

Review

Next-Generation TB Vaccines: Progress, Challenges, and Prospects

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Abstract: Tuberculosis (TB), caused by *Mycobacterium tuberculosis* (MTB), is a prevalent global infectious disease and a leading cause of mortality worldwide. Currently, the only available vaccine for TB prevention is Bacillus Calmette–Guérin (BCG). However, BCG demonstrates limited efficacy, particularly in adults. Efforts to develop effective TB vaccines have been ongoing for nearly a century. In this review, we have examined the current obstacles in TB vaccine research and emphasized the significance of understanding the interaction mechanism between MTB and hosts in order to provide new avenues for research and establish a solid foundation for the development of novel vaccines. We have also assessed various TB vaccine candidates, including inactivated vaccines, attenuated live vaccines, subunit vaccines, viral vector vaccines, DNA vaccines, and the emerging mRNA vaccines as well as virus-like particle (VLP)-based vaccines, which are currently in preclinical stages or clinical trials. Furthermore, we have discussed the challenges and opportunities associated with developing different types of TB vaccines and outlined future directions for TB vaccine research, aiming to expedite the development of effective vaccines. This comprehensive review offers a summary of the progress made in the field of novel TB vaccines.

Keywords: tuberculosis (TB); *Mycobacterium tuberculosis* (MTB); vaccines; clinical trials; deep learning



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1. Introduction

Tuberculosis (TB) is an ancient disease widely distributed across the world and is the leading cause of death from bacterial infections [1]. In 17–18th century Europe, TB was known as the “white plague”, with almost 100% of Europeans infected and 25% of them dying from the disease [2]. In 1882, Robert Koch, a German microbiologist, deciphered *Mycobacterium tuberculosis* (MTB) as the etiological factor responsible for TB, thereby opening a new chapter in the prevention, diagnosis, and treatment of TB [3]. With the continuous development of anti-TB drugs and improvements in sanitation and living conditions, the incidence and mortality of TB decreased significantly. However, since the 1990s, the global TB epidemic has worsened due to factors such as the emergence of drug-resistant strains of MTB, the use of immunosuppressive agents, drug addiction, poverty, and population movements [4]. TB has become a leading re-emerging infectious disease and a serious global health problem, especially in developing countries.

Despite the effectiveness of anti-TB drugs, eradicating TB still faces many challenges. On 27 October 2022, the World Health Organization (WHO) Global TB Report showed that approximately one-quarter of the world’s population is infected with MTB [4]. In 2021, the estimated global number of new TB cases was 10.6 million, a 4.5% increase from 2020, and the number of deaths from TB was 1.6 million, a 6.7% increase from 2020 [5]. China is one of the countries with a high burden of TB, with an estimated number of TB cases only second to India and Indonesia, accounting for 7.4% of the global TB incidence [5]. In 2015, the WHO introduced the “End TB Strategy”, a comprehensive plan that outlines ambitious targets for the period of 2020–2035. These objectives include a significant reduction of 90% in the

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Quarterly Economic Review of Hungary ,1984 *Transformations in Hungary* Peter Meusburger,Heike Jöns,2001

During the first decade after the turn towards democracy and market economy Hungary's society experienced profound changes that affected its regions towns villages and individual places in different ways This is documented by thirteen essays that analyse related political legal institutional and socio economic structures and processes in time and space in order to contribute to a further understanding of Hungary's ongoing transformation processes and its current situation as one of the leading candidates for EU membership The topics include constitutive elements of a modern market economy such as banking foreign direct investment entrepreneurship knowledge resources the labour market and the housing market Further essays explore education and income structures the poverty situation post communist voting behaviour regional and urban development as well as Hungary's cross border co operations With regard to European integration processes the role of Budapest within the European city system and Hungary's economic situation within Europe are discussed Drawing together comprehensive empirical data and a great variety of viewpoints this collection of essays offers innovative examples of the application of different theoretical approaches to studies of economy and society in general and transformation studies in particular

Hungary Barry Leonard,1999 Presents a comprehensive look at Hungary's commercial environment using economic political and market analysis Hungary has made significant economic progress and established itself as a good business partner it leads the region in foreign direct invest Report includes economic trends and outlook political environment marketing U S products and services leading sectors for U S exports and investment trade regulations and standards investment climate trade and project financing and business travel Appendices country data domestic economy trade investment statistics U S and country contacts market research and trade events Hungary's Negotiated Revolution Rudolf L. Tökés,1996-09-28 In this book first published in 1996 Rudolf T k s offers a comprehensive overview of the rise and fall of the Kadar regime in Hungary between 1957 and 1990 The approach is interdisciplinary reviewing the regime's record with emphasis on politics macroeconomic policies social change and the ideas and personalities of political dissidents and the regime's successor generation The study provides a fully documented reconstruction of the several phases of the ancien r gime's road from economic reform to political collapse based on interviews with former top party leaders and transcripts of the Party Central Committee T k s gives an in depth account of the personalities and issues involved in Hungary's peaceful transformation from one party state to parliamentary democracy and a comprehensive assessment of Hungary's post Communist politics economy and society Congressional Record United States. Congress,1968 **Everyday**

Nationalism in Hungary Alexander Maxwell,2019-09-23 This book examines Hungarian nationalism through everyday practices that will strike most readers as things that seem an unlikely venue for national politics Separate chapters examine nationalized tobacco nationalized wine nationalized moustaches nationalized sexuality and nationalized clothing These

practices had other economic social or gendered meanings moustaches were associated with manliness wine with aristocracy and so forth The nationalization of everyday practices thus sheds light on how patriots imagined the nation s economic social and gender composition Nineteenth century Hungary thus serves as the case study in the politics of everyday nationalism The book discusses several prominent names in Hungarian history but in unfamiliar contexts The book also engages with theoretical debates on nationalism discussing several key theorists Various chapters specifically examine how historical actors imagine relationship between the nation and the state paying particular attention Rogers Brubaker s constructivist approach to nationalism without groups Michael Billig s notion of banal nationalism Carole Pateman s ideas about the nation as a national brotherhood and Tara Zahra s notion of national indifference

e-Pedia: Game of Thrones (season 6) Wikipedia Contributors,2017-02-22 This carefully crafted ebook is formatted for your eReader with a functional and detailed table of contents The sixth season of the fantasy drama television series Game of Thrones premiered on HBO on April 24 2016 and concluded on June 26 2016 It consists of ten episodes each of approximately 50 60 minutes largely of original content not found in George R R Martin s A Song of Ice and Fire series Some material is adapted from the upcoming sixth novel The Winds of Winter and the fourth and fifth novels A Feast for Crows and A Dance with Dragons The series was adapted for television by David Benioff and D B Weiss HBO ordered the season on April 8 2014 together with the fifth season which began filming in July 2015 primarily in Northern Ireland Spain Croatia Iceland and Canada Each episode cost over 10 million This book has been derived from Wikipedia it contains the entire text of the title Wikipedia article the entire text of all the 593 related linked Wikipedia articles to the title article This book does not contain illustrations e Pedia an imprint of e artnow charges for the convenience service of formatting these e books for your eReader We donate a part of our net income after taxes to the Wikimedia Foundation from the sales of all books based on Wikipedia content

Extraordinary Renditions Andrew Ervin,2010-12-10 Set in Budapest a city marked by its rich cultural heritage the scars of empire the fresher wounds of industry and the collateral damage of globalism Extraordinary Renditions is the sweeping story of three equally tarnished expatriates World renowned composer and Holocaust survivor Lajos Hark lyi has returned to Hungary to debut his final opera and share his mother s parting gift the melody from a lullaby she sang as he was forced to leave his Hungarian home for the infamous Czech concentration camp Terez n Private First Class Jonathan Brutus Gibson is being blackmailed by his commanding officer at the US Army base in Hungary one of the infamous black sites of the global War on Terror and he must decide between going AWOL or risking his life to make an illegal firearms deal in Budapest Aspiring musician Melanie Scholes is preparing for the most important performance of her career as a violinist in Hark lyi s opera but before she takes the stage she must extricate herself from a failing relationship and the inertia that threatens to consume her future As their lives converge on Independence Day they too will seek liberation from the anguish of the Holocaust the chains of blackmail and the bonds of conformity A formidable new voice in American fiction Ervin tackles the big themes of war prejudice and art

lyrically examining the reverberations of unrest in today's central Europe the United States legacy abroad and the resilience of the human spirit Problems of Communism ,1988 **What was Socialism, and what Comes Next?** Katherine Verdery,1996-03-07 By analyzing her primary data from Romania and Transylvania and synthesizing information from other sources Verdery lends a distinctive anthropological perspective to a variety of themes common to political and economic studies on the end of socialism themes such as civil society the creation of market economies privatization national and ethnic conflict and changing gender relations Redeemed Penny Lane,2025-07-30 Penny is just four years old when she is snatched away from her all American home by the Hungarian father who abandoned her when she was a baby After facing isolation and neglect in a strange dysfunctional household where heartache rejection and physical abuse rule her life she escapes only to find herself in a relationship with a man who's just converted to fundamentalist Christianity Penny's road is long winding and often painful but gradually she begins to listen to her inner voice stand up for herself and refuse to bow to the pressures of either her family or society freeing herself to build a life on her own terms and find her way to happiness A rise from the ashes hero's story of overcoming abuse trauma and unbearable odds of being waylaid by both family and religion's promise of love and harnessing the resilience to find the way home Redeemed offers a rare window into Eastern European immigrant culture and reads like a page turning thriller Especially relevant today a time when marginalized people are increasingly finding a voice this memoir will serve as an inspiration to women everywhere encouraging them to overcome their obstacles and go after their dreams *Monthly Catalog of United States Government Publications* United States. Superintendent of Documents,1962-07 Billboard ,1973-01-06 In its 114th year Billboard remains the world's premier weekly music publication and a diverse digital events brand content and data licensing platform Billboard publishes the most trusted charts and offers unrivaled reporting about the latest music video gaming media digital and mobile entertainment issues and trends **A Cause for Our Times** Maggie Black,1992 Maggie Black gives a wide ranging sometimes critical account of Oxfam's first 50 years In doing so she projects Oxfam's own development against a backdrop of changing ideas in international affairs and charitable giving of which its growth is both an inspiration and an expression The World Reacts to the Holocaust David S. Wyman,Charles H. Rosenzweig,1996-09-24 Among the issues examined are the extent of the human destruction the degree of collaboration Jewish reactions and efforts to save the Jews **Communism, Capitalism and the Mass Media** Colin Sparks,Anna Reading,1997-12-08 Colin Sparks provides a challenging reassessment of the impact of the collapse of communism on the media systems of Eastern Europe He analyzes both the changes themselves and their implications for the ways in which we think about the mass media while also demonstrating that most of the orthodox accounts of the end of communism are seriously flawed There are much greater continuities between the old system and the new than are captured by the theories that argue that there has been a radical and fundamental change Instead of marking the end of critical inquiry or the end of history as some have suggested Sparks argues that the collapse of the communist

systems demonstrates how very limited and frequently incorrect the main ways of discussing the mass media are He concludes with a provocative discussion of the ways in which we need to modify our thinking in the light of these developments **PlanEcon Report** ,2000 **Hitler's Foreign Policy 1933-1939** Gerhard L. Weinberg,2010-03-01 Hitler's path to war consisted of two different stages that paralleled the internal development of Germany From 1933 to the end of 1936 he created a diplomatic revolution in Europe From a barely accepted equal Germany became the dominant power on the continent With the remilitarization of the Rhineland the stalemate in the Spanish Civil War the forming of the Axis and the signing of the Anti Comintern Pact the first phase was completed In the second phase the diplomatic initiative in the world belonged to Germany and its partners Germany's march toward war therefore became the central issue in world diplomacy *Slovak Pittsburgh* Lisa A. Alzo,2006 No other city in the United States is home to more Slovaks than Pittsburgh It is estimated that close to 100 000 Slovak immigrants came to the area in the 1890s looking for work and the chance for a better life The hills and valleys of this new land reminded newcomers of the farms forests and mountains they left behind They lived in neighborhoods close to their work forming numerous cluster communities in such places as Braddock Duquesne Homestead Munhall the North Side Rankin and Swissvale Once settled Slovak immigrants founded their own churches schools fraternal benefit societies and social clubs Many of these organizations still enjoy an active presence in Pittsburgh today serving to pass on the customs and traditions of the Slovak people Through nearly 200 photographs Slovak Pittsburgh celebrates the lives of those Slovaks who settled in Pittsburgh and western Pennsylvania and the rich heritage that is their legacy **Daily Consular and Trade Reports** ,1913

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