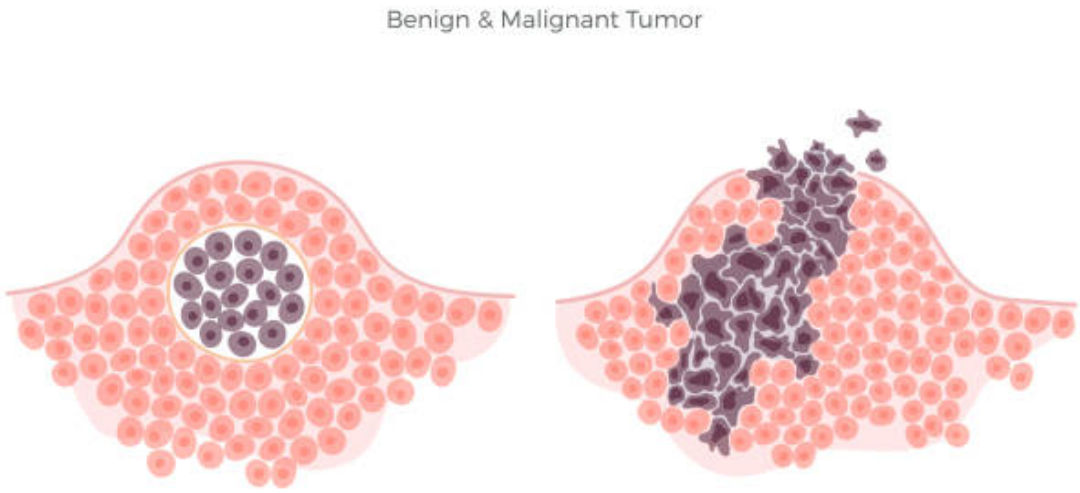
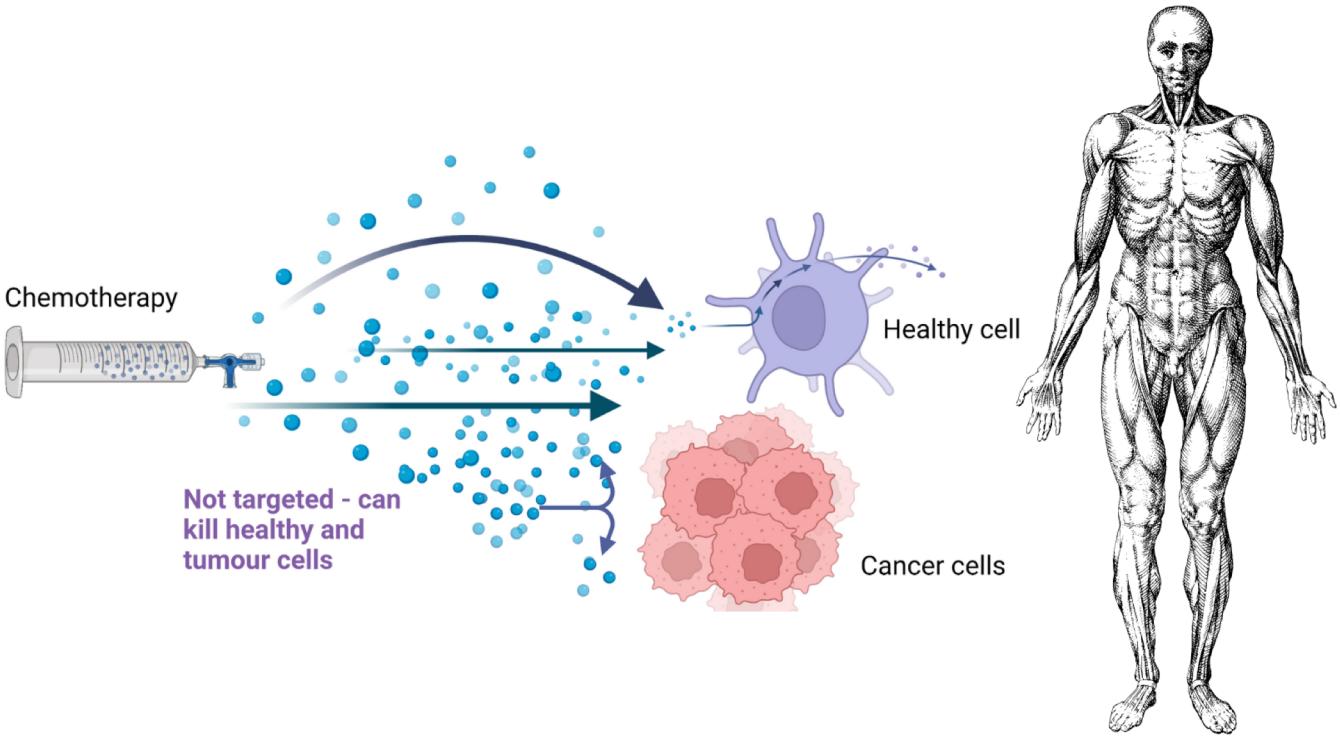
UKRI TAS NODE IN FUNCTIONALITY

Cancer occurs when abnormal cells divide in an uncontrolled way

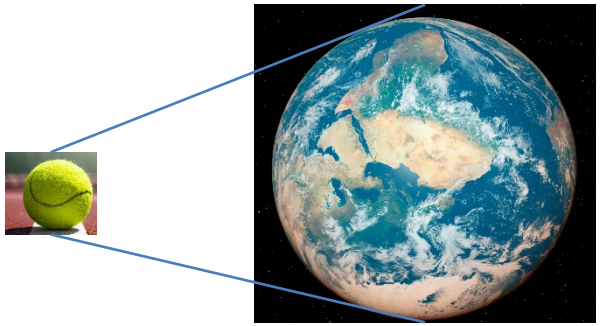


Traditional Chemotherapy

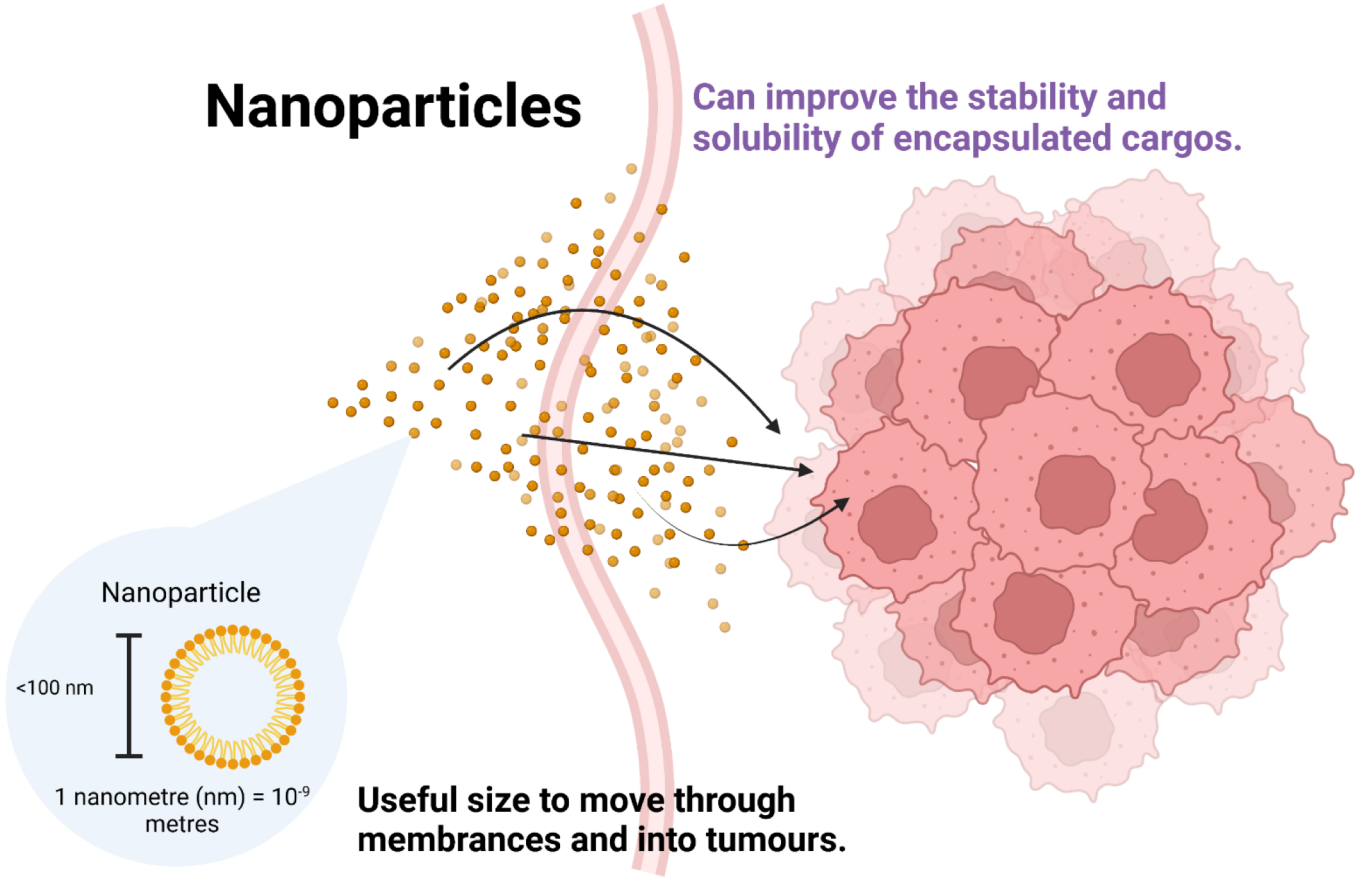


Cancer Nanomedicine

- The medical application of nanotechnology to treat cancer



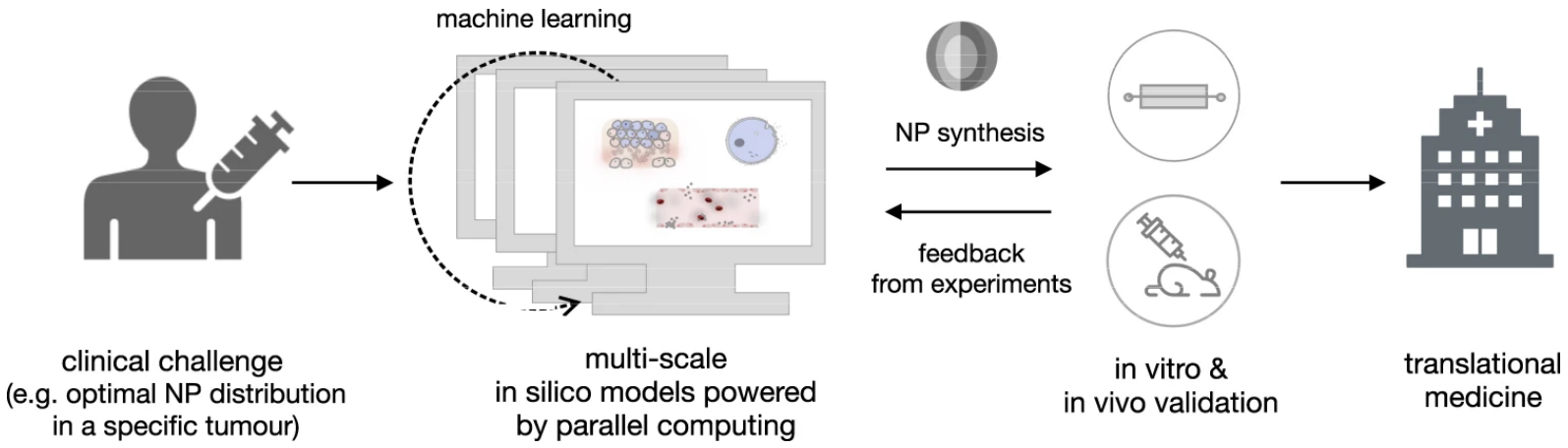
- Deals with matter at dimensions between approximately 1 and 100 nanometers.



Nanoparticles can assist the delivery of chemotherapy drugs to a tumour.

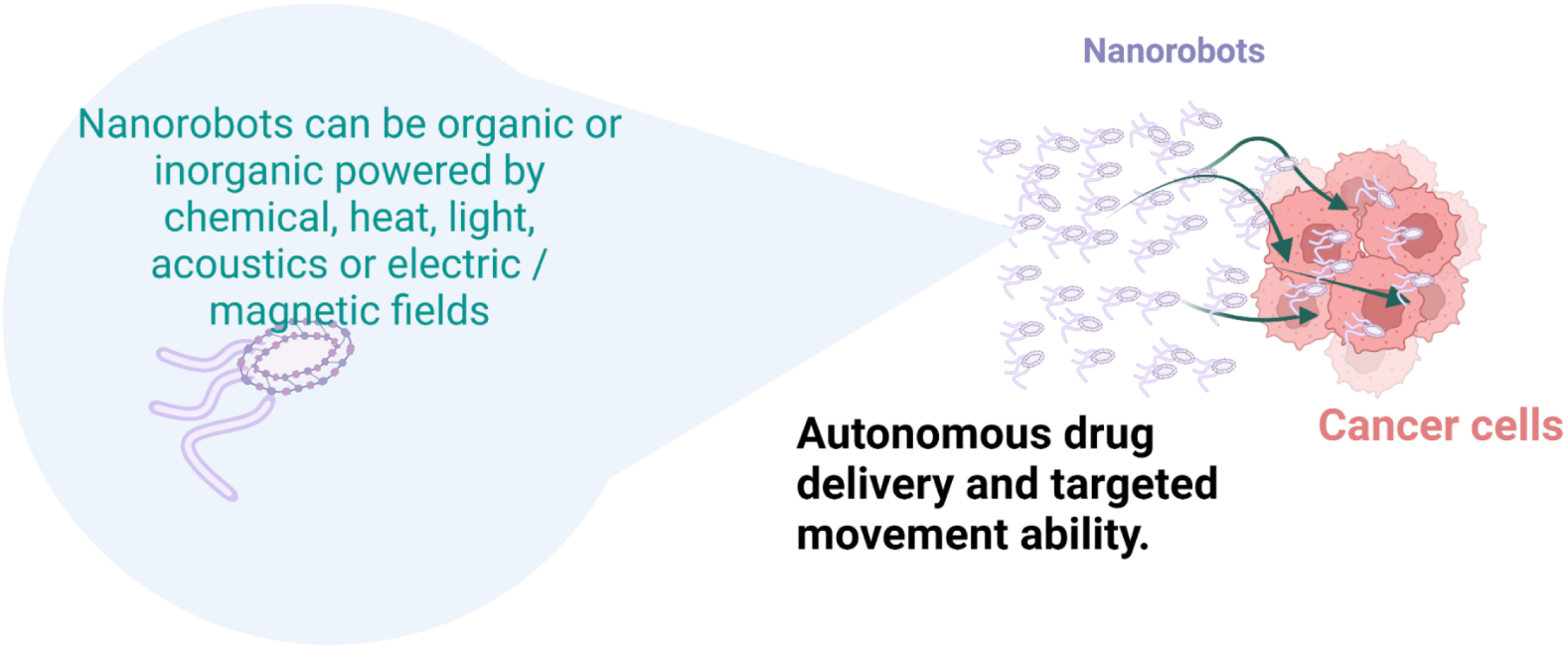
Systems Nanomedicine

Clinical Translation using in silico models to select nanoparticle design



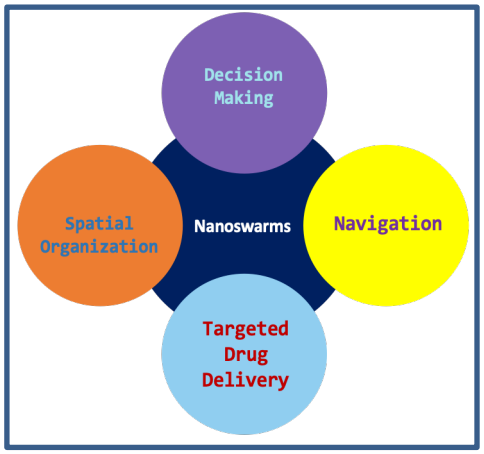
Stillman, N.R., Kovacevic, M., Balaz, I. et al. In silico modelling of cancer nanomedicine, across scales and transport barriers. npj Comput Mater 6, 92 (2020). https://doi.org/10.1038/s41524-020-00366-8

Nanorobots



Nanobots are nano-sized entities that can control their motion and interactions with the environments.

Nanoswarms take inspiration from swarms in nature



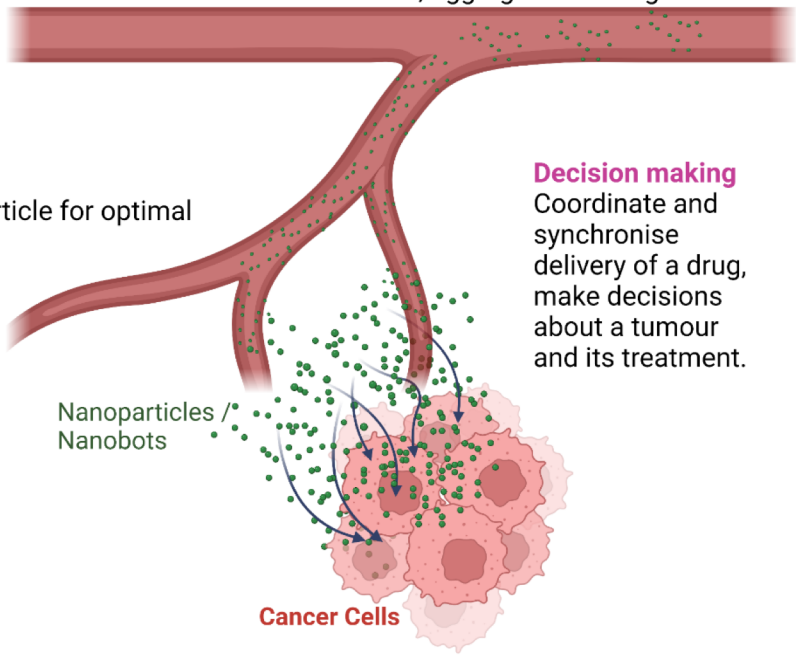
Nanoswarms

Cooperative/ Collective behaviours exhibited by nanoswarms.

Navigation
Find and target a tumour cell using mapping, collective motion, aggregation or migration.

Optimisation
Selection of best nanoparticle for optimal drug delivery.

Decision making
Coordinate and synchronise delivery of a drug, make decisions about a tumour and its treatment.



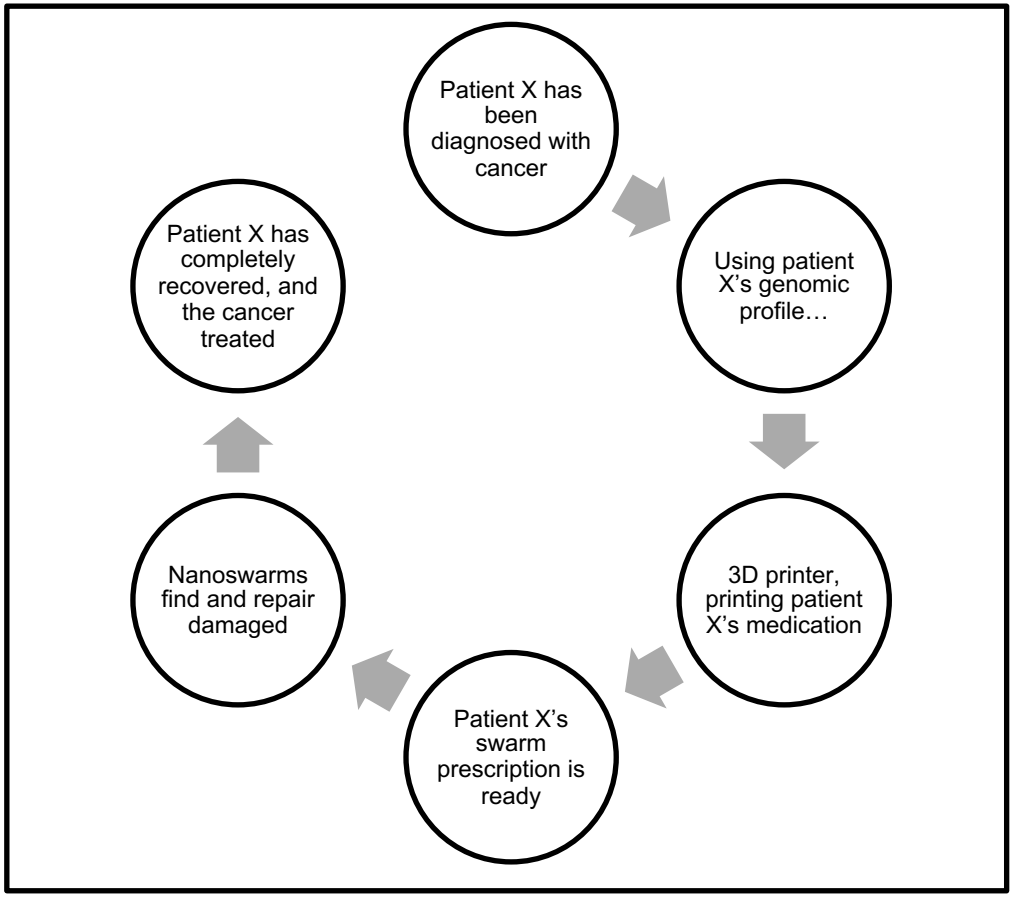
S. Hauert and S. N. Bhatia, “Mechanisms of cooperation in cancer nanomedicine: towards systems nanotechnology,” Trends Biotechnol, vol. 32, no. 9, pp. 448–455, Sep. 2014, doi: 10.1016/J.TIBTECH.2014.06.010.

Micro-nanorobotics can use three methods of eradicating a tumour

- carry, deliver and release drug in a tumour
- activating or simulating the immune system against a tumour
- mechanically kill a tumour and induce cell death

Schmidt CK, Medina-Sánchez M, Edmondson RJ, Schmidt OG. Engineering microrobots for targeted cancer therapies from a medical perspective. Nat Commun. 2020 Nov 5;11(1):5618. doi: 10.1038/s41467-020-19322-7. PMID: 33154372; PMCID: PMC7645678.

“Here’s your swarm prescription”

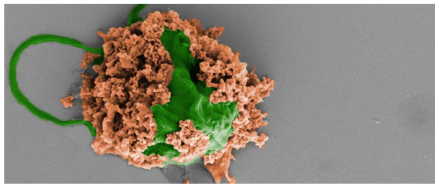


Swana, M., Blee, J., Stillman, N., Ives, J., Hauert, S.: Chapter 12. Swarms: The next frontier for cancer nanomedicine. Emergence, Complexity, Computation, Vol. 46, Igor Balaz and Andrew Adamatzky (Eds): CANCER, COMPLEXITY, COMPUTATION. Springer; 1st ed. 2022. 978-3-031-04378-9

Where are we now?

Tiny Robots Have Successfully Cleared Pneumonia From The Lungs of Mice

HEALTH 27 September 2022 By DAVID NIELD



The microbot, with the algae in green and the nanoparticles in brown. (Fangyu Zhang and Zhengxing Li)

Scientists have been able to direct a swarm of microscopic swimming robots to clear out pneumonia microbes in the lungs of mice, raising hopes that a simila treatment could be developed to treat deadly bacterial pneumonia in humans.

Article | Published: 22 September 2022

Nanoparticle-modified microrobots for in vivo antibiotic delivery to treat acute bacterial pneumonia

Fangyu Zhang, Jia Zhuang, Zhengxing Li, Hua Gong, Berta Esteban-Fernández de Ávila, Yaou Duan, Qiangzhe Zhang, Jiarong Zhou, Lu Yin, Emil Karshalev, Weiwei Gao, Victor Nizet, Ronnie H. Fang, Liangfang Zhang & Joseph Wang

Nature Materials (2022) | Cite this article

1957 Accesses | 680 Altmetric | Metrics

Abstract

Bioinspired microrobots capable of actively moving in biological fluids have attracted considerable attention for biomedical applications because of their unique dynamic features that are otherwise difficult to achieve by their static counterparts. Here we use click

Bionaut Labs wins humanitarian use device designation to treat rare pediatric brain disorder

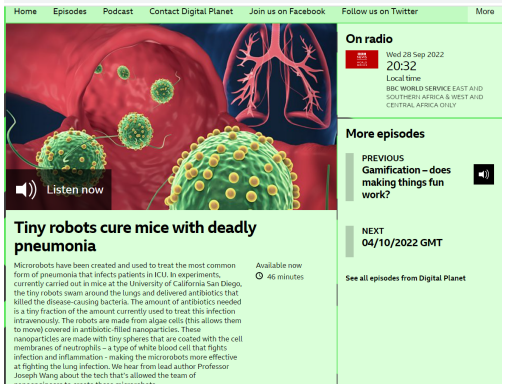
otember 23, 2021 By Brian Buntz

crorobotics startup Bionaut Labs has announced that A has granted a humanitarian use device designation for e device known as BNL-201 to treat Dandy-Walker ndrome, a congenital brain malformation affecting the rebellum.

cording to the National Organization for Rare Disorders, e syndrome affects one out of every 25,000 to 35,000 live ths.

ere are currently few treatment options for the condition. urgically-placed cerebral shunt can relieve excess fluid in

A Bionaut prototype. The final device may undergo alteration based on FDA feedback. (Image courtesy of Bionaut Labs)



Enzyme-powered nanorobots behave like a swarm

29 June 2021 | Cordelia Sealy

A microrobotic system guided by photoacoustic computed tomography for targeted navigation in intestines in vivo

Wu, Zhiguang and Li, Lei and Yang, Yiran and Hu, Peng and Li, Yang and Yang, So-Yoon and Wang, Lihong V. and Gao, Wei (2019) *A microrobotic system guided by photoacoustic computed tomography for targeted navigation in intestines in vivo*. Science Robotics, 4 (32). Art. No. eaax0613. ISSN 2470-9476. PMCID PMC7337196. doi:10.1126/scirobotics.aax0613. https://resolver.caltech.edu/CaltechAUTHORS:20190724-151755826

Living robots made from frog cells can replicate themselves in a dish

Swarms of tiny "xenobots" can self-replicate in the lab by pushing loose cells together – the first time this form of reproduction has been seen in multicellular organisms

FDA Grants Humanitarian Use Device Designation to Bionaut Labs for Treatment of Dandy Walker Syndrome

September 23, 2021

First-in-class Bionaut™ treatment modality will use remote-controlled microscale robots to treat rare pediatric neurological disorder

Company also appoints renowned expert in targeted therapeutics and former Kite CEO Aya Jakobovits, Ph.D., to its advisory board

LOS ANGELES, Calif., September 23, 2021 – Bionaut Labs, a company focused on revolutionizing the treatment of central nervous system (CNS) disorders with its Bionaut™ precision medicine treatment modality, today announced that the U.S. Food and Drug Administration (FDA) has granted the Company humanitarian use device (HUD) designation for BNL-201 for the local

RESEARCH ARTICLE | APPLIED SCIENCES AND ENGINEERING

Magnetically steerable bacterial microrobots moving in 3D biological matrices for stimuli-responsive cargo delivery

MUKRIME BIRGUL AKOLPOGLU, YUNUS ALAPAN, NIHAL OLCAY DOGAN, SAADET FATMA BALTACI, ONCAY YASA, GULSEN AYBAR TURAL, AND METIN SITTI Authors Info & Affiliations

SCIENCE ADVANCES · 15 Jul 2022 · Vol 8, Issue 28 · DOI: 10.1126/sciadv.abo6163

Swarms of Nanobots for in vivo Diagnosis of Endogenous Diseases

Nanorobot is any artificial machine with overall size of the order of a few micrometers or less in all spatial directions and constituted by nanoscopic components with individual dimensions in the interval 1-10^2 nm [14]. The exploitation of nanobots for medical application was already discussed in the late 1960 (e.g., in the movie *Fantastic Voyage*), and in the last 10 years it has become a matter of scholar debate (see [5] for a recent review).

A major challenge is the design of nanobots:

Surgical intervention

Drug

Classification?

Medical device

Something else

Software as a medical device

The nanoswarm dual-use dilemma

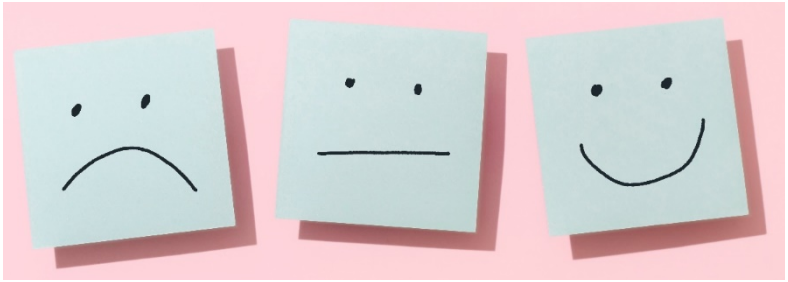
Potential Harm

Privacy and confidentiality

Enhancement vs therapy

Military weapon

Health inequality



Benefits

Knowledge

Targeted treatments

Disease monitoring

Other

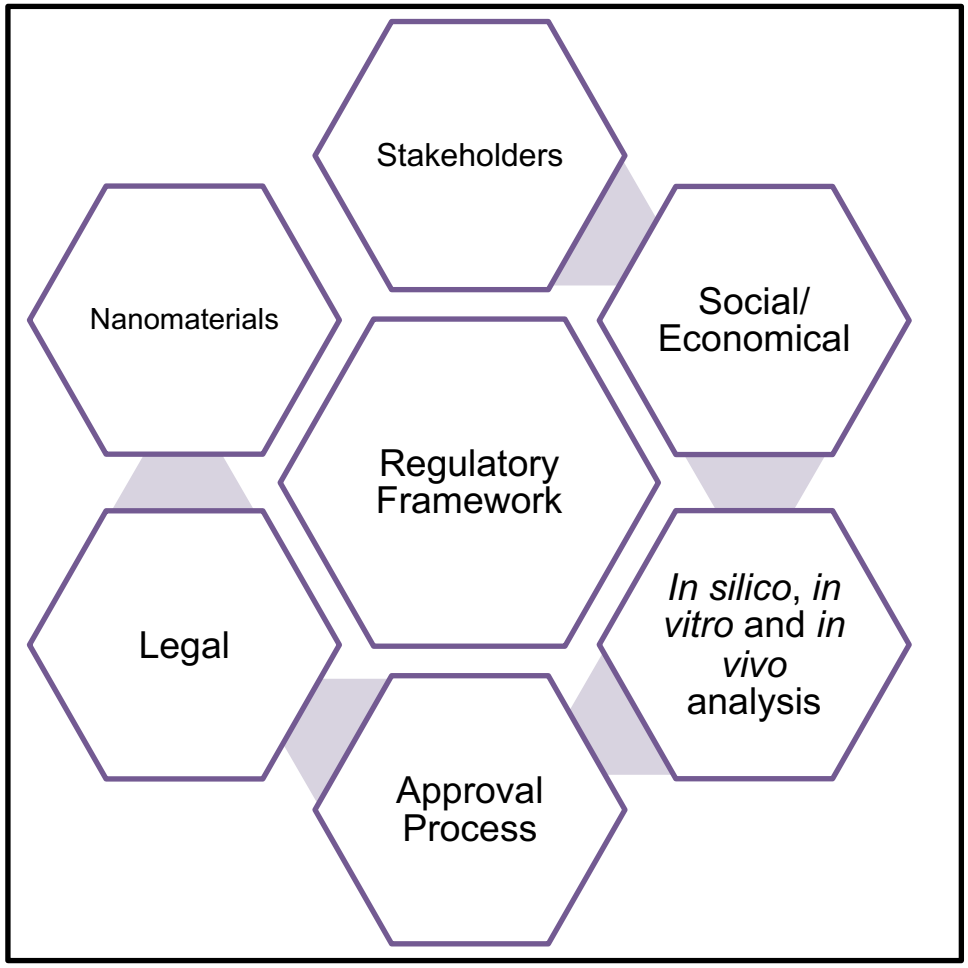
Direct-to-consumer therapies

Hippocratic Oath for Software Engineers

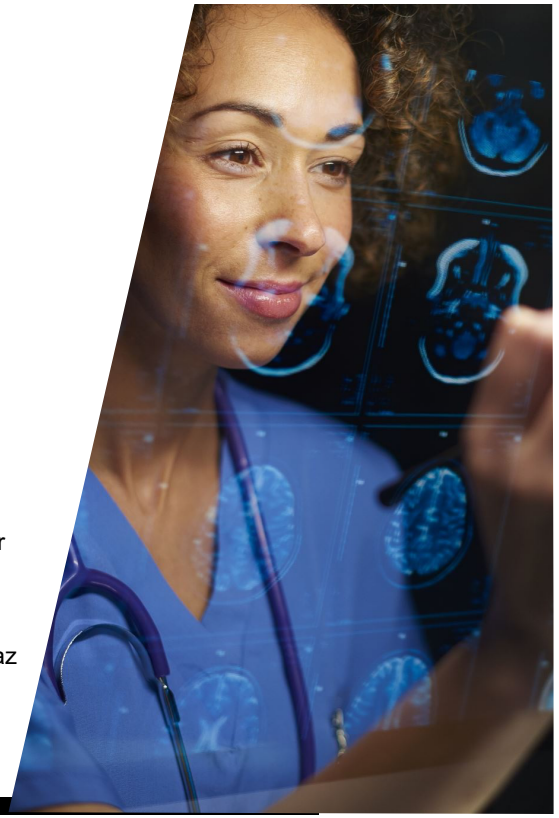
Considerations

- Create a set of standards for AI-driven cancer therapies such as nanoswarms
- Embedding bioethics into policy from the beginning
- Ensuring regulation that does not hinder innovation

Key regulation and guidance domains



Swana, M., Blee, J., Stillman, N., Ives, J., Hauert, S.: Chapter 12. Swarms: The next frontier for cancer nanomedicine. Emergence, Complexity, Computation, Vol. 46, Igor Balaz and Andrew Adamatzky (Eds): CANCER, COMPLEXITY, COMPUTATION. Springer; 1st ed. 2022. 978-3-031-04378-9



What will the first-in-human cancer nanoswarm clinical trial look like?