that in *E. coli*, as in mammalian cells, factors besides SRP and FtsY are required for the release of the signal sequence from SRP and successful targeting. These could be an as yet unknown SR$\beta$ homologue, a chaperone or components of the translocation site.

Protein components of the translocation site were first identified by genetic screens in *E. coli*[11], then in the yeast *Saccharomyces cerevisiae*[12], and most recently by a biochemical approach in mammalian cells[5]. Strikingly, the central part of the translocation complex in all three systems seems to consist of related proteins. Using crosslinking approaches, Sec61-$\alpha$ of mammalian cells, SEC61p of yeast and SecY of *E. coli* have been shown to line the postulated translocation pore[5] (see figure). Structurally, these proteins are quite similar.

**Factors involved in protein secretion in mammalian cells, yeast and *E. coli***

| | Mammals | Yeast | *E. coli* |
|---|---|---|---|
| **Cytosol** (signal recognition, chaperoning) | | | |
| SRP-RNA | 7S RNA | SCR1 | 4.5S RNA |
| SRP proteins | 9, 14, 19 | SEC65 | |
| | SRP54 | SRP54 | Ffh (P48) |
| | 68, 72 | ? | |
| | | | SecB |
| **Membrane** (docking) | | | |
| SRP receptor (SR) | SR$\alpha$ (DP) | SR$\alpha$ | FtsY |
| | SR$\beta$ (DP) | ? | ? |
| | ? | ? | SecA |
| **Membrane** (translocation) | | | |
| Translocation machinery | Sec61-$\alpha$ | SEC61p | SecY |
| | Sec61-$\beta$ | ? | ? |
| | Sec61-$\gamma$ | SSS1p | SecE |
| | | | band 1 |
| | | | SecD |
| | | | SecF |

In all systems, other proteins associate with Sec61/SecY. These are Sec61-$\beta$ and Sec61-$\gamma$ in mammalian cells, SecE and band 1 in *E. coli*, and SEC62p, SEC63p and SEC66p in yeast. Mammalian Sec61-$\beta$ and Sec61-$\gamma$ have now been isolated and sequenced by Hartmann *et al.*[3]. Both proteins are predicted to span the membrane once. Of particular interest is that mammalian Sec61-$\gamma$ bears significant homology to SSS1p of *S. cerevisiae* and can functionally replace it; SSS1p protein was discovered last year as a suppressor of *sec61* temperature-sensitive mutants[13]. Sec61-$\gamma$ also has a small, but probably significant, resemblance to the SecE protein of bacteria.

Reconstitution studies have shown that, in *E. coli*, SecA and SecY/E are the only membrane proteins required for translocation of a pre-protein across membranes. Similarly, mammalian SR and the Sec61 complex reconstituted into lipid vesicles promote protein translocation[14,15]. It therefore seems that the core components of the translocation site have been characterized and consist of the pore protein, Sec61/Y, and associated proteins. Two small proteins associate with mammalian Sec61 and *E. coli* SecY, but until now only unrelated proteins have been found to associate with yeast SEC61p and it has been suggested that two of them (SEC62p and SEC63p) are involved in signal recognition and targeting[12]. So we can expect further growth in the number of proteins that are found to be in, or associated with, the translocation site. For instance, little is known about the release of the nascent chains from the translocation site. In *E. coli*, such a function could conceivably be performed by SecD and SecF.

No eukaryotic homologues for the *E. coli* SecB and SecA have yet been found. These two proteins interact during the targeting of some secretory proteins to the plasma membrane. It is perfectly possible that they constitute an alternative targeting pathway to the SRP/FtsY system, a notion which finds support in the fact that deletion of Ffh does not affect the secretion of SecB-dependent proteins[16]. In yeast there are also strong indications for alternative targeting pathway(s) involving the heat-shock protein HSP70 and possibly SEC62/63p[12]. So it seems that as well as the common pathway represented by SRP/SR and Sec61/Y, species- and substrate-specific secretion pathways have also evolved. □

*Bernhard Dobberstein is in the Centre for Molecular Biology (ZMBH), Postfach 106249, 69052 Heidelberg, Germany.*


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DAEDALUS

## Deep insight

**THE ocean floor is less well known than the surface of the Moon. At present, a few isolated patches can occasionally be glimpsed by robot submersibles. Daedalus now suggests a new approach. He is devising an undersea vehicle to crawl along the existing submarine cables.**

**This neat trick has many advantages. Each cable has a known diameter and surface texture, so a matching drive mechanism can be designed to grip and traverse it. The cable could easily transmit signals to the crawler, and pick up its results, by induction (spy submarines used to read cable traffic in this way). Even coaxial and fibre-optic cables could communicate with the crawler inductively via the power leads for their repeater–amplifiers. A signal sent along the cable to the crawler would take time to reach it, and time to return. This delay would give its exact position on the ocean floor.**

**For some of its length, a cable may be buried in the mud of the ocean floor, either by the impact of laying or subsequently by slow deposition of detritus from above. The crawler's drive would have to be powerful enough to push this overburden aside. It would also need a certain flexibility to negotiate splices and amplifier pods in the cable, and marine organisms such as shellfish which might be growing on it (though these should be rare in the depths). The crawler would project some sort of buoyant mast upwards to survey the ocean bottom from above the opaque muddy clouds raised by its passage.**

**The power supply for the crawler poses problems. Its inductive coupling to the cable could only provide it with milliwatts. It might burn carbonaceous fuel in the ocean's dissolved oxygen, as a fish does. But Daedalus prefers a metallic fuel which slowly dissolves in the surrounding water and generates electricity directly, in battery fashion. With certain chemical precautions, lithium seems the metal of choice. Being lighter than water, it adds no weight to the crawler. A fairly modest supply should power it across the widest ocean.**

**Cheap and effective, cable crawlers will transform oceanography. Along every cable, a succession of crawlers will map the ocean floor and log its changing fauna. Not only will they transmit images and data back to shore; on command they will gather specimens for later study. But careful traffic control will be needed. Two crawlers which met on the same cable could never get past each other. At least one would have to let go, develop buoyancy, and rise to the surface to await rescue.** David Jones