纳米颗粒形状和细胞膜刚性对胞吞作用的影响研究获进展

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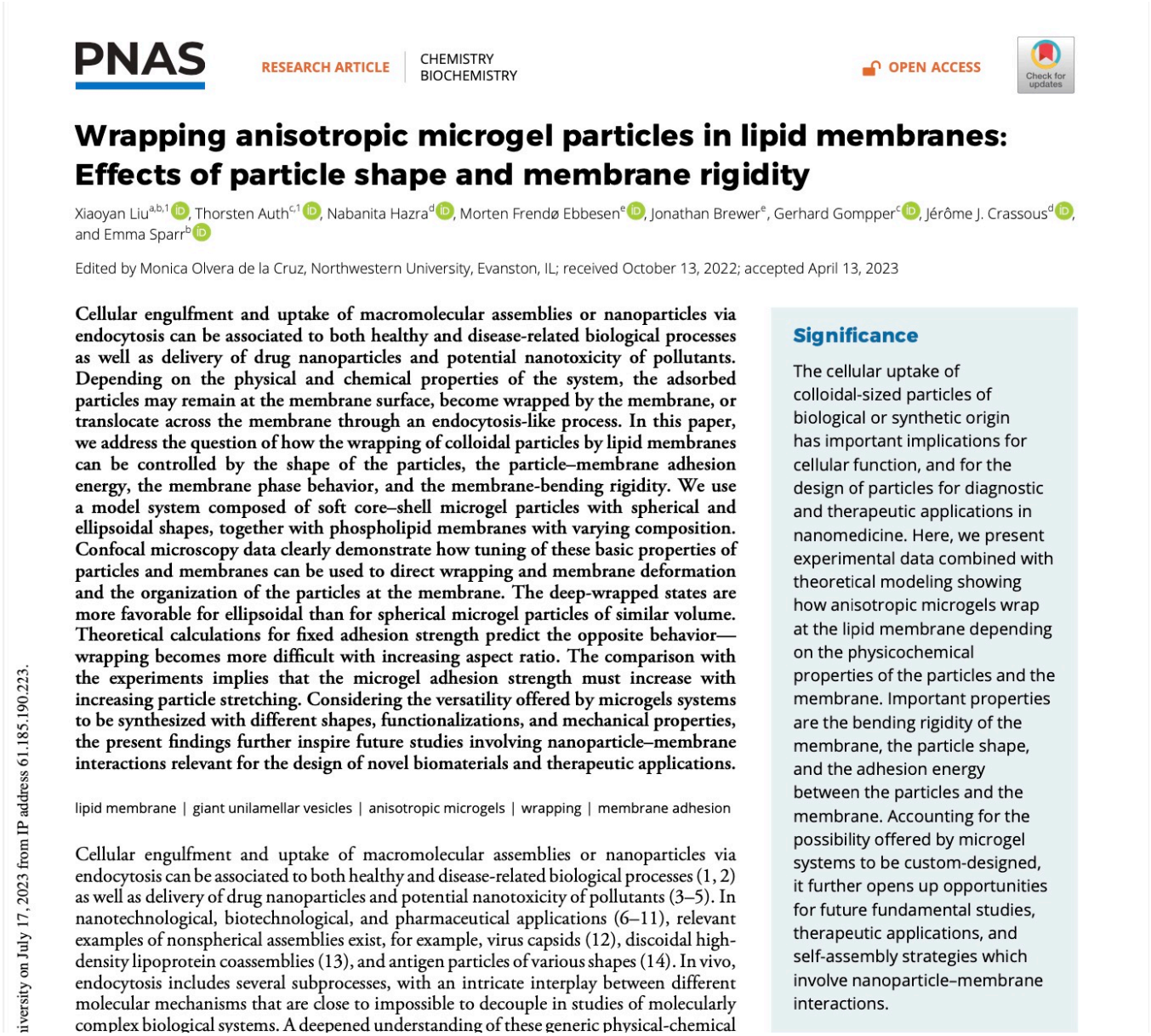
近日，陕西师范大学化学化工学院光子鼻与分子材料研究团队在《美国科学院院报》(PNAS)在线发表了以各向异性纳米颗粒的形状和细胞膜的刚性对胞吞作用的影响为题的研究论文。



PNAS RESEARCH ARTICLE | CHEMISTRY BIOCHEMISTRY OPEN ACCESS

Wrapping anisotropic microgel particles in lipid membranes: Effects of particle shape and membrane rigidity

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Cellular engulfment and uptake of macromolecular assemblies or nanoparticles via endocytosis can be associated to both healthy and disease-related biological processes as well as delivery of drug nanoparticles and potential nanotoxicity of pollutants. Depending on the physical and chemical properties of the system, the adsorbed particles may remain at the membrane surface, become wrapped by the membrane, or translocate across the membrane through an endocytosis-like process. In this paper, we address the question of how the wrapping of colloidal particles by lipid membranes can be controlled by the shape of the particles, the particle–membrane adhesion energy, the membrane phase behavior, and the membrane-bending rigidity. We use a model system composed of soft core–shell microgel particles with spherical and ellipsoidal shapes, together with phospholipid membranes with varying composition. Confocal microscopy data clearly demonstrate how tuning of these basic properties of particles and membranes can be used to direct wrapping and membrane deformation and the organization of the particles at the membrane. The deep-wrapped states are more favorable for ellipsoidal than for spherical microgel particles of similar volume. Theoretical calculations for fixed adhesion strength predict the opposite behavior—wrapping becomes more difficult with increasing aspect ratio. The comparison with the experiments implies that the microgel adhesion strength must increase with increasing particle stretching. Considering the versatility offered by microgels systems to be synthesized with different shapes, functionalizations, and mechanical properties, the present findings further inspire future studies involving nanoparticle–membrane interactions relevant for the design of novel biomaterials and therapeutic applications.

lipid membrane | giant unilamellar vesicles | anisotropic microgels | wrapping | membrane adhesion

Cellular engulfment and uptake of macromolecular assemblies or nanoparticles via endocytosis can be associated to both healthy and disease-related biological processes (1, 2) as well as delivery of drug nanoparticles and potential nanotoxicity of pollutants (3–5). In nanotechnological, biotechnological, and pharmaceutical applications (6–11), relevant examples of nonspherical assemblies exist, for example, virus capsids (12), discoidal high-density lipoprotein coassemblies (13), and antigen particles of various shapes (14). In vivo, endocytosis includes several subprocesses, with an intricate interplay between different molecular mechanisms that are close to impossible to decouple in studies of molecularly complex biological systems. A deepened understanding of these generic physical-chemical

Significance

The cellular uptake of colloidal-sized particles of biological or synthetic origin has important implications for cellular function, and for the design of particles for diagnostic and therapeutic applications in nanomedicine. Here, we present experimental data combined with theoretical modeling showing how anisotropic microgels wrap at the lipid membrane depending on the physicochemical properties of the particles and the membrane. Important properties are the bending rigidity of the membrane, the particle shape, and the adhesion energy between the particles and the membrane. Accounting for the possibility offered by microgel systems to be custom-designed, it further opens up opportunities for future fundamental studies, therapeutic applications, and self-assembly strategies which involve nanoparticle–membrane interactions.

研究论文发表在PNAS。(陕西师范大学供图)

细胞通过胞吞作用吞噬和摄取大分子组装体或胶体纳米颗粒与药物递送、医学诊疗、以及纳米颗粒的潜在毒性密切相关。胞吞作用受到体系的物理和化学属性影响，附着在细胞膜上的纳米颗粒可能稳定吸附在膜表面、或者被膜包裹、也可能穿过细胞膜进入细胞内部。此研究通过设计合成各向异性的纳米颗粒和合成细胞膜研究了胶体颗粒与脂质膜的相互作用，致力于揭示胞吞作用受纳米颗粒和细胞膜物理和化学属性影响的规律。

研究发现，体积相近的各向异性软物质纳米颗粒更容易进入细胞内部，细胞膜在具有较高流动性时更有利于胞吞作用发生。通过理论计算预测了纳米颗粒的粘附强度对胞吞作用的影响，阐明了细胞膜和各向异性纳米颗粒的物理属性、颗粒与细胞膜之间的粘附强度对胞吞作用的影响，并且发展了制备二维胶体晶体组装结构的新方法。

此工作主要由陕西师范大学与瑞典隆德大学、德国于利希研究中心合作完成。化学化工学院刘小燕副研究员为第一作者和共同通讯作者，陕西师范大学为第一署名单位。(来源：中国科学报

严涛)

相关论文信息：https://doi.org/10.1073/pnas.2217534120

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