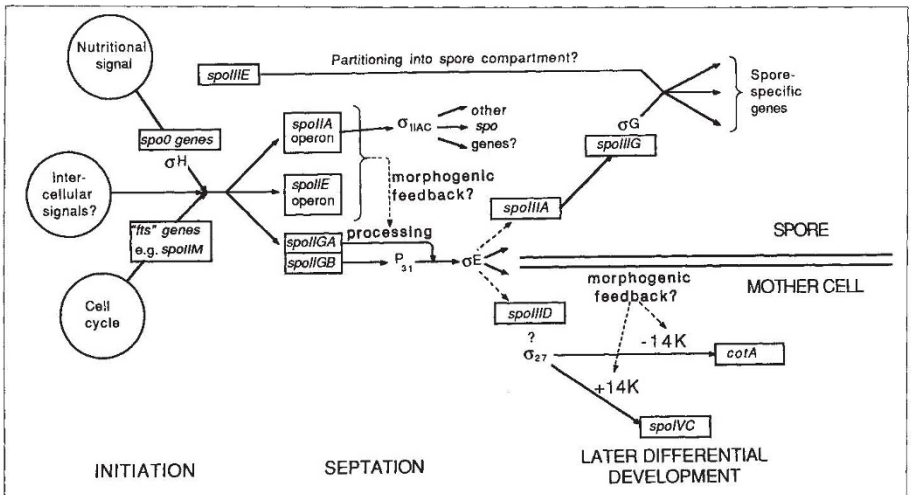

Fig. 2 Schematic diagram illustrating some of the recent advances made in understanding regulation of spore formation. Boxes, important regulatory genes placed according to approximate time of expression. Several of these encode products (sigma factors, σ) that confer an altered promoter specificity on RNA polymerase. Solid arrows, 'dependence relationships' (ref. 2); the gene or signal at the base of the arrow is necessary for the expression of the gene at the head of the arrow. The decision to leave the vegetative cycle and initiate sporulation depends upon three types of signal: starvation, population density and progress through the cell cycle. Little is known of the mechanism controlling the next step, septation, but the completion of the septum may have an important influence on the production of mature σE, which is required for further development in both differentiating cells. Two genes involved in controlling the differential gene expression that occurs subsequently are *spoIIIA* and *spoIIID*. Their implied dependence on σE has not yet been established (dotted arrows). The phenotypes of *SpoIIID* mutations make it a good candidate for the gene encoding the newly discovered mother-cell specific sigma factor, σ27.

sporulation in the mother-cell compartment. The 14K protein, and possibly another protein encoded by the *gerE* gene, could be bifunctional proteins that are integral components of the spore coat as well as genetic regulators. It could be envisaged that the regulatory activity of such proteins is modulated by either the onset or the completion of their assembly into the developing spore coat.

Another example of the coupling of morphogenesis and gene regulation was recently described by Stragier *et al.*[5]. The regulation of events occurring after stage II of sporulation are controlled by proteolytic processing of an inactive precursor (P_{31}) of σE (see above) into its active form. Stragier *et al.* propose that the processing of P_{31} is mediated by the product of a coordinately regulated gene, *spoIIGA*, but that the 1-hour delay in this event is caused by the assembly of *SpoIIGA* into a processing complex that depends on the completion of the spore septum, which acts as a 'landmark' event in the developmental process. It will be interesting to see whether other examples of coupling between morphogenic events and the regulation of sporulation gene expression can be found. A good candidate must be the completion of the engulfment event that results in closure of the prespore within the mother-cell cytoplasm.

Finally, much work is being done on the genes that control the initiation of sporulation — the decision to divide vegetatively or enter the sporulation cycle. In this area it is clear that at least one specialized form of sigma is involved, σH (σ30, the product of *spo0H*[6]). Other genes, *spo0A* and *spo0F*, encode products that belong in the *ntrC ompR* family[7], perhaps implicating protein phosphorylation in the controlling mechanism[8]. Alan Grossman (Harvard University) has identified at least two extracellular factors that appear to transmit intercellular signals, coordinating the decision to differentiate with the density of the population of cells. A third extracellular factor is probably operative at a later stage of spore development (Glen Chamblis, University of Wisconsin).

Clearly, the fortunes have gone full circle for *Bacillus* sporulation. Several aspects of the mechanisms of regulation now being unravelled, proteolytic activation, 'hormonal' signalling, protein phosphorylation and complex transcriptional regulation, are reminiscent of eukaryotic systems. Perhaps the general pattern of rules governing cellular development and differentiation will, like those of intermediary metabolism, turn out to be almost universal. □

1. Errington, J. & Jones, D. *J. gen. Microbiol.* **133**, 483–492 (1987).
2. Mandelstam, J. & Errington, J. *Microbiol. Sci.* **4**, 238–244 (1987).
3. Dawes, I.W. *et al. Nature* **230**, 567–569 (1971).
4. Helmann, J.D. & Chamberlin, M.J. *A. Rev. Biochem.* (in the press).
5. Stragier, P. *et al. Cell* **52**, 697–704 (1987).
6. Dubnau, E. *et al. J. Bact.* **170**, 1054–1062 (1987).
7. Trach, K.A. *et al. Proc. natn. Acad. Sci. U.S.A.* **82**, 7260–7264 (1985).
8. Ninfa, A.J. & Magasanik, B. *Proc. natn. Acad. Sci. U.S.A.* **83**, 5909–5913 (1986).

Jeffery Errington is in the Microbiology Unit, Department of Biochemistry, University of Oxford, Oxford OX1 3QU, UK.

Daedalus

Orderly ascent

LAST week, Daedalus decided that a planar explosion-front traversing a single crystal of high explosive would do so in perfect molecular order. It would release the reaction products not as randomly thermalized hot gas, but as a fan of collimated molecular beams, travelling fast enough (many kilometres per second) to carry off by their sheer velocity all the chemical energy of the explosive. Daedalus is now using the effect in rocketry. He is designing a collimated-combustion rocket so cheap, simple and effective as to take space exploitation away from the grandiose posturing of government agencies, and give it to organizations with so little money that they are driven to use their resources sensibly and profitably.

Even Daedalus does not intend to make a solid-fuel rocket out of one huge unmodified single crystal of high explosive. A rocket fuel should not detonate, but must burn steadily at a few tens of centimetres per second. So Daedalus will make his rocket motor from a conventional soft, amorphous, slow-burning propellant binder, maximally loaded with small needle- or plate-shaped single crystals of explosive. By proper rolling or deforming of this composition during the shaping of the motor into its final conical form, the crystals will be aligned in the binder so that each is set to eject its molecular-beam pulse accurately down the axis of the cone. When the cone is ignited at the base, therefore, it will be thrust into the air point first. The planar combustion face will move up the cone at a rate set by the slow-burning binder; but the propulsive effect will come overwhelmingly from the collimated combustion of the explosive crystals, each ejecting its forceful pulse of high-speed molecules.

Thus, the complexities of traditional rocket design are totally bypassed. No rocket nozzle is needed, for the exhaust gas is already perfectly collimated; the motor itself has no internal pressure and needs no casing. Best of all, the rocket need not be staged. A conventional space rocket has several stages, each a complex and vulnerable entity in its own right, each with the job of lifting all the stages above it, and separating cleanly when it has done so. But Daedalus's conical rocket simply burns away from the base upwards, and is thus continuously transformed into an ever smaller copy of itself. This elegant 'self-similar rocket' has, in effect, an infinite number of infinitesimal stages. The asymptotic paragon of rocket efficiency, it consists of practically nothing but fuel and payload. Only a guidance package of electronics and steering thrusters in the nose mars its ultimate simplicity.

David Jones