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The Convergence of Nanotechnology, Biotechnology and Cancer Medicine in the Fourth Industrial Revolution

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Medical technologies of the fourth industrial revolution (Industry 4.0), such as nanotechnology, biotechnology, artificial intelligence (AI), 3D printing and advanced materials are already transforming medical technology and the pharmaceutical industry by offering accurate diagnoses, targeting therapies with fewer side effects, and providing better medical imaging and personalised medicine. Industry 4.0 will be driven by the convergence and synergy of innovative technologies, including nanotechnology and biotechnology, and not by these technologies working in isolation. Nanotechnology is defined by others as the prime mover of Industry 4.0. It provides new tools that boost the performance and functionality of other emerging technologies, while offering unique properties to these technologies. While biotechnology deals with the manipulation of molecular and biological systems and processes to make or modify products and services, the advantage of using nanotechnology is that it deals with the creation and manipulation of the chemical and physical properties of a substance at the nanoscale and molecular level (i.e. 1-100 nm). These characteristics of nanotechnology and biotechnology allow for the treatment of complex health conditions, such as cancer, whose early diagnosis and targeted treatment provides for better patient prognosis.

The convergence of nanotechnology and biotechnology

The intersection of nanotechnology and biotechnology created a new subject - i.e. nanobiotechnology or bionanotechnology or nanobiology. The role of nanotechnology in this convergence is to equip biotechnology with tools and materials that can interact directly with biomolecules. In medicine, the convergence of these two technologies offers innovative solutions to unmet needs such as early detection of disease, rapid diagnostics, imaging, target delivery and personalised medicine. In addition, nanotechnology will allow biological scientists to recognise, measure and interact with single biological events, changing the dynamics of diagnosis and treatment. The convergence of nanotechnology and biotechnology is maturing and currently progressing at a rapid rate, particularly in cancer medicine.

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The convergence of nanobiotechnology and cancer nanomedicine

The number of cancer cases are on the rise in Africa, with the most common being cancers of the cervix, breast, liver and prostate, as well as Kaposi's sarcoma and non-Hodgkin's lymphoma. Approximately 14 million people were diagnosed with cancer and more than 8 million people died from various cancers in 2012. More than half these cases, and almost two-thirds of deaths, occurred in Africa and other low to middle-income regions. It is estimated that these numbers will increase to approximately 22 million cases and 13 million deaths by 2030. The growth of cancer cases on the continent can be attributed, amongst various factors, to population growth and lifestyle changes - smoking, unhealthy diets, physical inactivity, obesity, etc. Infection is also important in the pathogenesis of cancers especially in Africa. The WHO estimates that 22-24% of cancers are due to infectious aetiologies.

Most cancer cases are diagnosed at an advanced stage in Africa, which contributes to poor prognoses. Furthermore, there is a scarcity of cancer treatment (over 20% of African countries have no access to medications and access is sporadic in others) and limited access to conclusive diagnoses at various healthcare facilities on the continent. With a general move towards technology-based solutions globally, tackling the rising cancer crisis in Africa by using technologies that will drive the fourth industrial revolution should be explored.

The challenge of treating various cancers is that most types of cancer can only be detected once the tumour has already developed, making very early detection difficult with prognosis then being worse as treatment is then less effective. The convergence of nanobiotechnology and cancer nanomedicine has immense potential towards the advancement of early diagnosis and hence

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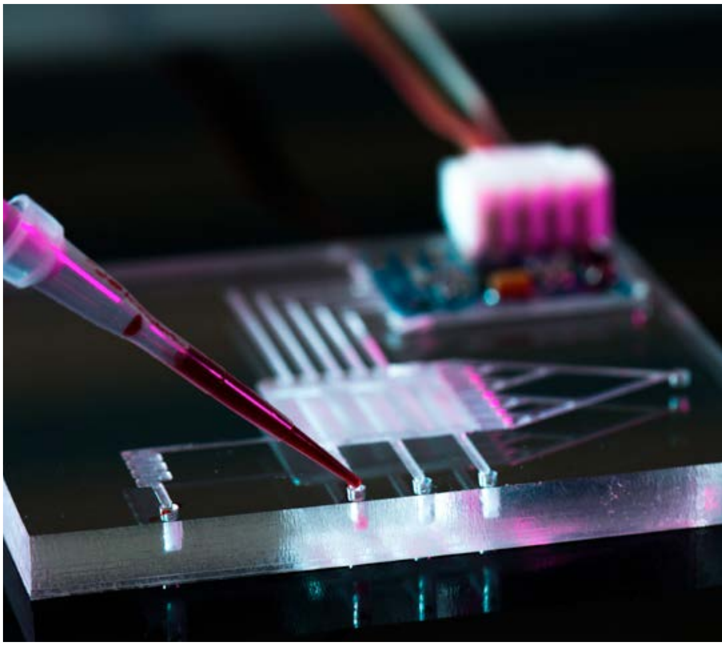
more effective treatment for cancer patients. Nanobiosensors and quantum dot imaging are examples that promise better approaches towards identifying cancer at an early-stage, before the tumour develops. Nanobiosensors and quantum dot technologies are highly sensitive and biospecific, with the capability to detect a specific cancer through cell-surface biomarkers. Furthermore, bionconjugated quantum dots can detect small numbers of malignant cells in the early stages of cancer or metastasis, which is very difficult with current imaging techniques such as X-ray imaging, magnetic resonance imaging (MRI), and computed tomography (CT).

Another advantage of using nanobiotechnology in combating cancer includes targeted drug delivery - i.e. the capability of delivering anticancer drugs to where they will be most effective. Nanoparticles incorporated with active pharmaceutical ingredients (APIs) can be surface functionalised with different biological ligands such as proteins, monoclonal antibodies, folic acid, carbohydrates, fructose, and receptors so that they can be localised at the cancer sites, without affecting the normal cells and/or healthy tissues. Targeted drug delivery reduces side-effects while improving drug safety and effectiveness. This means better cancer treatments, less medications and lower costs. The use of nanoparticles to deliver the CRISPR-Cas9 gene editing tool holds promise for cancer treatment by deleting and/or editing the defective genes that cause cancer. The arrival of fully autonomous DNA nanorobots, that are capable of transporting anticancer drugs, to target and destroy tumours, will revolutionise the way cancer is treated in the 21st century.

Although nanotechnology promises endless opportunities in medicine, one cannot discount that this emerging technology might have unintended effects on human health and the environment. Nanoparticles are relatively new; their risks are largely unknown due to insufficient data on possible risks, therefore there is a need for further studies to explore the long-term harmful effects on both human health and the environment. In recent studies, researchers have found that inhaling airborne nanoparticles, or oral or dermal exposure to some nanomaterials, may lead to pulmonary diseases and/or induce skin aging through oxidative stress. The gap between the development of nanotechnologies and nanoethics is wide: there remains a substantial lack of suitable and thorough risk and life cycle analyses of nanotechnologies. Thus, due to unknown long-term impacts on both health and the environment, many countries are starting to look at the establishment of a nano code of conduct for nanotechnology research and development (R&D) to protect students, research participants, patients and the environment. To support sustainability for nanomedicine or nanotechnology, R&D will require implementation of a nano ethical code of conduct that includes educating the public about the benefits, limitations and perils associated with this emerging technology. Essentially, the regulation of nanotechnologies needs to be firm enough for effective nanoethics, but also flexible enough to allow for innovation. ■



A lab-on-a-chip (LOC) is integration device with several laboratory functions - Image