Carl G. Hartman Award. The 2006 recipient of the Carl G. Hartman Award is Dr. R. Michael Roberts. Dr. Roberts is internationally recognized as a leader in the field of reproductive biology. His remarkable contributions span the fields of animal agriculture, biotechnology, reproductive biology, and human and veterinary medicine. His work during 15 years at the University of Florida and 21 years at the University of Missouri has focused primarily on the molecular events of early recognition of pregnancy, particularly in cattle and sheep.

Dr. Roberts, who holds a Ph.D. in plant sciences from Oxford University, joined the University of Florida in 1970. There he met Dr. Fuller Bazer, and together they started working on uterine secretory proteins. One of the first proteins they identified was uteroferrin, a deep purple, ironbinding protein that is an extremely potent acid phosphatase. The Roberts-Bazer research group illustrated that the probable role of uteroferrin during pregnancy in pigs is not as an enzyme but, instead, as a source of iron for the fetus. This discovery was of monumental importance since neonatal iron deficiency is a major nutritional problem in the swine industry. The Roberts laboratory later showed that uteroferrin is identical to a class of lysosomal enzymes known as the tartrate-resistant acid phosphatases (TRAPs). His group was the first to purify, sequence, and then clone the human TRAP. Since TRAP is elevated in the serum of patients with high rates of bone turnover, TRAP immunoassays are beginning to be used in the screening of postmenopausal women for osteoporosis, a condition that afflicts at least 20 million women in the United States alone. This development is a direct outcome of Dr. Roberts's initial description of the human spleen and bone enzymes.

After studying a number of uterine proteins, the Roberts- Bazer research team concentrated their efforts on the elusive antiluteolytic embryonic factor secreted by the pre-implantation conceptuses of domestic ruminant species, which had initially been recognized as a protein by Jacques Martal. The factor, which was purified from the medium after culturing conceptus flushed from the maternal uterus, was initially named either ovine trophblast protein-1 (oTP-1) or bovine trophoblast protein-1 (bTP-1), depending on the source, and was capable of extending the estrous cycle when injected into the uterine lumen of nonpregnant animals. Purification of the oTP-1 and production of a specific antiserum allowed cDNA libraries to be screened and, in 1987, the eventual identification of oTP-1 and bTP-1 as type 1 interferons, resembling interferon-alpha and -beta. Until that time, interferons had only been known as antiviral agents, induced briefly following an infection. The conceptus interferons were the first cytokines shown to have a role in a constitutive developmental process. Ultimately, these antiluteolytic factors became known as interferon-tau.

In 1985, Dr. Roberts moved to the University of Missouri. By then he had extensive experience in protein biochemistry and was steadily gaining experience in molecular biology. He focused his laboratory's efforts initially on the cloning of oTP- 1 and bTP-1,

determining the number of their functional genes, mapping and sequencing some of these genes, and defining their regulatory regions and particularly how their promoters differed from those of the virally inducible interferon- alphas and -betas.. His laboratory and those of others also produced large amounts of pure recombinant bovine and ovine interferon-tau, allowing the physical, biochemical, and biological properties of these proteins to be examined and their effects on reproductive parameters to be tested.

By the early 1990s, Roberts had realized that the conceptus interferons, now officially known as interferon-tau, had a restricted distribution and were not found in all eutherian mammals. Instead it became apparent to him and others in the field that the ruminant artiodactyls (sheep, cattle, goats, deer), which exhibit minimal trophoblast invasion of the maternal endometrium, had evolved a unique means of rescuing the corpus luteum during early pregnancy that involves the production of interferon-tau. His laboratory calculated that the interferon-tau genes had originated quite recently, at about the time that the lineage to ruminants became established, and were still evolving at an unusually high rate. Dr. Roberts further studied the transcriptional control mechanisms that restrict interferon-tau gene expression to the mononucleate cells of the trophectoderm for a limited period between blastocoel formation and the time of definitive attachment of the trophoblast to the uterine endometrium. His laboratory cloned and characterized the interferon-tau receptors from the endometrium of cattle and sheep and showed that they were identical to the receptors responsible for signal transduction initiated by other type 1 interferons. The laboratory also began to study other rapidly evolving families of genes found in the placenta, and identified trophoblast Kunitz domain proteins (TKDP) and, with Jean-Francois Beckers, the pregnancy-associated glycoproteins (PAG). The latter are used as the basis for a biochemical test for pregnancy in ruminants, especially in dairy cattle.

Some of the most recent work from the Roberts laboratory is on sexual dimorphism in embryos, and, in particular, how the diet of the mother at around the time of conception may have a role in determining the sex of offspring. Evidence for this hypothesis came in association with Cheryl Rosenfeld from mice, in which a diet very high in fat, but nutritionally complete, was seen to bias the litter toward males, whereas a diet high in carbohydrates led to female-dominated litters. Litter sizes are not altered and are the same as those in chow-fed animals. Dr. Roberts is particularly excited by this phenomenon because it might allow sex of offspring to be manipulated by diet in livestock species. The Roberts laboratory is also studying the differentiation of human embryonic stem cells and particularly their conversion to trophectoderm. Finally, his group has recently shown that the lineage to trophectoderm may already be pre-patterned within the oocyte during mouse embryonic development.

The high quality and exceptional productivity of Dr. Roberts's research program is clearly evident upon review of his publication record. He has authored or co-authored 254 papers in a variety of refereed journals and 72 book chapters and invited reviews, and with his collaborators been granted two patents. His international reputation as an innovative scientist and his well-known willingness to discuss his research findings have resulted in invitations to make presentations at 180 seminars and symposia during the

past 25 years. These have included invited addresses to national societies. In particular, he was the 2nd Sydney Asdell Lecturer at Cornell University in 1990, the Amoroso Lecturer at the meeting of the Society for the Study of Fertility in 1994, the Nalbandov lecturer at the University of Illinois in 2000, and the keynote speaker at the Annual Meeting of the Society for the Study of Reproduction in 2001.

The research accomplishments of Dr. Roberts have been recognized by numerous awards. These include the SSR Research Award (1990), NIH MERIT Award (1990–2000), USDA Distinguished Scientist (1992), Milstein Award from the International Society for Interferon and Cytokine Research (1995), Alexander von Humboldt Award (1996), and Wolf Prize for Agriculture (2003). He was included in the *Scientific American* ‘‘Top 50’’ list for accomplishments in research and technological leadership in 2005.

Dr. Roberts’s research has been supported continuously by the National Institutes of Health since 1972 with several grants, including a Career Development Award and a 10-year MERIT Award. He has also been funded continuously from the USDA since the inception of the USDA competitive grants programs, and has received research funding from six different companies.

Dr. Roberts’s dedication to research is not confined to his laboratory work. He served as a member of the NIH Reproductive Biology Study Section (1987–91), on the advisory panel of NSF (1984–87), and as a grant reviewer for MRC (UK), MRC (Canada), Veterans Administration, Wellcome Foundation, and Melon Foundation. He has served as chief scientist with the Competitive Grants Program for the U. S. Department of Agriculture (1998–2000). He has organized a number of high-quality scientific meetings such as the Gordon Research Conferences on Reproductive Tract Biology (1986, 1988). He has trained 25 Ph.D. students and over 30 postdoctoral trainees over his career at Florida and Missouri. Many of his students have become professors at prominent universities or research leaders in government agencies. These students themselves have won numerous honors and awards.

Dr. Roberts has served SSR in various capacities. He has been a Director (1993–96), chair of the Membership Committee (1985–86), and member of the Program Committee (1992). As a member of the Editorial Board of *Biology of Reproduction* (1986–90) and reviewer of numerous manuscripts, he has helped make BOR one of the most prominent journals in the field of reproduction.

Recognition of Dr. Roberts’s great scientific contributions, his leadership, and the high esteem in which he is held by his scientific colleagues was expressed by his election to membership in the National Academy of Sciences in 1996.

In summary, Dr. Roberts is a world-class scientist with astonishing drive and critical follow-through that have contributed greatly to the advancement of reproductive biology and to the benefit of society.