EDITORIAL

# Chemical Engineering and Drug Delivery

## Historical background

Since its beginnings (first decade of the 20th century), chemical engineering has undergone several and fundamental transformations. Indeed, the affirmation of the concept of "*unit operation*" (distillation, extraction, filtration, crystallization, and so on) marked the definitive detachment of chemical engineering from the original chemistry frame[1]. The idea that each "*unit operation*" was governed by its own distinct principles was definitively overcome in 1960 when some valuable researchers (in particular Neal R. Amundson, Rutherford Aris, R. Byron Bird, Edwin N. Lightfoot and Warren E. Stewart) affirmed that all the "*unit operations*" are connected by a unique leading concept represented by the mass, energy and momentum balance. This situation represented the ideal background for another important transformation of Chemical Engineering, i.e the development of the so called Biomedical Engineering[1]. Although a clear evidence of the extension of the cultural horizons of Chemical Engineering was felt only in the mid 1970s, the seed of Biochemical Engineering must be searched in the early 1960s when valuable researchers (such as, for example, Elmer L. Gaden, Arthur B. Metzner, R. Byron Bird, Edward W. Merrill) understood that the concept of balance (mass, energy and momentum) could be profitably applied also to knowledge fields, such as medicine, biology, pharmacy and psychology, that were, traditionally, far from Chemical Engineering. In so doing, these researchers introduced the concept of interdisciplinary that is so important in the modern research and that represents, according to me, the winning strategy also for the future.

## State of the art

Undoubtedly, the attitude of chemical engineers to transfer laboratory findings to the practical level and the rapid improvement of personal computers favoured the development of Biomedical Engineering. Indeed, Chemical Engineering could contribute to the above mentioned not traditional knowledge fields in different ways among which, in my opinion, one of the most important was represented by mathematical modelling[2]. As a mathematical model can be defined as a mathematical metaphor of some aspects of reality (objects and devices behaviour)[3], mathematical modelling is a cognitive activity of human mind that requires a deep knowledge of the phenomena under study and good mathematical skills. Accordingly, mathematical modelling implied the merging of typical (chemical) engineers skills with those of pharmacists, biologists, medical doctors, psychologists and so on, to get common and higher results. In so doing, mathematical modelling has become a common tool overcoming the cultural barrier existing among the different knowledge fields and it has given a fundamental improvement to the interdisciplinary approach. In other words, both chemical engineers and biomedical researchers recognised the culturally transversal role of mathematical modelling. The scientific literature is full of examples about this interdisciplinary approach[1,2,4,5] and it is not possible mentioning all of them in this preface. However, it is sure that, following the path underwent by very important researchers such as, for example, Higuchi and Peppas, a great part of the mathematical modelling activity was devoted to the study of drug release from the many kinds of release systems available. This aspect is also witnessed by the topics matched in this special issue on drug delivery. Indeed, 53% of the papers deal with the problem of release kinetics, 20% are about the characterisation of the polymeric matrix devoted to the drug release, 13% match the problem of the bioavailability enhancement of poorly soluble drugs, 7% are devoted to the in silico designing of nano-vectors and 7% are about the modelling of stem cells differentiation. Interestingly, the interdisciplinary character of these papers is underlined by the cultural provenience of their authors that are chemical engineers, material engineers, pharmacists, biologists and medical doctors.

## Future developments

As recently pointed out by Siepmann[6], I agree[7] with the convincement that one of the new challenge for Biomedical Engineering is the combination of mechanistic theories able to realistically de-

scribe the simultaneous processes of drug release and the subsequent ADME processes (drug Adsorption, Distribution, Metabolisation and Elimination) within the human body. A further, subsequent, challenge relies on pharmacodynamics, i.e the prediction of the effect of a drug released from a specific delivery system[8]. This aspect is not only important *per se*, but it acquires considerable relevance in the light of the emerging concept of "personalised medicine"[9] whose target is to optimize the dose regimen for each patient. Accordingly, we are proceeding towards the Leonardo da Vinci concept of true science: "*niuna umana investigazione si può dimandare vera scienzia, s'essa non passa per le matematiche dimostrazioni*" (no human investigation can be defined true science if it cannot be mathematically demonstrated)[10]. Thus, the mathematical model becomes the theoretical legitimacy of the experimental findings.

## References


1. *Peppas, N. A., Langer, R.*, AIChe J. **50** (2004) 536.
2. *Grassi, M., Grassi, G., Lapasin, R., Colombo, I.*, Understanding drug release and absorption mechanisms: a physical and mathematical approach", CRC Press, Boca Raton (FL, USA), 2007, 1–627.
3. *Israel, G.*, In: Modelli Matematici nelle Scienze Biologiche, Freguglia, P. Ed., QuattroVenti, 1998.
4. *Peppas, N. A., Langer R.*, AIChe J. **49** (2003) 2990.
5. *Langer, R.*, AIChe J. **46** (2000) 1286.
6. *Siepmann, J., Siepmann, F.*, Int. J. Pharm. **314** (2008) 101.
7. *Grassi, M., Lamberti, G., Cascone, S., Grassi, G.*, Int. J. Pharm. **418** (2011) 130
8. *Evans, D.*, Sci. Pharm. **78** (2010) 588.
9. *Wening, K., Breitkreutz, J.*, Int. J. Pharm. **404** (2011) 1.
10. *da Vinci, L.*, 1651. Trattato della Pittura.



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