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Peptide Drugs: Precision Weapons in Biomedicine, Breakthroughs from Weight Loss to Cancer Treatment

From the wisdom of traditional Chinese medicine to precision molecules designed by modern AI, peptide drugs are quietly revolutionizing the medical field. In biopharmaceuticals, these compounds—formed by amino acids linked via peptide bonds—are emerging as a focal point in new drug development due to their unique advantages. Positioned between small-molecule chemotherapeutics and large-molecule protein drugs, peptides offer high specificity, significant therapeutic efficacy, and superior safety profiles. Scientists worldwide are exploring peptides' potential in treating cancer, metabolic disorders, cardiovascular diseases, and infectious diseases. Breakthroughs in AI-driven design and self-assembly technologies are propelling peptide drug development into a new era.

1. Fundamentals of Peptide Drugs: Small Molecules, Big Impact

Peptides serve as pivotal regulators of cellular functions across various domains, including hormones, neurotransmission, cell growth, and reproduction. Nearly all cells are modulated by peptides, with tens of thousands identified in living organisms. Compared to traditional small-molecule drugs, peptide therapeutics offer advantages of high specificity, potent activity, and low toxicity. Compared to large-molecule antibody drugs, peptide drugs also exhibit strong tissue permeability, low immunogenicity, and relatively lower production costs. These characteristics make peptides an ideal template for drug design. Peptide drugs have diverse origins, including chemical synthesis, biosynthesis, marine microbial extraction, and phage display technology. Notably, in recent years, peptide drugs extracted from animal tissues are gradually being replaced by chemical synthesis and recombinant gene expression.

2. Clinical Applications of Peptide Drugs: From Common Diseases to Intractable Conditions

2.1 Treatment of Metabolic Diseases

In recent years, peptides have achieved breakthrough progress in treating metabolic diseases. Peptide drugs, represented by GLP-1 analogues, have become important options for obesity and diabetes treatment. In September 2025, Wanbangde announced that its independently developed innovative small-molecule cyclic peptide drug (MCR cyclic peptide) demonstrated superior weight-loss effects compared to existing GLP-1 peptides in preclinical studies. The metabolic regulatory action of the novel MCR cyclic peptide stems from its activation of the melanocortin-4 receptor(MC4R). As the "central commander" of energy homeostasis, MC4R suppresses excessive food intake, regulates glucose and lipid levels, and maintains muscle homeostasis through amultidimensional regulatory network, thereby achieving comprehensive metabolic and energy balance. After 8 weeks of treatment, mice in the high-dose MCR cyclic peptide group exhibited approximately 1.25 times greater weight loss compared to the GLP-1 peptide group, while preserving muscle mass and exerting comprehensive regulatory effects on metabolic indicators such as blood glucose and lipids.

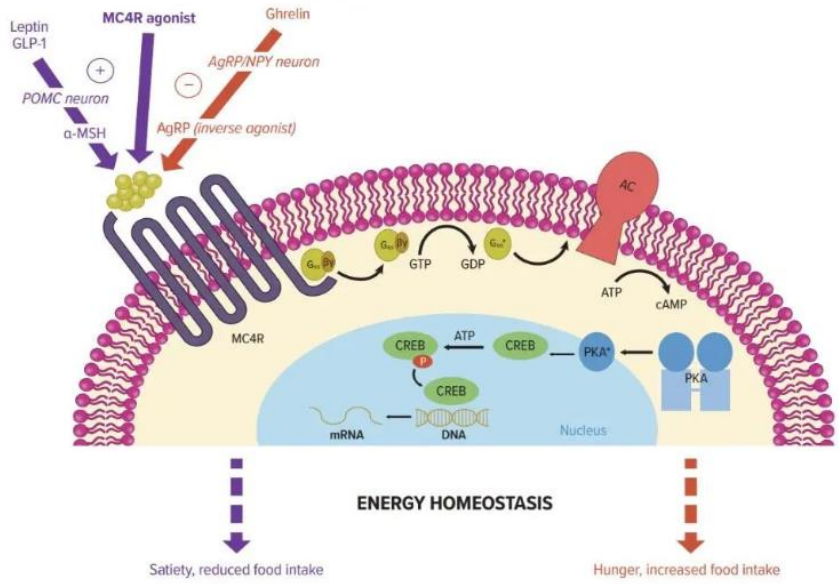


Figure 1 Mechanism of energy balance regulation mediated by melanocortin

Image Source: Wanbangde Pharmaceutical Group Official Website

2.2 Antitumor Applications

Peptides exhibit diverse mechanisms in antitumor applications. They can induce tumor cell apoptosis by promoting the " " pathway; for instance, synthetic SMAC-mimetic peptides penetrate cell membranes, inhibit apoptosis-suppressing proteins, and trigger tumor cell death. Peptides also inhibit tumor angiogenesis—such as Actinotoxin 10 isolated from marine gastropods, which significantly reduces tumor blood flow by up to 90%. Certain peptides, like Mere15 extracted from the body of the clam Mytilus edulis, can inhibit the proliferation of A549 lung cancer cells in vitro. Peptides can also serve as targeted carriers, precisely directing chemotherapy drugs to tumor sites. By exploiting specific markers expressed on tumor blood vessels, scientists have identified peptides such as RGD peptides that can specifically target tumor vasculature, enhancing therapeutic efficacy while reducing side effects.

2.3 Antiviral and Antibacterial Effects

In antiviral applications, peptides function by blocking viral attachment to host cells or inhibiting key viral replication enzymes. This offers novel approaches for combating pathogens like SARS-CoV-2 and HIV. Against the backdrop of the global antibiotic resistance crisis, significant progress has also been made in antimicrobial peptide development. In September 2025, Lai Ren's team at the Kunming Institute of Zoology, Chinese Academy of Sciences, designed a novel self-assembling antimicrobial peptide, Tryptolydin (TRPY). This peptide self-assembles into nanoparticles that recognize bacterial surface components upon proximity, rapidly forming dense "nanofiber nets" to efficiently eliminate multiple drug-resistant bacteria. It can even eradicate biofilms resistant to antibiotics.

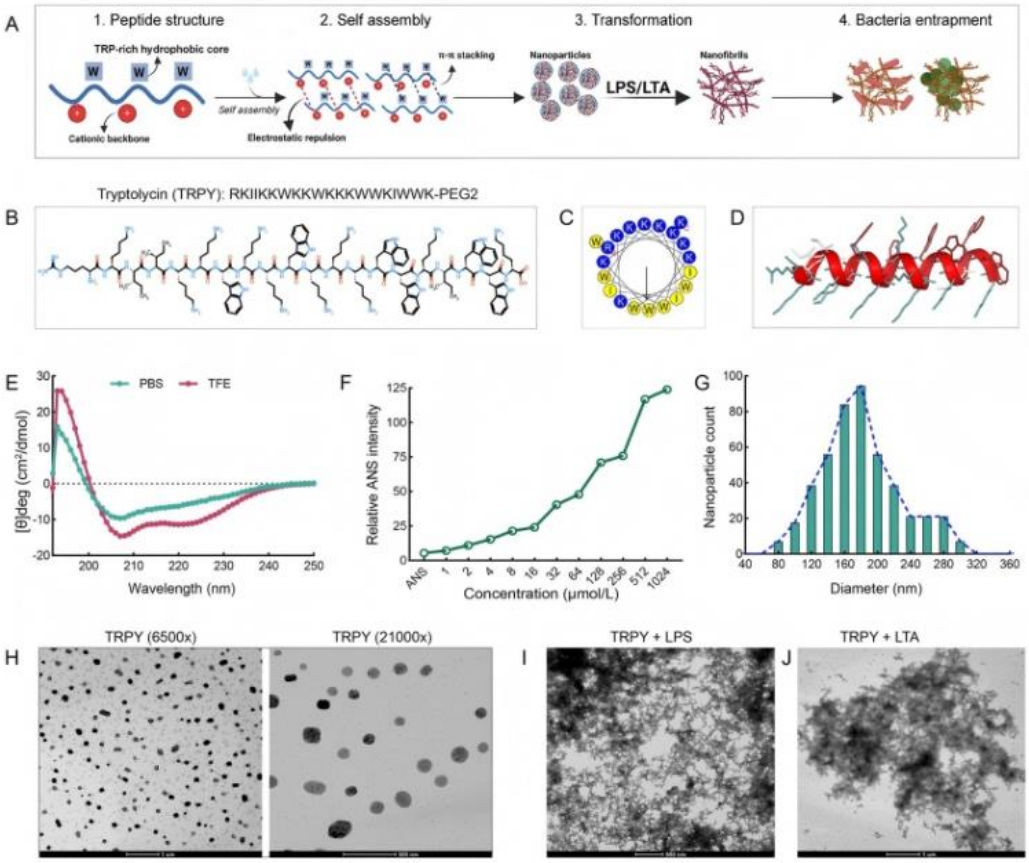
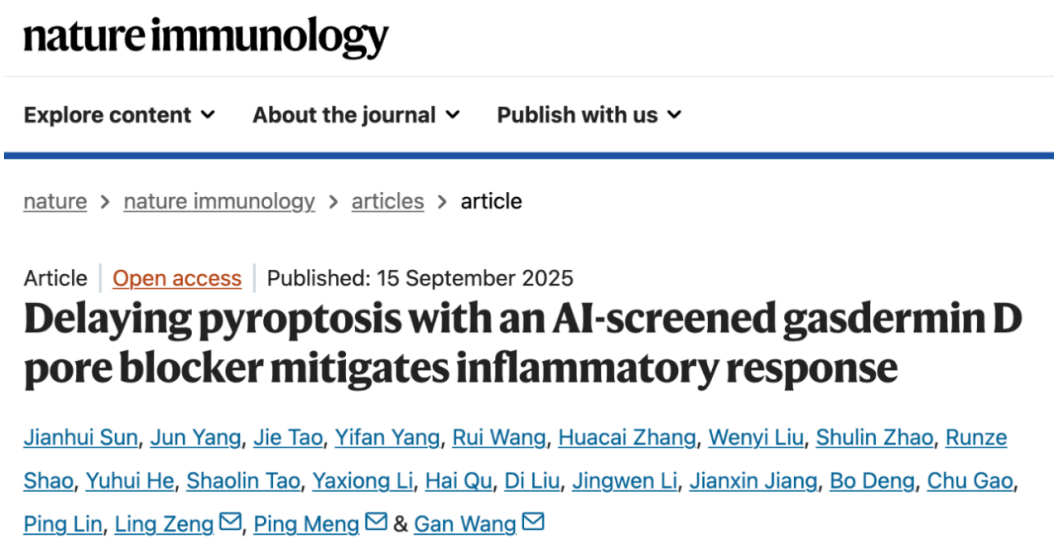


Figure 2 Structural characterization of the lead peptide TRPY

Image Source:James Mwangi et al.， 2025

2.4 Inflammation and Autoimmune Diseases

In the treatment of inflammatory diseases, AI technology has revolutionized peptide design. In September 2025, a collaborative team led by Professor Wang Gan from the Chengdu Institute of Biology, Chinese Academy of Sciences; Associate Researcher Meng Ping from the Yunnan Provincial Key Laboratory of Cardiovascular Medicine at Kunming Yan'an Hospital; and Researcher Zeng Ling from the National Key Laboratory of Trauma and Chemical Poisoning at Daping Hospital published a study titled "Delaying pyroptosis with an AI-screened gasdermin D pore blocker mitigates inflammatory response" in Nature Immunology, a Nature journal. Using AI, they designed a novel peptide, SK56, which precisely inhibits gasdermin D (GSDMD)-mediated pyroptosis—a critical component of theexcessive pro-eimmune response observed in sepsis and autoimmune diseases.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Delaying pyroptosis with an AI-screened gasdermin D pore blocker mitigates inflammatory response

Jianhui Sun, Jun Yang, Jie Tao, Yifan Yang, Rui Wang, Huacai Zhang, Wenyi Liu, Shulin Zhao, Runze Shao, Yuhui He, Shaolin Tao, Yaxiong Li, Hai Qu, Di Liu, Jingwen Li, Jianxin Jiang, Bo Deng, Chu Gao, Ping Lin, Ling Zeng ✉, Ping Meng ✉ & Gan Wang ✉

Figure 3: Research paper by Wang Gan et al. published in Nature Immunology

3. New Technologies and Directions in Peptide Drug Development

3.1 AI-Driven Design

AI technology is revolutionizing the development model for peptide drugs. Traditional peptide drug discovery relies on extensive experimental screening, whereas AI can rapidly analyze massive datasets to design peptide molecules with specific functions. This precision design significantly accelerates peptide drug development and enhances success rates.

3.2 Self-Assembly Technology

Self-assembling peptide technology represents another breakthrough advancement. By designing peptides with specific sequences that spontaneously assemble into nanofiber networks or nanoparticles under defined conditions, the stability and therapeutic efficacy of peptides can be significantly enhanced.

3.3 Novel Synthesis Methods

Peptide synthesis technology has also witnessed innovation. In August 2025, a team from Nanjing University developed a new generation of solid-phase peptide synthesis technology based on a ribosome-like molecular reactor. This breakthrough overcomes the longstanding challenge of synthesizing highly steric-hindered peptides in solid-phase synthesis—a bottleneck that had remained unresolved for six decades—providing a universal solution for producing peptide drugs with enhanced stability and membrane permeability.

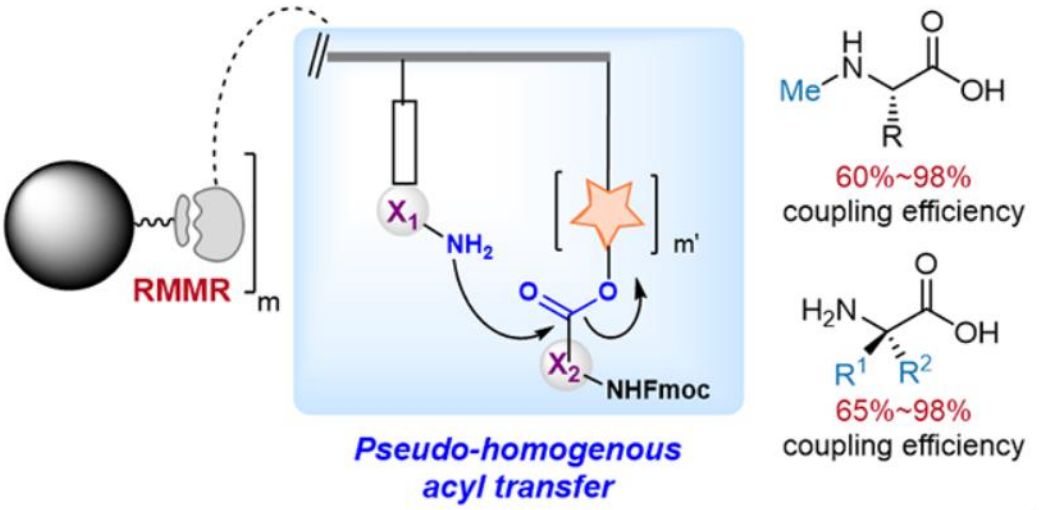

Figure 4 Schematic of RMMR-based synthesis of highly steric-hindered peptides using immobilized molecular reactors

4. Challenges and Future Prospects for Peptide Drugs

4.1 Challenges Faced

Despite the promising prospects of peptide drugs, several challenges remain. Peptide molecules suffer from poor stability, susceptibility to enzymatic degradation, and low oral bioavailability. Furthermore, inadequate membrane permeability limits their application. Scientists are actively seeking solutions to these challenges. Incorporating N- or α-alkylated amino acids into the peptide backbone can effectively enhance stability and membrane permeability. Cyclic peptide structures, such as Wanbond's MCR cyclic peptide, also improve stability and biological activity.

4.2 Future Outlook

With technological advancements, peptide drugs hold promise for expanding their therapeutic value across more fields. In the era of personalized medicine, the ease of synthesis and modification of peptide drugs makes them ideal carriers for tailored treatments. In the future, designing individualized peptide drugs for specific patients will become feasible. Peptide drugs are also expected to achieve breakthroughs in areas such as neurodegenerative diseases and rare disorders. As our understanding of disease mechanisms deepens, peptide drugs will become a vital component of precision medicine.

Driven by breakthroughs in AI-driven design, self-assembly technologies, and novel synthesis methods, peptide drugs are entering a golden era of development. Future peptide therapeutics will be more precise, efficient, and personalized, potentially enabling tailored treatment plans for each patient's specific condition. As scientists have predicted: "This century belongs to peptides." With advancing research, peptide drugs hold promise as the key to solving many of today's major medical challenges.

Original Article:

https://www.wanbang.com.cn/news/

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James Mwangi, Dawit Adisu Tadese, Yi Wang, Demeke Asmamaw, Min Yang, Brenda. B. Michira, Mehwish Khalid, Zi-Yi Wang, Qiu-Min Lu, Ren Lai. 2025. Integrating a cationic backbone with a hydrophobic core: A structure-function strategy for designing self-assembling antimicrobial peptides with enhanced activity. Zoological Research, 46(5): 1203-1218. DOI: 10.24272/j.issn.2095-8137.2025.303