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Potential practical implications of nanotechnology in animal reproductive biotechnologies

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Abstract

This review focus on the potential benefits, threats, and challenges of nanotechnology in animal reproduction. The investigation of gamete cells in high-resolution, production of nanobiosensors, and development of nanosystems aiming the sustained release of gonadotropins and steroid hormones are only some few examples of growing interest areas. Current facts and future prospects have highlighted the great potential of nanotechnology in reproduction field. Emerging concepts and technologies will be contextualized, reviewed, and explored in this review.

Keywords: nanoparticles, nanotechnology, sustained release systems.

Introduction

Nanotechnology is an exciting scientific and technological area that is considered one of the hot topics of the 21st century (Toumey, 2014). This emerging field is about the rational investigation and potential uses of the matter at the nanometer scale (Toumey, 2014). Nanostructures developed by rational approaches are among the most impressive manmade materials and exhibit unique chemical, physical, and/or biological features (Albanese *et al*., 2012). These features allow the nanostructures to be used for an unprecedented number of applications ranging from electronics and agriculture to medical and health care (Gupta *et al*., 2013). It is also noteworthy that nanotechnology has begun to blossom in the field of reproduction and fertility (Chen and Yada, 2011; Verma *et al*., 2012). In this way, the aims of these nanotechnology-based investigations related to animal reproduction are: i) characterize the nanoscale features of gamete cells using atomic force microscopy and related scanning probe microscopy techniques (Carvalho *et al*., 2013); ii) develop nanobiosensors for detection of physiological or altered (pathogens and diseases) reproductive status (Monerris *et al*., 2012); iii) develop chemical approaches for production of metal nanoparticles for fertility control applications (Jha *et al*., 2014); iv) develop nanodevices for secure cryopreservation of gametes and embryos (Wang *et al*., 2014); and v) develop sustained release systems of molecules, including hormones, vitamins, antibiotics, antioxidants, nucleic acids, among others (Weibel *et al*., 2014). The goal of all these innovative efforts is not just to be able to characterize and manipulate the matter on nanoscale, but also develop products and processes with economic, social, and environmental value added with emphasis on the development of solutions to animal reproduction challenges.

Atomic force microscopy as a tool for investigation of reproductive cells

Atomic force microscopy (AFM) is a powerful high-resolution technique for imaging the surface topography of biological samples, including live and fixed cells, allowing the surface topography imaging at subnanometer resolution and the elucidation of the interactions at molecular level (Silva and Rech, 2013). Due to its capability to observe nanometric details of the samples, AFM has revolutionized the perspective in which microscopists explore biological structures and processes from micrometric cells to nanometric biomolecules (Silva, 2005). In fact, AFM is redefining the concept of microscopy and emerging as complementary and even sometimes foremost tool in several scientific areas, including reproduction science (Carvalho *et al*., 2013). The shape, size, and nanoroughness are only some few examples of the number of primary characters that could be obtained from gamete cells (spermatozoa and oocyte) using AFM (Carvalho *et al*., 2013). The extraordinary benefits that AFM can offer for studying the nanoscale features of cells represent a significant advance for the future on the cell biology of the reproduction.

Nanobiosensors for the detection of reproductive status/stages

Nanobiosensors are very sensitive devices equipped with immobilized probe biomolecules and which are made up of nanomaterials, such as nanoparticles, nanotubes, nanowires, nanofibers, and others (Monerris *et al*., 2012). Nanobiosensors are mainly applied in environmental monitoring and clinical diagnostics (Sagadevan and Periasamy, 2014). The development and validation of nanobiosensors for the detection of diseases, pathogens, oestrus, hormone

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levels, and metabolites profile provide to such systems the status of an important and promising tool for reproductive management (Monerris *et al*., 2012). Critical advances are made every year in nanobiosensors for reproduction processes; however, these advances must ultimately reach the reproductive chains. Insights from the current and ongoing studies will help research and development professionals in bringing new products to the market.

Sustained release nanosystems for the delivery of reproductive hormones

The development of nanostructured systems facing the delivery and sustained release of molecules towards specific targets represents a frontier area of nanoscience and nanotechnology (Joanitti and Silva, 2014), with the possibility of contributing substantially to advances in animal reproduction. Nanoparticles, nanoemulsions, nanogels, nanocapsules, and liposomes are among the most common forms of administration of bioactive molecules based on nanobiotechnology (Joanitti and Silva, 2014). Currently, nanostructured delivery systems have been intensively developed and evaluated due to several advantages shown in biological applications (Bonifácio *et al*., 2014). Overall, nanosized delivery systems enhance the therapeutic efficacy of several bioactive molecules, including reproductive hormones, by simply improving their pharmacokinetic and/or pharmacodynamic properties. These systems are able to carry a wide variety of molecules enhancing their sustained release, showing low systemic toxicity, allowing targeted treatment, and avoiding premature inactivation or degradability of bioactive compounds which are sensitive to light (e.g. vitamins), oxidation (e.g. steroid hormones), and/or hydrolysis (e.g. gonadotropic hormones; Joanitti and Silva, 2014). The true impact of such nanosystems on reproduction will be really measured only in the next decades.

Nanostructures for the sterilization of animals

Despite the advantages associated with the use of nanoparticulate systems in order to optimizing the reproductive performance, it is largely accepted that some nanoparticles (e.g. metal nanoparticles) can elicit toxic and deleterious side effects towards living organisms (Love *et al*., 2012). However, this toxicity may also be used for reproduction technologies on the basis of contraceptive approaches (Jha *et al*., 2014). Since several metals, including cadmium, at low to moderate concentrations may lead to sterility in a dose-dependent fashion, the delivery of metals as nanoparticles to reproductive organs remains as a wide field to be explored by researchers. Metal nanoparticles can be actively driven to reproductive and related organs (e.g. pituitary) by targeting molecules (e.g. antibodies) or using some physical characteristic (e.g. magnetic field-based delivery of magnetic nanoparticles) and thus avoiding or at least minimizing the systemic toxicity (Manuja *et al*., 2012).

Nanosystems for cryopreservation of gametes and embryos

Cryopreservation of gonadal tissues, sperm, oocytes, and embryos has brought about novel and exciting research field in animal reproduction (Saragusty and Arav, 2011). The use of biocompatible metal nanoparticles for cryopreservation of cells and tissues may become the next step of cryopreservation technologies to achieve ultra-fast cooling rates and also allow rapid and homogeneous rewarming of the biological materials under near physiological conditions. However, there are an incipient number of studies carrying out the use of nanoparticles for cryopreservation of cells and tissues (Wang *et al*., 2014). Thus, a huge number of innovative possibilities are opened to fulfill this and meet cryopreservation area expectations.

Conclusion

Nanotechnology in animal reproduction is a growing and flourishing field for research and development. This emerging field offers outstanding opportunities for challenging researchers to provide new solutions to old issues, and has potential to demonstrate continuous forward progress in the next years.

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