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COVER Over time, natural selection has led to the formation of well-adapted structures and highly efficient biological mechanisms. Scientists and engineers are continually amazed by the unique structures, morphologies and functions of biological materials, and draw inspiration from nature in their innovations. Interfacial materials with desirable properties and functions have attracted tremendous attention because of their theoretical importance and wide variety of applications in industrial, military, biomedical and domestic fields. There has been growing interest in using biomaterials with subtle hierarchical structures as biotemplates to fabricate smart, multifunctional interfacial materials. As one of the most complicated three-dimensional periodic substrates in nature, the butterfly wing has become a popular biomimetic template because of its outstanding characteristics in terms of structural coloration (iridescence), aerodynamic performance, chemical recognition ability, and heat dissipation efficiency. This work reveals that the cooperation between the multiscale surface structures and hydrophobic composition of butterfly wings is probably the origin of their low adhesive superhydrophobicity and excellent self-cleaning ability. The structure of butterfly wings may be mimicked in technologies that contribute to the next generation of bioinspired materials and devices such as intelligent microcontrollable interfaces, novel microfluidic channels, anisotropic wetting substrates, and nanoscale dust-free coatings. The cover image shows the colorful butterflies in northeast China and the multi-dimensional microstructures on the wing surface (see the article by Yan Fang et al. on page 256).



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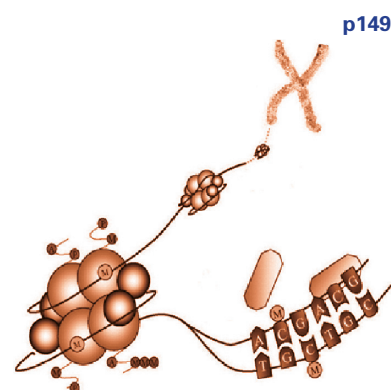
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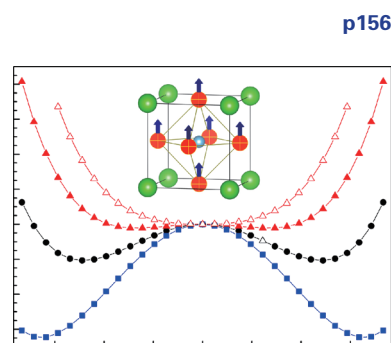
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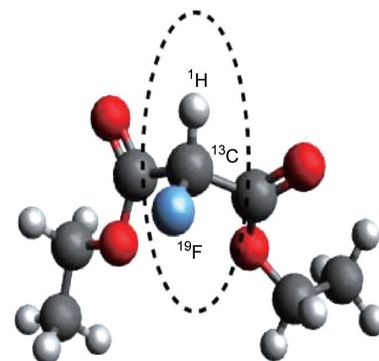
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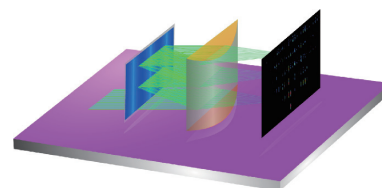
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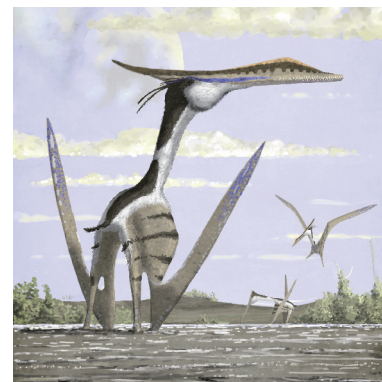
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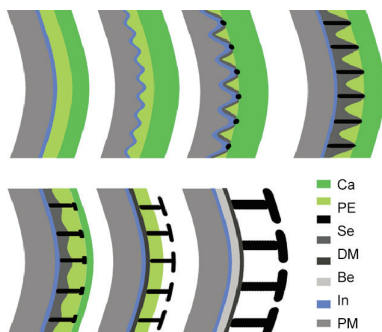
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蝴蝶翅表面多级微/纳结构疏水模型及耦合机理

房岩, 孙刚, 毕雨涵, 智亨

使用扫描电子显微镜(SEM)、接触角测量仪和红外光谱仪(FT-IR), 观测了27种蝴蝶翅表面的微观结构、复合浸润性和化学成分. 利用Cassie方程建立了蝴蝶翅表面微/纳结构疏水模型, 从生物耦合角度探讨了疏水机理. 结果表明, 蝴蝶翅表面由天然疏水材料组成, 具有复杂的多级微/纳结构, 包括一级结构(微米级鳞片)、二级结构(纳米级纵肋和横桥)和三级结构(纳米级突起). 翅表面具有高疏水性(接触角 138° ~ 157°)和低黏附性(滚动角 1° ~ 3°). 翅表面微观形貌和自清洁性具有显著的各向异性. 这种特殊的复合浸润性是材料耦元与结构耦元耦合作用的结果. 微米级鳞片的宽度越小、间距越大, 纳米级纵肋的高度越小、宽度越小、间距越大, 翅表面疏水性越强. 研究结果有助于进一步流调结果揭示生物表面的疏水机理, 为智能界面材料的仿生设计和制备提供启示.

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DNA甲基化在精神分裂症中的作用: 研究进展及挑战

宗小芬, 胡茂林, 李宗昌, 曹红宝, 陈晓岗, 唐劲松

精神分裂症是一种异质性精神障碍, 目前多数学者认为该病由遗传及环境风险因子共同致病. 传统的遗传学研究识别了一些精神分裂症的候选基因, 然而, 外显率及比值比较低, 以及可重复性较差, 使得这些候选基因在精神分裂症发病机制中的角色受到限制. 精神分裂症的流行病学研究发现了一些可能与该病相关的环境风险因子, 但仍受到方法学的限制以及互相矛盾的流行病学调查结果的困扰. 目前, 在环境与基因中间起调解作用的表现遗传学, 可能在精神分裂症的发病机制中起重要作用. DNA甲基化是最稳定且研究最深入的一种表现遗传学修饰. 本文简要介绍DNA甲基化机制, 主要评述精神分裂症中基因组及特异位点如候选基因*Reelin*与*COMT*甲基化研究现状, 以及DNA甲基化在精神分裂症中的研究困境.

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多铁和磁电材料的第一性原理研究

方跃文, 丁航晨, 童文旖, 朱皖骄, 沈昕, 龚士静, 万贤纲, 段纯刚

多铁材料是一类由自旋、电荷、晶格和轨道等多种自由度的相互作用引起的具有2种或者2种以上铁序的功能材料. 近年来关于多铁性的报道屡见报端杂志, 表明越来越多的研究人员关注着这一领域的研究进展. 在这些研究成果中, 第一性原理研究在解释实验观测, 发现新物理机制和预测新型多铁、磁电材料方面都扮演着先锋角色. 本文回顾了第一性原理在材料领域, 尤其是多铁性、磁电效应和隧道结研究中的广泛应用和主要成果. 结合最近发展的理论研究方法, 例如选择性轨道加场法, 评述了这些手段在解释多铁和磁电材料中奇异物理现象方面的有效性. 由于电控磁性是多铁领域和自旋电子学领域追求的共同目标, 因此总结了第一性原理研究在电控磁性方面所取得的成果. 最后, 本文概述了多铁和磁电材料在实际应用中亟待解决的问题, 并且着重展望了若干种利于解决多铁和磁电材料领域实际问题的研究方法. 本文通过深入探讨过渡金属氧化物中的铁电起源以及多铁体中铁电性和磁序的共存现象, 期望能有益于新型多铁和磁电材料的探索.

评述 p156

陆地水-碳酸盐- CO_2 -水生光合生物相互作用产生碳汇的重要性

刘再华, Wolfgang Dreybrodt

全球变化科学最重要的问题之一是如何平衡大气 CO_2 收支. 至今仍存在每年10亿吨级的陆地碳汇不知去向, 即所谓的“遗失碳汇”问题. 这些不明碳汇的位置、量级、变化和形成机制目前仍不确定, 并存在巨大争议. 尽管全球变化和岩石化学风化的正相关关系已体现在大气 CO_2 的地球化学模型中, 但这一反馈被认为只在地质长时间尺度起作用, 因此, 针对人类活动对碳收支影响的讨论时常不考虑风化碳汇的贡献. 本文基于岩石风化研究的最新进展, 并综合水生生态系统碳泵效应研究的成果, 发现陆地水-碳酸盐- CO_2 -水生光合生物相互作用产生的碳汇不仅很重要(每年近5亿吨碳), 而且在气候变暖和土地利用变化的影响下呈现显著的增加趋势, 因此, 必须包括在现今全球碳收支的评价中.

评述 p182

鱼腥藻PCC 7120中激活*patA*在营养细胞表达的*HetR*结合位点参与控制异形胞正常图式的形成

侯圣伟, 周芳, 彭珊, 高宏, 徐旭东

鱼腥藻PCC 7120是研究细胞分化和图式形成的最简单的模式生物, 因为其仅由一列原核细胞组成, 在缺氧诱导条件下分化出异形胞, 大致形成每间隔10个左右营养细胞(光合)出现一个异形胞(固氮)的图式. 在异形胞分化机理的研究中, 主调控因子如何控制异形胞形成基因和图式形成基因是关键所在. 本研究的目的即是分析主调控因子*HetR*对一个图式形成基因*patA*的调控机理以及对其他基因的调控模式. 通过体外实验证明, *HetR*确实能够结合我们以前预测的*patA*上游的识别位点; 将该位点缺失掉导致*patA*不能在营养细胞表达, 而其在异形胞的表达则依赖于另一调控因子. *patA*突变株只能在长藻丝两端形成异形胞, 通过导入带有上游序列的完整的*patA*进行互补可恢复有规律间隔形成异形胞的表型, 但缺失*HetR*识别位点则不能互补. 通常认为主调控因子在异形胞或原异形胞中上调表达, 受其调控的基因也在这些分化细胞上调表达并参与异形胞形成过程. 本研究则发现, *HetR*通过激活*patA*在营养细胞的表达影响正常图式的形成. 此外, 本研究证明, *HetR*还可以抑制某些基因在异形胞或全藻丝的表达, 共有4种不同调控模式.

论文 p192

内质网应激反应中microRNA的表达变化

戴丽敏, 黄川, 陈亮, 单革, 李兆勇

各种生理学和病理学条件导致内质网腔中未折叠或错误折叠蛋白质的积累, 引发内质网应激. 通过RNA深度测序, 我们发现内质网应激胁迫下, HeLa和HEK293细胞中一些microRNA的表达发生改变. 通过利用实时定量PCR技术, 我们进一步验证了在这些细胞中hsa-miR-423-5p的表达上调, 而hsa-miR-221-3p和hsa-miR-452-5p的表达下调. 荧光素酶活性检测和Western blotting实验证实CDKN1A是hsa-miR-423-5p的靶基因, 而CDKN1B是hsa-miR-221-3p和hsa-miR-452-5p的靶基因. 我们推测microRNA通过调控它们的靶基因, 在内质网应激的适应性反应中协同作用.

论文 p202

手性铜(I)/SaBOX配合物催化cis-1,2-二取代烯烃与 α -硝基重氮乙酸酯的高非对映选择性以及高对映选择性环丙烷化反应

冯良文, 王鹏, 王丽佳, 唐勇

利用手性金属铜(I)与边臂修饰的双噻唑啉的配合物作为催化剂, 发展了一种催化cis-1,2-二取代烯烃与 α -硝基重氮乙酸酯发生高立体选择性环丙烷化反应的新方法. 该反应可以获得高达97%的收率、99/1 dr和98%的对映选择性, 得到多取代的手性环丙烷. 这一方法为合成具有光学活性的环丙烷 α -氨基酸以及非天然 α -氨基酸衍生物提供了有效途径.

论文 p210

一种新型高效生物可降解 ϵ -多聚赖氨酸修饰阳离子聚合物抗菌剂的合成与性能

赵瑞芳, 王海, 季天骄, Greg Anderson, 聂广军, 赵宇亮

目前临床上使用的大多数抗生素杀菌或抑菌的主要机制为: 选择性的作用于细菌细胞核酸和蛋白合成系统的特定环节, 妨碍细菌生命活动, 导致细菌死亡. 然而, 细菌形态结构完整性仍然保持, 导致细菌产生耐药性. 最近研究发现大肠杆菌和金黄色葡萄球菌感染是一些慢性疾病发生的重要因素. 纳米颗粒能够选择性的作用于微生物表面, 破坏细菌结构完整性, 抑制细菌耐药性的产生. 本文设计并合成一种生物相容性好且生物可降解 ϵ -多聚赖氨酸修饰阳离子聚合物(EPL-PCL). 该多聚物能够自主装形成单分散的纳米颗粒, 且对大肠杆菌、金黄色葡萄球菌和枯草芽孢杆菌具有广谱的抗菌活性. 相比于 ϵ -多聚赖氨酸, EPL-PCL纳米颗粒具有更强的抗菌活性. 进一步研究发现, EPL-PCL纳米颗粒抗菌作用的主要机制为: (1) 带正电的EPL-PCL纳米颗粒与带负电的细菌表面相互作用并穿透细胞壁和细胞膜, 破坏细菌表面完整性, 抑制细菌耐药性的生成; (2) EPL-PCL纳米颗粒暴露显著提高细菌内ROS水平; (3) ROS水平升高显著的破坏细菌细胞代谢, 例如提高碱性磷酸酶活性破坏细菌磷的稳态平衡. 因此, 本文合成的可降解 ϵ -多聚赖氨酸修饰阳离子纳米聚合物可以作为一种有效且广谱的抗菌剂, 特别是用于病原菌感染的疾病.

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抗坏血酸稳定纳米铜/壳聚糖复合物的原位制备、表征及抗菌性能

何苗, 路丽英, 张金池, 李旦振

以抗坏血酸为稳定剂, 通过原位还原络合于壳聚糖表面的铜离子, 制备了平均粒径(2.57 \pm 0.5) nm的高稳定的纳米铜/壳聚糖复合物. 利用X射线光电子谱(XPS)和傅里叶变换红外光谱(FT-IR)表征了复合物的合成过程及其稳定性, 同时采用最低抑菌浓度法(MIC)定量表征了复合物的抗菌性能. 结果表明稳定结合于壳聚糖表面的纳米铜具备高效的广谱抗菌性能, 特别针对革兰氏阳性菌如金色葡萄球菌以及真菌如白色念珠菌. 纳米铜/壳聚糖复合物对金色葡萄球菌的MIC为6.4 $\mu\text{g mL}^{-1}$, 该数值优于已报道的其他纳米铜材料. 常温常压存放90天后, 纳米铜/壳聚糖复合物仍具备稳定的结构和良好的抗菌性能.

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壳聚糖基原位水凝胶作为肺栓塞剂的应用研究

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肺气肿是终末细支气管至肺泡内持续含气量过多、过度膨胀使弹力组织破坏的常见慢性阻塞性肺疾病, 临床表现为不可逆气流受限、胸闷、气促、重则呼吸衰竭. 通过堵塞支气管使肺不张以达到肺减容目的的治疗方法因其能够避免外科手术风险而被广泛关注. 本研究的目的是基于具有良好生物相容性的壳聚糖水凝胶制备一种可注射的原位水凝胶, 考察该体系的凝胶时间、凝胶强度及细胞毒性等, 并将其应用于肺栓塞以达到肺减容. 研究结果表明, 壳聚糖/京尼平/磷酸钠原位可注射水凝胶的凝胶时间为8 min, 凝胶强度195 Pa, 在生理条件下膨胀率超过100%; 小鼠成纤维细胞(3T3)与凝胶接触48 h后细胞活性仍保持80%以上, 表明凝胶无生物毒性; 将该水凝胶注入狗的肺细支气管, 胸部CT显示水凝胶在定位的细支气管中形成栓塞, 3周后在支气管肺段发生了局部肺不张, 达到了肺减容的目的.

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真实空间的相互作用费米子体系动力学实验数字量子模拟

陆遥, 冯冠儒, 李岩松, 龙桂鲁

上个世纪80年代, Benioff和Feynman分别从降低热耗和模拟量子体系的需求出发独立地提出了量子计算机的概念. 现在Shor算法、Grover算法和量子模拟是最著名的3类量子算法, 也是应用最多的量子算法. 量子模拟可分为相似量子模拟和数字量子模拟. 相似量子模拟要求两个体系在结构上要很接近, 这限制了其应用范围. 而数字量子模拟避免了这一要求, 因而具有可以普适模拟量子体系. 由于多体量子体系的复杂性, 其量子模拟很困难, 以前量子模拟研究主要在单个粒子的情形. 本工作首次实现了真实空间中相互作用的多粒子数字量子模拟实验. 在小型核磁共振量子信息处理体系, 实验再现了费米子

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在吸引排斥库伦相互作用下的排斥,和在吸引相互作用下的靠近等量子动力学过程.这一结果充分表明,利用数字量子模拟算法,我们可以利用现有的小型量子信息处理器,能够充分模拟多体量子动力学的空间演化.而空间量子动力学演化在许多领域如多体量子体系物理研究、量子化学过程、生物钟的量子效应等起着重要的作用.本工作对量子模拟的研究具有重要的推动作用.

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实验实现光学量子棘轮

张驰,李传锋,郭光灿

粒子在外势场中的演化可以用薛定谔方程描述.研究发现可以用光场的相位调制模拟粒子的外势场,只要制备出感兴趣的位相分布调制,就可以利用光束的演化模拟粒子在外势场中的演化.实验上利用相位镜产生锯齿状的外势,从而在全光系统中实现了量子棘轮,用肉眼就可以看到22步的棘轮效应.进一步还演示了棘轮效应中的量子共振现象.本工作实现了用经典光模拟量子粒子的演化,从而可以研究其他有趣的量子现象.

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中国甘肃一例前足迹主导的翼龙足迹组合:对行为学的影响

李大庆,邢立达, Martin G. Lockley, Laura Piñuela, 张建平, 代辉, Jeong Yul Kim, W. Scott Persons IV, 孔得来

翼龙是已知的、最早飞上天空的脊椎动物,目前已经发现了成千上万件化石,代表着这一大家族从晚三叠世到晚白垩世在全球范围内的蓬勃发展史.自2004年甘肃盐锅峡地区首次报道翼龙足迹以来,中国陆续发现了一批翼龙足迹化石,绝大多数的足迹点都保存了翼龙的前后足迹.2013年,我们在盐锅峡地区发现了至少20个翼龙前足迹的凸型足迹,而没有发现任何后足迹,这些足迹可归为一个单独翼龙遗迹属——*Pteraichnus*.这是中国第一次发现由前足迹主导的翼龙足迹组合,这可能反映了翼龙前后足迹在同等保存条件下的不同深度.更重要的是,盐锅峡的这批翼龙足迹与当地发现的大量虫迹相关,一些足迹甚至就保存在虫迹面上,这些虫迹包括*Cochlichnus*, *Spongiomorpha*和*Paleophycus*,因此推断这批翼龙遗迹者很可能以这些无脊椎动物遗迹者为食.

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超微结构显示拟南芥花粉壁孢粉素沉积模式及外壁内层的形成

周韵,朱骏,崔永兰,杨仲南

花粉壁由外壁和内壁组成,外壁又分为外壁外层和外壁内层.外壁由绒毡层控制,而内壁由小孢子自身控制.自从有了电子显微镜,就了解到花粉壁有三层结构.花粉外壁内层是高度保守的结构,只有在电镜下才能观察到,但是对其如何形成并不清楚.最近报道了模式植物拟南芥中*TEK*基因特异调控外壁内层的形成,在该突变体中外壁内层特异缺失而外壁外层能正常形成(*Nature communications* 5:3855).本文在该项工作的基础上,对模式植物拟南芥花粉壁形成过程进行全面深入分析.发现在四分体的细胞质中存在的深灰色物质可能是外壁内层成分的前体,其组成成分可能与孢粉素有所不同,当小孢子从四分体中释放时,这些前体物质能够迅速组装成外壁内层.在此基础上,提出了一个拟南芥花粉外壁的发育模型:在减数分裂形成的四分体中,胼质壁和小孢子质膜间形成初生外壁.随后小孢子质膜显示出波浪型结构,绒毡层分泌的孢粉素沉积在波浪型质膜顶端发育成外壁外层结构,而绒毡层分泌的外壁内层物质积累在小孢子质膜表面发育成外壁内层结构.四分体胼质壁完全降解释放小孢子后,在外壁内层和小孢子质膜间形成内壁.这一包含花粉壁三层结构的模型不仅有助于其他植物物种花粉壁结构和形成过程的了解,也有助于花粉壁分子机理的深入研究.

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Quantum ratchet with photons

Gui-Lu Long · Tian-Cai Zhang

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Quantum simulation is one of the most important applications of quantum computers. Unlike full-scale quantum computing where hundreds of qubits are required, quantum simulation can be performed at small-scale quantum information processing system. In a recent work [1], Zhang et al. from the University of Science and Technology of China (USTC) have experimentally demonstrated a quantum simulation of an interesting phenomenon with photons, the quantum ratchet.

A classical ratchet is a spatially periodic rotor in which the directed motion of particles can be realized without a bias force. Similarly, in a quantum ratchet, a quantum particle is directed evolved under apparent no bias force. Quantum ratchet effect has attracted much attention recently. The effect may exist in many quantum systems [2], and it was demonstrated with cold atoms in optical lattice [3]. This quantum effect plays a crucial role in many related studies, such as dynamical localization, quantum resonance, and quantum chaos, and has potential applications in solving the evolution of wave functions.

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Researchers in USTC elaborately created a delta-kicked Hamiltonian quantum ratchet [4] in an all-optical system, and this quantum rotor is driven by Hamiltonian chaos, in the absence of noise. Directed motion and quantum resonance are observed. They constructed successfully a delta-kicked potential for light by a phase mirror which is the key of the periodically flashing potential in the experiment and the potential is determined by the etched depth of the phase mirror. The quantum particle is the photons which are reflected between a plane mirror and the phase mirror, and these photons encounter the phase mirror again and again with a certain temporal interval. In order to obtain the momentum information, they use skillfully a cylindrical lens to convert the pattern of the position distribution into that of the momentum distribution on the focal plane of the lens. They eventually successfully observed the quantum ratchet and quantum resonance in the experiment in the momentum and kinetic energy space with photons. Since the experiment is performed using classical light, the effects can be even observed with a naked eye for up to 22 steps. Compared to the massive quantum ratchet, photons have longer wavelength which provides longer spatial period and makes the quantum ratchet easier to control and measure.

Light is easy to be coherently controlled and detected. The approach and the result provided here are significant to simulate other quantum phenomena.

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