DRUG DELIVERY

Principles of penetration

With an increasing number of large-molecule drugs on the market, painless needle-free drug delivery is an attractive goal. For small molecules, such as nicotine or contraceptive hormones, delivery through the skin is widely used, but this method depends on a limited number of approved chemical penetration enhancers (CPEs) to help therapeutics permeate skin.

The use of CPEs is a convenient way to overcome the skin barrier, but when used at the concentrations necessary for penetration, these molecules are also potent irritants. In a recent issue of *Proceedings of the National Academy of Sciences*, Mitragotri and colleagues identify design principles for the use of CPEs, finding that it is possible to separate beneficial penetration properties from irritation.

Skin, the largest organ of the human body, possesses very low permeability to the movement of foreign molecules across it because of the hierarchical structure of the stratum corneum (SC), a lipid-rich matrix with embedded corneocyte cells. Although more than 350 molecules have been identified that perturb the SC barrier to facilitate molecular delivery, safety concerns relating to the health of the skin membrane remains the bottleneck for their use in the development of transdermal therapies.

Using Fourier transform infrared spectroscopy, the authors showed that existing CPEs perturb the skin barrier via extraction or fluidization of the lipid bilayers. By contrast, the irritation response correlated with the denaturation of SC proteins. Of the 10 diverse chemical functionalities analysed, two classes emerged. In the first class, the enhancement ratio (ER; measurement of potency) increased proportionally with the irritation potential (IP; measurement of toxicity). In the second class, the ER did not show a good correlation with the IP. Using 35 molecular parameters that contributed to the ER/IP ratio, the authors defined a descriptor for the overall quality of a CPE. These studies reveal fundamental constraints in

GENE THERAPY

Permanent correction without selection

Rapid and stable modification of the human genome at a specific location has been hindered for a long time by technical limitations. Urnov *et al.* now describe a method that uses engineered zinc-finger nucleases (ZFNs) to stimulate homologous recombination, both in transformed and primary human cells. Although this approach has been previously used in model systems, the new study establishes the usefulness of ZFN-driven genome editing for human genetics, and highlights the potential for 'gene modification' therapy of inherited diseases.

The approach takes advantage of two fundamental biological processes: DNA recognition and DNA repair. Targeted cleavage of DNA is achieved by zinc-finger proteins that have been designed to recognize unique chromosomal sites and are fused to the non-specific DNA cleavage domain of a restriction enzyme. A double-strand break that is induced by the resulting ZFNs can create specific alterations in the genome by stimulating homology-directed repair between the locus of interest and an extrachromosomal donor molecule.

The authors designed a large collection of selected zinc-finger modules that would improve ZFN specificity and efficiency. They created a donor plasmid that carries a wild-type *GFP* sequence, which was introduced into cells along with a mutated GFP-encoding gene. Action by the ZFNs restored *GFP* function in 10% of cells — a substantial increase in homologous recombination frequency over that obtained in other selection-free settings. But can we achieve permanent and precise modification of an endogenous gene?

Indeed, the authors succeeded in changing the sequence of the interleukin 2 receptor-γ (*IL2Rγ*) gene in a targeted fashion by transfecting ZFNs and a mutated donor DNA, both into transformed and primary T cells, and showed that ZFNs can induce modification of the endogenous locus in 20% of cells within 4 days of treatment and without drug-based selection. Taking this result a step further, cells that were homozygous for the knockout allele were isolated and rapidly corrected to the wild-type phenotype by using the same ZFNs and a donor DNA molecule that repairs the mutation.

Although this approach was efficiently used to correct a mutation, it still requires optimization in appropriate whole-organism systems. Delivery of ZFN-encoding and donor DNA molecules to cells and the potential immunogenicity of ZFNs impose certain limitations, but these recent advances are promising for therapeutic strategies that involve *ex vivo* cell manipulation, especially for correcting monogenic disorders of the haematopoietic system and disrupting genes that are involved in infectious disease.

Ekat Kritikou, Nature Reviews Genetics

References and links

ORIGINAL RESEARCH PAPER Urnov, F. D. *et al.* Highly efficient endogenous human gene correction using designed zinc-finger nucleases. *Nature* 3 April 2005 (doi:10.1038/nature03556)

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optimizing the balance between potency and safety.

However, using the structural understanding gained from previous experiments, the authors used *in silico* screening followed by *in vitro* testing to identify a number of improved CPEs. They selected the best CPEs from the 10 different chemical classes and 'mutated' them to generate variants. A significant number of the 'mutants' were better fluidizers. The lead candidate, stearyl methacrylate, was tested *in vitro*, and yielded a predicted ER/IP value of about 12, which is substantially higher than the commonly used oleic acid with a value of 3.8.

With further safety testing, these second-generation molecules could broaden the repertoire of CPEs available for transdermal applications in the future.

Melanie Brazil

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PROTEASES

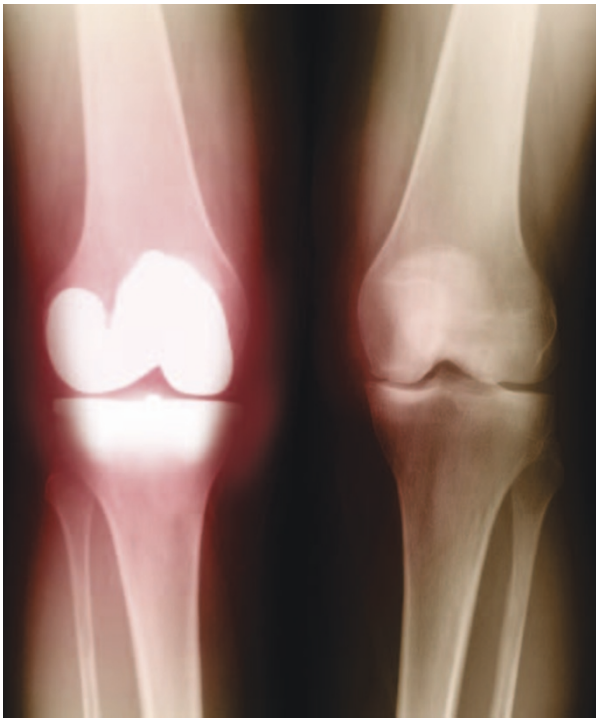
Joint advantage

Two studies simultaneously published in *Nature* suggest that the metalloprotease ADAMTS5 is the main culprit of cartilage degradation in arthritis. The results, which were obtained with ADAMTS5-null mice, need corroborating in human tissue but provide the first evidence of a single gene deletion directing the progression of cartilage degradation in models of arthritis. Developing targeted protease inhibitors against ADAMTS5 to halt the progression of joint destruction would be a significant step forward in treating this debilitating, progressive disease.

Arthritis is characterized by the breakdown of cartilage, which is thought to be caused by dysregulated proteolytic activity within the extracellular matrix. A major target for proteolytic breakdown is the proteoglycan aggrecan, which is cleaved at a specific site by several members of the ADAMTS protease family. Two members of this family seem to be particularly active aggrecanases in cartilage — ADAMTS4 and ADAMTS5 — but the extent to which either plays a role in aggrecan degradation in arthritis has not been determined. By using mice in which the gene for either ADAMTS4 or ADAMTS5 has been knocked out, two groups have now convincingly shown that ADAMTS5 is the primary aggrecanase responsible for degrading cartilage in mouse models of osteoarthritis (OA) and rheumatoid arthritis (RA).

Amanda Fosang and colleagues examined the presence of ADAMTS-specific aggrecan degradation products in cartilage extracted from unmanipulated mice and found a reduction of these products in both ADAMTS4- and ADAMTS5-null mice, indicating that both enzymes might have a role in normal cartilage turnover. The reduction of the degradation products was more substantial in the ADAMTS5-null mice cartilage extracts.

In the study by Elisabeth Morris and colleagues, cartilage degradation was initiated in wild-type mice and ADAMTS5-null mice, by surgical induction of joint instability (an established model of OA). Mice lacking functional ADAMTS5 had significantly reduced cartilage degradation compared with wild-type mice. Analysis of joints using an antibody against the cleavage product generated by ADAMTS4 and ADAMTS5 showed that aggrecan degradation was markedly reduced in the ADAMTS5-null mice.



Inflammatory modulators have been reported to induce degradative enzyme activity and the release of aggrecan *in vitro*, and are known to be implicated in the pathogenesis of both OA and RA. Both studies looked at the effects of inflammatory modulators on aggrecan release in a culture of articular cartilage, and found that interleukin-1α (IL-1α) caused a significant increase in the release of aggrecan in cultures of cartilage from the wild-type and the ADAMTS4-null mice. Characterization of this released aggrecan confirmed it had been cleaved at the ADAMTS-specific cleavage site. By contrast, there was little aggrecan release from cartilage of mice lacking ADAMTS5. Finally, Fosang and colleagues showed that when ADAMTS5 activity was ablated in a mouse model of inflammatory arthritis (an established model of acute RA), only 7% of joints showed cartilage erosion, compared with 36% of joints in the control mice.

Both reports clearly demonstrate that ADAMTS5 is the major aggrecanase in mouse cartilage and suggest that inhibiting its activity could be a new therapeutic strategy for human arthritis.

Joanna Owens

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