Recent Advances in Human Physiology

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Abstract: The study of human physiology provides important insight into the complex nature of the human body, increasing our understanding of the various systems and processes that occur to keep us alive. Developments in this field provide the basis for the development of novel treatments and therapies that are crucial for the advancement of medicine and improving the health and well-being of people around the world. Recent research into the pathogenesis of SAR-CoV-2 and the discovery of novel treatments for its symptoms have bought this field of science to the forefront. Yet there have also been several other recent advances that have increased our understanding of the human body and provided opportunities for the development of new medicines and therapies. Here we discuss the latest advances in this field, highlighting recent progression in our understanding of cancer metastasis, the development of the brain, and the use of organoids in the study of the human body. Finally, we examine the work of two physiologists that received the Nobel Prize in 2021 for their work in understanding the mechanism behind how humans feel the heat, cold, and mechanical force.

Keywords: physiology, SAR-CoV-2, organoids

Introduction

Antimicrobial Human physiology is a branch of science dedicated to the study of the mechanical, physical, and biochemical functions of the human body. This involves studying the normal function and vital processes of the human body by exploring the functions of its organs and the cells that they are composed of. The study of this sub-section of biology can be traced back as far as 420 BC and covers a range of subjects such as cellular physiology, organ physiology, biological compounds, and anatomy, and the interactions between them that make life possible. Advances in the study of human physiology have uncovered several mysteries about how the body functions, from understanding homeostasis to discovering how signals are sent between different tissues and cells to enable to body to function normally (Kholodenko, 2006; Modell et al.,2015). These discoveries have also increased our understanding of the pathogenesis of many human diseases and subsequently resulted in the advancement of medicine through the development of various treatments and therapies.

In recent years, SARS-CoV-2 has been the focus of many areas of research in human physiology, as researchers have explored the pathogenesis of the virus and developed therapies and treatments to combat the negative health effects that the virus has caused (Cao et al., 2021). In addition, several advances have been made our understanding of how the brain functions, in cancer research, and in the successful use of organoids in replacing animal models (Pun et al., 2021). In 2021, the Nobel Prize in physiology and medicine was awarded to two researchers for their work on understanding how humans feel pain and temperature (Caterina et al., 1997; Coste et al., 2010; McKemy et al., 2002). Here we present a review of these latest advances in human physiology, focusing on how they have advanced our understanding of the human body and where applicable, what this means for the treatment of human diseases.

SARS-CoV-2

Not surprisingly, a lot of the recent work in human physiology has centred around understanding the impacts that SARS-CoV-2, also known as COVID-19, has on the human body. Physiologically, COVID-19 is known to damage several organs and affect some patients' sense of smell and taste as well as causing respiratory disorders (Wu et al., 2020; Wu et al., 2021). Recent results in this field support the hypothesis that COVID-19 infection causes variation in heart rate during the recovery period (Solinski et al, 2022). Further, studies into so-called long covid which look at the long-term impacts of COVID-19 infection have found several mechanisms that could help to explain the COVID-19 linked pathophysiology leading to multiorgan systemic disorder. For example, several studies have established that COVID-19 can cause direct viral tissue damage through entry into cells in the body via an entry receptor called angiotensin-converting enzyme 2 (ACE2). ACE2 is expressed in a variety of cells including epithelial cells, nasal goblet cells, gastrointestinal epithelial cells, and pancreatic β cells (Gupta et al, 2020; Hoffmann et al, 2020). In addition, COVID-19 infection can cause endothelial injury, disrupt the regulation of the immune system, and cause hypercoagulability which can lead to thrombosis (Nalbandian et al, 2021). Research has also shown that COVID-19 can alter the epigenetic age of those infected. Researchers discovered this by comparing the DNA methylation in blood samples taken from COVID-19 patients with those from a healthy population and applying epigenetic clocks and telomere length estimator to the methylation profile of each individual (Cao et al., 2022). Taken together, these recent advances give an insight into some of the long-term impacts that COVID-19 has on the human body and advance our understanding of how this virus operates which can pave the way for novel treatments.

Organoids

Most of the foundational knowledge that we have on human physiology has come from animal experiments but, while animal models have been useful in a lot of studies to date, they are not always suitable, and this is the reason that a lot of clinical trials fail. As a result, organoids are emerging as a good in-vitro model for studying specific viral infections such as COVID-19. Organoids are 3D structures grown from stem cells and under optimal culture conditions these stem cells differentiate to produce a complete arsenal of cell types found in the specific tissue of interest. This has revolutionised physiological studies, providing a model that produces results that are more likely to be indicative of what is happening in reality. For example, Mahalingam et al (2020) used single-cell RNA sequencing data to examine the expression of the entry receptors angiotensin-converting enzyme 2 (ACE2) and transmembrane serine protease 2 (TMPRSS2) to understand their role in SARS-CoV-2 pathogenesis. Their study demonstrates that organoids can be effectively used to study the pathogenesis of SARS-CoV-2 and to screen drugs that could be used to treat it. Building on this, Pei et al (2021) and Tiwari et al (2021) showed that SARS-CoV-2 can infect PSC-derived lung organoids and that the high expression of ACE2 and TMPRSS2 in the cells facilitated both infection and replication of the virus. In addition to studying viral infection and replication, organoids have also been used to examine what conditions predispose people to more severe COVID-19 infection. A recent study using brain organoids showed that those that have ApoE4, a known genetic risk factor for Alzheimer's, are more likely to have a more severe case of COVID-19 (Wang et al, 2021).

Developments in our understanding of the brain

The human brain is responsible for quite a large number of functions that take place within our body and in recent years there have been several significant advances in our understanding of how the brain works. There have been several advances made in understanding the development of the brain. For example, differences in the visual processing areas of infants diagnosed with autism spectrum disorder are apparent at 6 months of age. From this finding, researchers hypothesize that this disruption in visual processing could interfere with how the world appears to these children, affecting both their interactions and the way they learn (Girault et al, 2022). Another study looked to understand how stress, and more specifically the hormone cortisol, impacts the brain during childhood. Blankenship et al (2019) demonstrated that an increase in cortisol in response to a stressor during preschool (age 3 – 5) predicted increased anterior and posterior hippocampal connectivity with parts of the cerebral cortex called the precuneus and cingulate gyrus at school-age (age 5 – 9). This suggests that there are lasting impacts of stress on the brain from a young age. Previous research had led researchers to believe that the brain could adapt to changing situations. However, a recent study has shown that the brain is not as plastic as we once thought. Ortiz-Catalan et al (2020) used electrical stimulation of tactile nerve fibres to restore touch through a bionic hand. Often, attachment of a bionic hand results in misplaced nerve signals and as such the patient feels sensations in a different part of the hand that they are using. The researchers found that over time this could not be repaired, demonstrating that the brain is not as adaptable as we once thought.

Cancer Research

Recent progress in cancer research has identified several mechanisms involved in cancer metastasis. Exosomes are released by all cells as part of their normal physiology, and they can contain microRNAs; mRNAs; and proteins and can carry messages between cells allowing them to communicate. Recently, researchers have shown that exosomes are also released from cancer cells and contribute to cancer growth. For example, exosomes released from cancer cells can destroy the blood-brain barrier which enables it to metastasize to the brain (Cai et al., 2018; Lu et al., 2020). In addition, researchers have found that cancer exosomes can cause new blood vessels to develop in the tumour microenvironment by modulating gene expression which also contributes to metastasis (Yang et al., 2018). Exosomes released by normal cells can also have an impact on how cancer progresses. For example, exosomes released from mesenchymal cells that originated in the bone marrow can cause some cancer cells to become dormant. This is problematic because these dormant cells become resistant to chemotherapy and can be responsible for the disease reoccurring (Ono et al., 2014). Together, this research demonstrates how important exosomes are in the development, metastasis, and reoccurrence of cancer. Exosomes are not the only molecule that is involved in cancer metastasis. Baksh and Finley (2022) recently identified an important early step in the metastasis of a tumour. They found that the variable expression of an enzyme was key to whether a tumour spread.

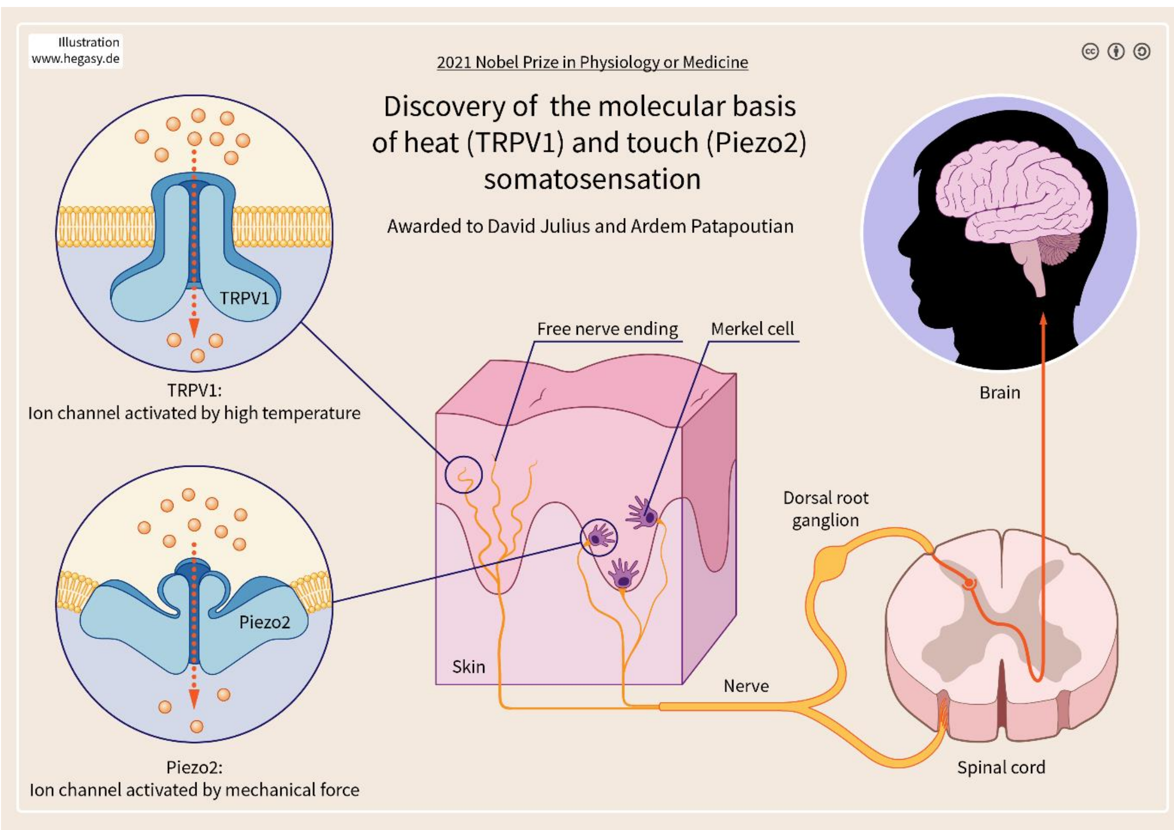

Figure 1: The 2021 Nobel prize was awarded to David Julius and Ardem Patapoutian for discovering the receptors that enable us to sense temperature and touch (Image by Guido4 via Wikimedia Commons).

Nobel Prize 2021

The Nobel Prize in physiology and medicine was awarded to David Julius and Ardem Patapoutian in 2021 for their work that discovered the receptors for temperature and touch. Their work demonstrated the mechanics involved in how humans perceive hot, cold, touch, and pressure through nerve impulses. This was achieved through several independent projects that together provide fundamental insights into how external stimuli and nerve impulses interact. Julius et al identified the cellular target of capsaicin, which is the molecule found in chilli peppers that causes heat (Caterina et al., 1997). By screening a cDNA library from sensory neurons, the researchers identified a novel ion channel that was named TRPV1. This channel was shown to be activated by temperatures perceived as painful. Julius and Patapoutian also independently found a cold-sensitive receptor now known as TRPM8 (McKemy et al., 2002). Several other TRP-receptors have since been identified. Patapoutian and his team discovered ion channels activated by mechanical stimuli by using a functional screen of candidate genes. The researchers identified two ion channels, named PIEZ01 and PIEZ02, that function as mechanical sensors (Coste et al., 2010). Further, PIEZ02 was identified as being the major mechanical transducer in somatic nerves and plays a vital role in our perception of touch and the position and movement of the body. Together, this work by the two laureates has demonstrated for the first time the molecular mechanism involved in sensing heat, cold, and mechanical force.

Conclusions

Recent advances in human physiology have increased our understanding of several processes in the human body and provided the basis for developing novel treatments to combat the symptoms of long covid caused by infection with SARS-CoV-2, for various forms of cancer, and for understanding the impacts that stress can have on a developing brain. In addition, the recent advances in the development of organoids for the study of the human body have shown promise in investigating the development and progression of various diseases and for testing novel treatments, removing the need for animal testing which could reduce the likelihood of treatments failing once they reach clinical trials. Finally, advances in human physiology were recognised in the awarding of the 2021 Nobel Prize to two researchers for their work in understanding the mechanisms behind how humans feel pain, heat, and cold which uncovers the mystery that has baffled researchers for decades.

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Conflicts of Interest

The authors state no conflict of interest.