperfusion protocols for humans in hepatic comas (Collins et al., 1994; Swindle, 1998).

Urogenital System

The female reproductive system has a bicornuate uterus with torturous fallopian tubes. The fallopian tubes of an adult female are the same diameter as those of humans, however they are much longer. The sow has an estrous cycle of 20-21 days rather than a menstrual cycle. Domestic farm breeds have larger litters, usually of 8-12 pigs, than miniature pigs which typically have litters of 4-6. The numbers are variable depending upon the breed and the parity of the sow. The gestation period of 112-114 days allows sows to have up to three litters per year. Uterine placentation is diffuse epitheliochorial. There are typically 12-14 paired mammary glands on the ventral abdomen (Swindle, 1998; Tumbleson, 1986; Tumbleson & Schook, 1996).

The sow has been used in studies of fetal surgery to create models that mimic the human situation. Even though the placentation is unlike humans, the physiologic characteristics of transplacental transfer of antiarrhythmics has been shown to be more similar to the human situation than the traditional ewe model. This transplacental transfer of therapeutic agents may make the sow a predictable model of teratogenicity and efficacy of pharmaceutical agents (Wiest et al., 1996).

The male reproductive system has the same structures as humans, however, the accessory sex glands which predominate are different. The scrotum and testicles are located in the perineal region. The penis is fibromuscular with a sigmoid
flexure on the ventral abdomen. The penis has a corkscrew shaped tip. The prepuce is located caudal to the umbilicus and has a preputial diverticulum which contains foul smelling urine and secretory material. The accessory sex glands are: vesicular glands, prostate gland, and bulbourethral glands. The, vesicular glands are prominent and located at the neck of the bladder. The prostate and bulbourethral glands are relatively small. The shape of the penis and the preputial diverticulum make it impossible to catheterize a male pig through the penile opening. Catheterization has to be performed in the perineal urethra percutaneously (Swindle, 1983; Swindle, 1998).

The kidneys of the pig are more like humans in anatomy and function than most other species of animals. The left kidney is cranial to the right and both are located ventrally to the transverse processes of L1-4. The adrenal glands are located near the cranial poles of both kidneys and the right gland is intimately associated with the wall of the postcava. The kidneys are multirenulate and multipapillate like humans. The blood supply to the kidney divides transversely between the cranial and caudal poles rather than longitudinally like most species (Brown & Terris, 1996; Pennington, 1992; Sachs, 1992; Terris, 1986).

The bladder is thin walled, but functionally is similar to other species. The innervation is derived from S2-4. The pelvic urethra courses along the ventral floor of the pelvis. The female urethra opens on the ventral floor of the vagina about 1/3 of the distance to the cervix. The male urethra courses through the penis as described above (Swindle, 1983; Swindle, 1998; Swindle & Adams, 1988).

Swine have been used in studies of developmental and pediatric urology because of the unique anatomy of the kidneys which allows them to develop vesicoureteral and intrarenal reflux (Swindle, 1998; Swindle & Adams, 1988; Terris, 1986). The kidney has also been used extensively in transplantation biology, including xenografic studies (Institute of Medicine, 1996; Pennington, 1992; Sachs, 1992; Swindle, 1998).

The anatomic and physiologic characteristics of the porcine kidney may make it useful for the study of pharmacologic agents since the anatomy of the kidney is more similar to humans than even primates. Swine can be utilized in studies of renal hypertension and can be developed as a model of intact renal DOCA salt induced hypertension or as surgical ablation models of renin induced hypertension (Swindle, 1998; Swindle & Adams, 1988; Terris, 1986).

Musculoskeletal System

The skeletal system of the pig is massive with relatively thick cortical bone. This is consistent with the support of a rapidly growing animal with a relatively small stature. The Vertebral formula for swine is C7, T14-15, L6-7, S4, Cy2O-23. There are 7 sternal and 7 asternal ribs. If a 15th rib is present, it is floating. The principle digits of the pig are III and IV. Digits 11 and V are vestigial and form the dewclaws. Swine are considered to be ungulate or hooved animals. The long bone epiphyses close by 3-4 years in domestic farm breeds and generally 1-2 years earlier in the miniature breeds (Adams, 1988; Donovan et al, 1993; Swindle, 1998).

The muscles of the pig tend to be massive which is consistent with its primary use as a food source. The muscles have a predominance of Type IIB fibers with lesser numbers of Types IIA and IIC. The quadriped locomotion of swine is different from humans and the muscles reflect this characteristic in their morphology like other quadrupeds (Adams, 1988).

Because of the massive nature of the musculoskeletal system and the quadriped locomotion characteristics, swine have rarely been used in studies of these systems. Recently, there has been increased interest in the model for temporomandibular joint studies as well as bone healing and grafting techniques (Adams, 1988; Bermejo et al, 1993; Donovan et al, 1993; Swindle, 1998).

Integumentary and Lymphatic Systems

Swine are relatively hairless animals with a fixed skin tightly attached to the subcutaneous tissues like humans. Overall, the skin is thicker and less vascular than humans, however, the cutaneous blood supply characteristics are similar. Apocrine sweat glands are absent. Fat cells may be located in the dermis. As the animal grows a substantial amount of subcutaneous fat is deposited. The skin tends to be thicker on the neck and dorsum of the animal (Bolton et al, 1988; Chvapil & Chvapil, 1992; Kerrigan et al, 1986; Montiero-Riviere & Riviere, 1996).
The **lymph nodes** of the pig have a unique histologic structure. The typical cortex and medulla are reversed with the germinal centers being located in the interior of the gland *(Swindle, 1983; Swindle, 1998)*.

The anatomy and physiology of the cutaneous blood supply and the wound healing characteristics have made the pig a standard model for plastic surgical and wound healing studies *(Kerrigan et al., 1986; Mertz et al., 1986)*. Recently interest has developed in the pig as a model of dermal and transdermal toxicology *(Montiero-Riviere, 1986; Montiero-Riviere & Riviere, 1996; Riviere et al., 1986)*. Besides the anatomic similarities swine are equivalent to primates for percutaneous absorption studies and have similar lipid biophysical properties, epidermal turnover kinetics and carbohydrate metabolism in the skin *(Montiero-Riviere & Riviere, 1996)*.

**Central Nervous and Ophthalmic Systems**

The brain is encased in a cranial vault formed by the massive cranial bones. The brain is relatively large with structures typical of those of other species. The spinal cord terminates at S2-3 with the origin of the cauda equina. The anatomy of the blood supply to the brain and spinal cord is similar to humans. A stereotactic atlas of the pig brain has been published *(Stodkilde-Jørgensen, 1986; Swindle, 1998)*.

The eye contains a nictitating membrane, Bowman's membrane and Descemet's membrane. Draining for the lacrimal glands is by either one or two puncta in the conjunctiva. The nictitating membrane contains a Harder's gland. The globe is relatively deep in the orbit with seven extraocular muscles. The eye has an open field of vision with a pupil and retina that resembles humans. The tapetum is absent *(Adams, 1988)*.

Relatively little work has been performed to study the function of the central nervous system in this species. Because of the massive bone structure, surgical access to the brain and spinal cord is difficult. However, the brain development of swine and the similar topical, histologic and vascular anatomy make them useful as general mammalian models. Hypophysectomy and cannulation techniques have been described *(Swindle, 1998)*.

**Discussion**

This review of the anatomy of the pig details the unique characteristics that differentiate it from other species. It also describes characteristics that are significant when using the animal as a biomedical model for humans. More detailed descriptions of the anatomy are available *(Getty, 1975; Gilbert, 1966; Leman et al., 1992; Poppesko, 1977; Sack, 1982)*.

The anatomic and physiologic characteristics of swine have made them a valuable animal model of human diseases as well as a model for general mammalian physiology. The systems that are most often studied experimentally are the cardiovascular, digestive, integumentary and urinary *(Stanton & Mersmann, 1986; Swindle, 1983; Swindle, 1992; Swindle, 1998; Swindle & Adams, 1988; Tumbleson, 1986; Tumbleson & Schook, 1996)*. Interest in the development of models using other systems is rapidly increasing because of the decreased availability and rising costs of other species such as nonhuman primates and dogs. It is likely that comparative descriptions of other systems will appear increasingly in the literature. The interest in swine as xenograft transplant donors is also likely to increase their characterization physiologically and at the molecular level *(Institute of Medicine, 1996; Swindle, 1998)*.

Swine can not replace all other large animal models in biomedical research, however, they are at least as similar to humans for many types of studies which use species such as ruminants and dogs. Consequently, they can be selected as a general mammalian model unless other models have been shown to develop unique physiologic responses to experimental manipulations.

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To: Top of Document | Acknowledgements | Introduction | How to Use This Document | Comparative Anatomy and Physiology of the Pig Bibliography | Web Resources on Swine

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**XENOGRIFIC TRANSPLANT**


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Web Resources on Swine

- **Articles, Pamphlets and Handbooks**

- **Bibliographies**

- **Books**

- **Courses/Learning Modules/Techniques**

- **General Swine Sites and Related Links**

- **Genetics and Breeding**

- **Journals**

- **Proceedings**

- **Literature Databases**

- **Model Research**

- **Organizations**

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**Articles, Pamphlets and Handbooks**

- **Is Outdoor Housing an Enriched Environment for Pigs?**
  http://www.nal.usda.gov/awic/newsletters/v7n3/7n3morro.htm#outdoor
  From the article *Environmental Enrichment for Dairy Calves and Pigs* by Julie Morrow-Tesch, Ph.D.

- **Recognition of Pain in Farm Animals**
  http://www.nal.usda.gov/awic/newsletters/v5n1.htm
  Article by James E. Breazile, M.A., D.V.M., Ph.D. in the Animal Welfare Information Center Newsletter Special Issue on Farm Animals in Research and Teaching.

- **Research Articles on Pigs**
  http://www.grandin.com/references/pigs.html
  A listing of articles compiled by Temple Grandin, Ph.D., expert in livestock handling and facility design.

- **Swine Care Handbook**
  http://www.pork.org
  The purpose of this handbook is to provide pork producers with current information on swine care practices that are recommended for safe, humane, and efficient pork production. Subjects covered include: husbandry, handling, breeding, environmental management, facilities and equipment, feeding and nutrition, and herd health management. Produced by the National Pork Board and revised in 2002.

- **Welfare Concerns for Farm Animals Used in Agricultural and Biomedical Research and Teaching**
  http://www.nal.usda.gov/awic/newsletters/v5n1.htm
  Article by Janice C. Swanson, Ph.D. in the Animal Welfare Information Center Newsletter Special Issue on Farm Animals in Research and Teaching.


**Bibliographies**


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**Anesthesia and Analgesia for Farm Animals: January 1989 - January 1995**

400 citations in English from the AGRICOLA database. Search page for swine terms (swine, pig, piglet, sow).

**Animal Models in Biomedical Research: Swine - 1994**

Contains citations regarding the use of swine as biomedical models compiled from a variety of scientific and agricultural sources dating from January 1980 to September 1990.

**Information Resources for Livestock and Poultry Handling and Transport: 1990 - December 1998**

Reference guide to information available on the handling and transport of farm animals. Separate section on swine references and videos.

**Environmental Enrichment Information Resources for Laboratory Animals: 1965-1995**

Articles and bibliographic citations included on a variety of laboratory species including swine.

**Housing, Husbandry, and Welfare of Swine: January 1991 - January 1995**

306 citations compiled from the AGRICOLA database.

**Housing, Husbandry, and Welfare of Swine: January 1991 - January 1994**

244 citations compiled from the AGRICOLA database.

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**Books**

**Amazon.com Pig Books**

Browse a number of swine books available for purchase online.

**Handbook of Animal Models in Transplantation Research**

Surgical handbook that provides detailed information concerning the transplantation of a variety of tissues in experimental animals, including swine.

**The Laboratory Swine**

Addresses the biology, husbandry, management, veterinary care and research application of the laboratory swine.
Swine Nutrition, Second Edition
http://www.crcpress.com:80/us/product.asp?sku=0696+++&dept%5Fid=1
A comprehensive reference that covers all aspects of the nutrition of pigs. Also suitable as an advanced undergraduate or graduate textbook.

Surgery, Anesthesia, and Experimental Techniques in Swine
Practical technical guide for the use of swine in biomedical research.

Swine as Models in Biomedical Research
Publication based on the proceedings of the Seventh Charles River International Symposium. Recognized experts in the use of swine as biomedical animal models present overview talks in their areas of interest.

Courses/Learning Modules/Techniques

Bleeding and Intravenous Techniques in Pigs
http://oslovet.veths.no/teaching/pig/pigbleed/
Teaching materials from the Norwegian Reference Centre for Laboratory Animal Science & Alternatives.

Farm Animals as Models for Biomedical Research VSC 443/543 - Fall 2002
http://www.ahsc.arizona.edu/uac/notes/classes/farmmodels/farmanim_as_biomodels02.html
Basic notes on the use of swine and other species as models for biomedical research.

IACUC Learning Module: Swine
http://www.iacuc.arizona.edu/training/swine/index.html
Notes on swine health, mating, gestation, and parturition, standard laboratory procedures, and euthanasia.

Swine Animal Models for Human Disease and Research Uses. I. Introduction
http://netvet.wustl.edu/species/pigs/pigmodel.txt
Notes on comparative anatomy and disease models of swine.

General Swine Sites and Related Links

NETVET Swine Links
http://netvet.wustl.edu/pigs.htm
Veterinary and animal related. Very comprehensive with many links.

Pig Health Website
http://www.PIGHEALTH.COM/
Searchable website which includes information on pig health, swine welfare, hogs management, pork safety, etc.

Swine Resources
http://www.ansi.okstate.edu/library/swine.htm
Provided by the Oklahoma State University, Animal Science Department Virtual Library.
Genetics and Breeding

Pig Genome Mapping
http://www.projects.roslin.ac.uk/pigmap/pigmap.html
Hosted by the Roslin Institute, Edinburgh, Scotland.

Breeders' World Livestock Directory on Swine
http://www.breedersworld.com/swine/index.html
Complete online livestock directory.

Review of Swine Genetics in the U.S.
http://www.nsif.com/Conferences/1995/review.htm
Article by Larry D. Young, USDA-ARS, U.S. Meat Animal Research Center Clay Center, Nebraska.

Swine Breeds
http://www.ansi.okstate.edu/breeds/swine/
An educational and informational resource on breeds of swine throughout the world. Provided by the Oklahoma State University, Department of Animal Science.

US Pig Gene Mapping Coordination Program
http://www.animalgenome.org/pig/
Links provided to swine gene databases, swine gene maps, and species comparative gene maps.

Journals

Current Veterinary Serials
http://www.bib.umontreal.ca/
Provided by the Faculte de medecine veterinaire, Universite de Montreal. Includes over 160 veterinary journals with the tables of contents added daily upon the receipt of new issues.

The Pig Journal on CD
Originally known as the Proceedings of the UK Pig Veterinary Society.

Lab Animal
http://www.labanimal.com
Lab Animal is a peer-reviewed journal for professionals in animal research, emphasizing proper management and care.

Laboratory Animals
http://www.lal.org.uk
Journal dedicated to the advancement in laboratory animal science, technology, and welfare.

Scandinavian Journal of Laboratory Animal Science
http://biomedicum.ut.ee/sjlas/index.html
Published by the Scandinavian Society for Laboratory Animal Science (Scand-LAS) whose aim is to further the progress of Laboratory Animal Science (LAS) in the Nordic countries.

Swine Health and Production
https://aasv.securesites.net/shap/guidelines.pdf
Refereed journal published bimonthly by the American Association of Swine Veterinarians.

Proceedings

Literature Databases

MinipigBase Literature Database
http://www.minipigs.dk/
  Consists of references on the use of miniature pigs in biomedical research.

Selected Databases for Biomedical, Pharmaceutical, Veterinary and Animal Science Resources
  Descriptive listing of free and for fee based databases.

Model Research

Ronald O. Ball, Ph.D.
http://www.utoronto.ca/nutrisci/faculty/Ball/
  Research interests in amino acid metabolism in swine and humans. Developed a unique surgically prepared piglet model for enteral and parenteral nutrition.

Institute of Experimental and Transplantation Surgery
http://www.unimi.it/engl/institutes.htm
  Selected publications listed on small bowel and liver allotransplantation in the pig.

Sinclair Research Center
http://www.sinclairresearch.com/
  Provides research facilities and services to the human health and biomedical industries. Swine models developed for research in diabetes, osteoporosis, atherosclerosis and other areas.

John G. Webster, Ph.D.
http://www.engr.wisc.edu/bme/faculty/webster_john.html
  Conducts research on electrode design for cardiac tachyarrhythmia ablation. Swine are used as models.

Organizations

Association for Assessment and Accreditation of Laboratory Animal Care (AAALAC) International
http://www.aaalac.org
  Contains complete information on AAALAC's accreditation program along with other news and resources for the animal care and use community.
American Association for Laboratory Animal Science (AALAS)
http://www.aalas.org
Forum for the exchange of information and expertise in the care and use of laboratory animals.

American Association of Swine Veterinarians (AASV)
http://www.aasv.org/
An educational professional society organized to increase the knowledge of veterinarians in the field of swine medicine, practice, etc.

American College of Laboratory Animal Medicine (ACLAM)
http://www.aclam.org
Organization of board certified veterinary medical specialists who are experts in the humane, proper and safe care and use of laboratory animals. Also establishes standards of education, training, experience and expertise necessary to become qualified as a specialist and recognizes that achievement through board certification.

American Society of Laboratory Animal Practitioners (ASLAP)
http://www.aslap.org
Promotes the acquisition and dissemination of knowledge, ideas, and information among veterinarians and veterinary students having an interest in laboratory animal practice.

Canadian Association for Laboratory Animal Science (CALAS/ACSAL)
http://www.calas-acsal.org/
Composed of a multidisciplinary group of people and institutions concerned with the care and use of laboratory animals in research, teaching and testing.

Canadian Council on Animal Care (CCAC)
http://www.ccac.ca/
Information on primary goals and many publications online. The page is in English and French. Includes full text of CCAC Guide to the Care and Use of Experimental Animals, Livestock Codes of Practice, transgenic animals, etc.

Federation of European Laboratory Animal Science Association (FELASA)
http://www.felasa.eu/
Composed of independent European national and regional laboratory animal science associations.

International Council for Laboratory Animal Science (ICLAS)
http://www.iclas.org
An international scientific organization dedicated to advancing human and animal health by promoting the ethical care and use of laboratory animals in research worldwide.

Institute for Laboratory Animal Research (ILAR)
http://dels.nas.edu/ilar/
Prepares and makes available scientific and technical information on laboratory animals and other biological research resources to the scientific community, the federal government, and the public.

NETVET
http://netvet.wustl.edu/org.htm
Includes veterinary and animal related information. Very comprehensive with many links.
Information resources on swine in biomedical research

The Animal Welfare Information Center, Contact AWIC
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