I'm J. Justin Gooding, founding Co-Director of the Australian Centre for NanoMedicine. I'm here to talk about sensors, what's happening scientifically, and their applications in health, environmental and food monitoring. AMA!

AmerChemSocietyAMA [1] and r/Science AMAs[1]

[1]Affiliation not available

April 17, 2023

Abstract

Hi Reddit! I'm a Scientia Professor at UNSW in New South Wales, Australia. I co-founded and co-direct the Australian Centre for NanoMedicine (ACN), a group that brings together experts in engineering, medicine, and science to solve big problems in human health. My research focuses on surface modification, biosensors, functional nanomaterials, cell-based diagnostic devices, and electroanalysis. I'm helping develop things like portable diagnostic devices, 3D cell bioprinters, and other cool stuff. My research group at UNSW specializes in ways to modify sensor surfaces at the molecular level. We use self-assembled monolayers, biological molecules, and nanomaterials to make sensors do things like selectively detect analytes, influence biological processes, and communicate electrically with biological molecules. I'm also the editor-in-chief of ACS Sensors, a brand-new journal that will publish the latest and greatest work in sensor science. Look for our first issue online in January 2016. This is a really exciting time for sensors research. Many experts think the global sensors market will surpass $110 billion by 2019. Much of this money will come from the many applications of "personalized medicine." For example, single-molecule sensors are about to explode. We could use them to find out immediately whether a patient will respond to a particular cancer treatment. We may also see sensors used in environmental and food monitoring. On the other hand, as a field we're constrained by what sensors can currently do, and are having trouble making certain types of sensors commercially viable. So ask me anything about this diverse, interdisciplinary field: biosensors, chemical sensors, gas sensors, intracellular sensors, single-molecule sensors, cell chips, arrays, or microfluidic devices. I'm happy to answer your questions about how sensors affect our everyday lives, as well as about the future challenges and directions facing our field. I will be back at 3:00pm ET (5:00am my time in Australia, please wake me gently).

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American Chemical Society AMA: I'm J. Justin Gooding, founding Co-Director of the Australian Centre for NanoMedicine. I'm here to talk about sensors, what's happening scientifically, and their applicat

AMERCHEMSOCIETYAMA R/SCIENCE

ABSTRACT

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NanoMedicine layman here... how realistic is it to hope that nanotechnology will replace certain medicines or treatments all together? Chemotherapy, as an example, is a horrible experience for anyone to go through. If your technology can identify cancer cells might they also be able to one day treat them specifically?

And then if this would one day be possible, how many years will it be until this is our reality?

And what can we do to help?

crtjester

And what can we do to help? This is an excellent question. The answer is realistic as we already have nanomedicines on the market and in clinical trials and most of these relate to cancer treatment. We could subdivide nanomedicine into three broad areas, 1) drug delivery or therapy, 2) sensors and

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imaging and 3) regenerative medicine where biomaterials a redeveloped that help the body regenerate itself. When most people think of nanomedicine they think of drug delivery and we have about 40 different drug delivery particles, typically I would refer to them as drug delivery vehicles, in the clinic already or in clinical trial. Most of these are liposomes loaded with drugs, lipid based particles, or polymer particles.
There is a good review on this at http://onlinelibrary.wiley.com/doi/10.1002/wnan.1257/abstract

If we think of sensors that use nanomaterials being used in sensors then again there are a number of technologies being developed that could be regarded as nanomedicine technologies. If we think of monolayers of molecules as nanotechnology, which they are generally regarded as, then there are even more sensing devices on the market that could be regarded as nanomedicines.

As for how you can help, I say learn a bit about the field. To research and study nanomedicine I suggest studying the fundamental sciences, chemistry, biology, physics in places where research into nanotechnology is strong.

Thank you for your time.

In your opinion how big of a problem is oxidation in nanomedicine?

Do you find oxidation having an impact such as degrading certain molecules before they can perform their intended function?

Also do you know of any sensor which can detect and or measure oxidation levels in a person? Which can be seen as a marker for inflammation or even autoimmune disorder.

desalinate
Nanodevices typically have high surface area so if oxidation is an issue for material then oxidation can be a problem. This can be solved using a material that does not oxidise. However, I think you are referring to the generation of oxidative species in the body and the detection of these species. There is a lot of research into sensors for reactive oxygen species, you can read about this at

Methods Mol Biol. 2013;1028:3-14. doi: 10.1007/978-1-62703-475-3_1.

As for nanomedicines promoting active oxygen species, I think it is important to be aware that nanomedicines undergo the same rigourous evaluation of their safety and efficacy as other medicines when placed in the body. People working in these fields really worry about issues of safety and efficacy.

Young grad student here really excited about field of rapid biosensors and health diagnostics. Two questions! As I get up to speed with the field reading literature it seems we are inundated with papers on clever designs and assays or modifications of existing diagnostic methods with only a fraction of them being adopted into scaled devices for market use. How would you advise a scientist's research approach to make their research market translatable? Second, clearly you are able to identify what research is 'about to explode' ... any tips for us non-editor-in-chiefs on how to identify what new research will be transformational in 5-10 years? Excited to add ACS Sensors to my reading list!

justkeepbiking
Regarding the first question, this is actually a fantastic question. There are many not only clever but incredibly effective biosensing technologies that never get to the market. This could be for a myriad of reasons. For example, it might be the market is not big enough, a figure I have heard mentioned is it might take 100 million dollars to get a device to market and therefore the market needs to be many times bigger than that. This is the main reason glucose biosensors are so successful. The lateral flow

devices, popularised by pregnancy test kits have served as an inspiration, philosophically for my research group. These are successful because the technology can be applied to many different analyte and so the risk of bringing a new technology to the market is spread across these analytes. So one of the things my group does is target what we call generic technologies, technologies that can be applied to many different species you want to detect. However, there may be other reason the device doesn't get to market. The regulatory environment might not have created the market or taken the market away. Or you might not find the right partners at the right time. Or can't convince them the technology is the opportunity you are looking for. What I have learnt is that often whether a technology can be commercialised might come down to the will, or skills, of the industrialist/entrepreneur. Saying all this, one thing often forgotten is many biosensors are incredible measurement tools and a lack of market still could mean they are incredibly valuable for scientific discovery.

How to spot what will be hot. Partly this is knowing the field, partly seeing where people are going but I think bigger issues are looking for where the challenges/problems are and addressing how to solve them in innovative ways. Abstract I know but I hope that helps.

One of the major issues in nanomedicine has been the problems in patent protection. Will this result in companies being hesitant to develop or research into this industry? Do you see the patent protection problems being resolved soon?

adamreddy
I think patents facilitate technology to be developed as they give the people taking the financial risk more confidence that they can benefit form that risk. Of course patents are designed to lock up technology to a given owner but I think without that people will be less inclined to develop the technologies.

Slightly off the medical field but given the amount of ICE fueled assaults in our casualty departments, are sensors likely to ever assist in tracking clandestine labs? Given a number of the precursor materials are volatile, and complete masking almost impossible, will it ever be possible to pinpoint labs? I'm imagining a grid of sensors throughout an area.

Cremasterau
This question really touches on one of the biggest challenges in sensing. Not detecting ICE but how do you make devices that can detect really low amounts of species. If we were to have grids of sensors detecting volatiles, as they dissipate from the source they become very dilute. To detect them becomes a major challenge. Also the more dilute something the larger the sample size required for reliable analysis which means the technology must be able to respond rapidly while analysing larger volumes. A big challenge. People work on these challenges but there is more work to do. It also relates to detecting small amounts of species in rivers, lakes etc as well. So I think regarding the question, I wouldn't say never but....

When do we get those mini nano-machines that go into our bodies?

joleplayer1
Well I would arguer that we are made using nanomachines as I think of proteins as nanomachines. But being less glib, as I commented to an earlier question we have some drug delivery vehicles that are already on the market. I think my main point here is in nanotechnology you think of machines differently to macromachines as different operating principles must apply.

What are biosensors made of? And how are they controlled?

lazylearner

Sorry missed this one. You name it biosensors can be made of it. I think the essential thing that defines a biosensor are two components. The first is a biological species that five the sensor it selectivity for the target species to be detected. This could be an enzyme as in the glucose meters, an antibody as in the pregnancy test kits, part of a protein, a whole cell or a sequence of DNA as in gene chips. The only component is a device that determines the extent of the reaction between the biology and the analyte and converts that to an electronic signal for the end user. We call this the transducer. This could be an electrode, an optical fibre or spectrometer, a mass sensitive device and something that measures the temperature during the reaction. Well anything that can measure the reaction actually and give you the information in a way you can digest. In most glucose meters it is an electrode. In the pregnancy test kits it is your eyes seeing small beads.

Dear Prof. Gooding,

I would like to ask a question on the role of nanotechnology in modern medicine today. Is it more about enabling new application that cannot be done via old methods, or is it more about improving existing applications? In your opinion, how will nanotechnology shape medicine in the future?

Thank you for your time on this AMA!

isison
I think it is both. Is a drug delivery vehicle that delivers an existing drug, in a targeted fashion, to the site of a pathology an improvement on existing applications or allowing us to do something completely new? I would probably argue both. I think new nanotechnologies that allow us to detect things inside the body is a new paradigm in measurement. I think technologies that encourage the body to repair itself is something we could not do before.

Will pollution be a problem a decade or so down the road?

spainguy
I too am assuming you are referring to nanomaterials persisting in the environment. This is certainly an issue to be concerned about and to ask questions about. I think it is no different to other species we develop going into the environment. Sometimes smaller may mean less of an issue, sometimes more. I think the main thing is for scientists not to ignore the issue. One approach that can be taken is to develop nanomaterials that degrade to benign product if possible. In my group we use a lot of silicon which in the body and water based fluids degrades to orthosilic acid which is the natural form of silicon in the body.

Do you expect it ever to be possible to detect analytes in the blood stream from a detector placed on the surface of the skin?

boomanwho
Another I missed. This one is a real tough one. In some cases yes. Light in the near infrared can pass through the skin for a centimeter or so and this is one strategy that might work. The other strategy I can think of is the nanopatch technology being developed in a number of groups around the work for vaccines amongst other things. These are small microprojections that pass through the skin without any pain and can collect analyte just below the skin. Such technologies can and are being applied to sensing so these would do the trick.

Non-Medical Sensors. I've been thinking of how chemical sensors could be implemented in atmospheric science -- there are few that have been deemed to be of a sufficient sensitivity for analysis of the types of compounds that are present in the atmosphere. In addition, there must

be a way to log the state of the chemical sensor - and when I think of chem sensing, I think low cost. I would imagine that the logging device (I hesitate to call IT a sensor!) could drive cost up quite significantly in some cases. Have there been solutions or major efforts on the 'detection' end of the chemical sensing field that drive costs back down? Is this simply locked up in the strength of the sensor's response to its chemical environment or the analyte of interest? For context, in atmospheric chemistry/climate, one thinks of inexpensive sensors as a tool for network deployments. Developing low cost sensors with sufficient capabilities for analyzing the trace concentrations of chemicals in the atmosphere (or in rain perhaps?) could be a major boon to the field in terms of spatial coverage. Any thoughts?

dbcollins
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This is a complex but excellent question. Low costs is a key driver for some applications. It all comes down to the information that is needed and how valuable it is. There has certainly been a push into paper based devices to reduce costs for resource challenged environments. For environmental sensing or water analysis one way to reduce the cost is to make sensors multi-use. This can be really challenging if the devices are interfacial, requiring something to selectively bind with a surface to give a signal, because fouling the surface can limit the long term use. Saying that, in gas sensing for example this is a well addressed challenge and we have many gas sensing technologies on the market that are multiuse. It is less easily achieved when fluids are involved but still has been achieved. Regarding, the IT side, I am not an expert on this but certainly, people are addressing and thinking about these problems. In fact many of the major computing/IT companies have developed software packages for distribute networks of sensors. One of the things about that is what do you send, a constant stream or refined/processed data. The latter, sending refined information, harks back to your thoughts on does it add cost. I think it will but it may not as sending more data also costs and so sending refined packages of information may in fact reduce costs. Just a thought. I think one of the reasons we have less sensors for environmental analysis than we would like is the question of who pays. We seem less inclined to pay for sensors for the environment than those that will directly save our lives.

Can we use sensors to control plant metabolism and ultimately plant growth and development?

badmooie
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Tough question. Sensors are of course for monitoring not necessarily controlling but the information they provide can tell you how to respond to something. So in principle yes. I suppose if you think of thermometers as sensors we already do this to some degree. I think with plant monitoring whether you have them or not will partly come down to cost versus benefit.

What do you consider to be the most promising emerging area of research in nanomedicine over the next decade, and why?

jbarnes222
I think one could argue that all areas of nanomedicine are promising. Certainly the most hype, most interest and most activity revolves around drug delivery. From y biased perspective I suppose I think nanodiagnostics/nanosensors is the most promising. Why? Well because sensors are designed to tell you whether there is an issue or not. So they tell you whether treatment is required. The earlier we can detect an issue is coming the more effective a therapy can be. For example we know many cancers are treatable id we detect them early enough.

Often in the media, whether general or specifically scientific, graphene is being hailed as a new super material. How do you see potential uses for this substance in your field? Will it allow for implementation of new techniques, processes, or developments once the technology matures further? Or is it just a media buzzword, with even more exciting materials just around the corner?

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I think graphene can and will have a major impact but the point of this article is partly to say don't just use it because it is hot, use it where it provides a distinct advantage. This is advice for any new material or technology though. Graphene has some unusual electronic and optical properties that could provide really opportunities in sensing.

I'm sure that you and your colleagues have anticipated dark uses for this tech. Would you comment on your thoughts and ways we might defend ourselves as it becomes cheaper and more prevalent?

Isthatyourfinger
A bit of a loaded question. Virtually all people in science are trying to do things that are positive for the world. We are optimistic people who want to make things better. That does not mean bad things have not been done with technology that has been developed for good. But it is an exceedingly complicated question. Is a technology that detects cancer before any symptoms are evident, such that it can be cured before any harm is done, good. I think most people would think yes. But if that information meant you lost your job because you are regarded as a medical risk that would not be good. That is where governments and regulation come in. The choice I make is to work on technologies where the core purpose is to benefit humanity and where the good clearly outweighs any possible adverse uses of the technology.

Hey professor, thanks for doing this AMA

Recent Biochemistry Grad who's been thinking of going to graduate school to study bioanalytics (it was my favorite course in undergrad). What advice would you give to somebody that's interested in finding a job/getting a graduate degree in this field? Also, how do you feel about implantable bio-sensors? Seems like a really interesting field but I've read that there has to be a lot of precaution when dealing with the materials that the bio-sensor is made of. Thanks for taking the time out of your day to answer our questions, Cheers!

Prot00ls
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I am really glad you are enjoying bioanalytics. One of the great things about science is you can do something that makes a difference, makes the world a better place, improves people's lives. So regarding getting a job or a graduate position, my advice is generic but not intended to be glib. The advice is do well and be passionate about what you do. If you show commitment you will always do well. I think following the direction that gets you inspired, passionate, interested is more important than make choices based on what people tell you will be an easy route to a job. That way you might be one of the people that makes a difference and hopefully you will enjoy your job. Being an academic for example is not an easy route to take but I love my job. I get to work with really optimistics driven people that are doing great things. What could be better than that. Regarding implantables, this is a really challenging field but what difference it could make. There are a few companies that have implantable biosensors on the market so great strides are being made in that direction. And yes, as with any technology put into the body, or anywhere else, safety aspects need to be properly evaluated. Good luck with your career choices.

Hello, I'm an undergraduate student who did research over the summer on using carbon nanotube threads as heavy metal sensors and I'm hoping my work is submitted in a journal within the next month or so. I was wondering if you have seen previous work published on these CNT sensors and what your thoughts were on the potential of using these in real world applications. Thank you for your time.

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Good luck with the paper, I really hope it is accepted. Publishing something is always exciting to me. My group was one of the early groups to use carbon nanotubes in electrochemistry. It was a research program that was highly successful for us. Since then people have made amazing advances and there are carbon nanotube sensing technologies on the market, and lots more work being done. One of the earliest examples was using carbon nanotubes in gas sensing. But there have also been some stunning research papers on detecting single molecules using carbon nanotubes.

Re: "as a field we're constrained by what sensors can currently do, and are having trouble making certain types of sensors commercially viable" ...

With regard to sensors and functionality, can you describe the top three 'practical' problems in your area(s) or breakthroughs you feel would most advance current medical sensor research?

I would like to know if these might align with AI in some respects -- such as more efficient power usage for sensors and learning capabilities for artificial neural networks.

Thanks for your time.

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Thanks for your time.

This is another good but tough question. Three practical problems are probably 1) Surface fouling which causes problems related to reuse and the reliability of the sensor (I alluded to this in an earlier question) 2) Detecting really small amounts of material in a reasonable time frame (I also alluded to this in an earlier question) 3) Multiplexing sensing devices so they can give you a suite of information about a variety of analytes. In my research group we work on trying to solve conceptual challenges in sensing such as these. And we are trying to address all these issues. The first one has mostly been tackled by trying to make better antifouling surfaces but such methods are never perfect and so I think a different way of thinking is required. Regarding all three challenges we are thinking about strategies to detect many single entity events. An entity being a molecule or a cell. That way we will get heterogeneity in signals which complicates the information but the information is also richer and we might be able to tell nonspecific effects such as fouling form the specific sensing event. Or we might be able to find and tell what is different about a rare, aberrant cell. Such approaches might solve all three issues but because of the large amount of data, certainly advances data management methods will be required and this could be AI.