Video Tutorial 6.1: Pairing and synapsis during prophase

The processes by which meiotic chromosomes recognize and pair with their appropriate homologues, and then establish and maintain synapsis along their lengths are not well-understood. [show the overview slide and then zoom in on the Prophase I portion]. These processes have been thoroughly documented by microscopy for many years, but because nuclei have many pairs of chromosomes and pairing and synapsis often happen rapidly, it has not been easy to get a good image of what occurs. Nabeshima et al. published a particularly striking and informative set of images in 2011 involving one of the autosomes in C. elegans, which gives us one perspective on these events.

Based on experiments involving chromosomes that have some of their regions deleted, duplicated, or rearranged, it is generally thought that one end of each meiotic chromosomes in C. elegans is involved in homologue recognition and the initiation of pairing. This end is referred to as the pairing center or homologue recognition region, although the precise sequences or structural features that comprise a pairing center are not known. Pairing centers have also been proposed for meiotic chromosomes in Drosophila and it is likely that something similar occurs for meiotic chromosomes in most or all eukaryotes, but this is not known. Thus, what Nabeshima et al. found for this chromosome in C. elegans may or may not be typical of what occurs for meiotic chromosomes in other organisms.

The experiment was as follows. Using the known genome sequence of C. elegans and libraries that had all of the sequences from the genome, Nabeshima et al. made copies in vitro of sequences of different parts of the chromosome II, one of the autosomes, and labeled the copies with one of three different fluorescent labels. Methods for labeling and hybridizing DNA similar to what they did are described in Tool Boxes in Chapter 2. Sequences from the region of chromosome II corresponding to the pairing center were labeled with the same fluorescent tag, which appears in their images as a green label. Sequences from the other end of the chromosome opposite the pairing center were labeled with a different fluorescent tag, which appears in their images as a blue label, while sequences from the middle of the chromosome were labeled with a third different fluorescent tag, which appears in their images as red. These labels are summarized in the diagram below the images.

The labeled sequences were then hybridized back to the meiotic chromosomes beginning prophase I, and the progression of pairing and synapsis was visualized. These experiments were possible because the ovary in C. elegans has its oocytes with the stages of prophase I in order, so by looking at oocytes at different locations in the same ovary, the progression of pairing and synapsis can be seen. Having the different stages of prophase I in sequence within the same ovary is not unique to oogenesis in C. elegans, but it is one of the advantages of studying meiosis in a model organism like C. elegans.

Let's begin with Figure A and describe what we see. Note that there are two distinct bodies, and that the three different labels regions clearly show up. These are the two homologues of chromosome II. Even at this early stage before pairing has occurred, the homologues are oriented in the same direction, possibly because their pairing regions are attached to the nuclear membrane. The nuclear membrane is not visible in these images. Note also how compact or condensed the chromosomes are.

Figure B shows that the homologues become elongated or decondensed. We don't see the green pairing region for one of the homologues, possibly because it is out of the plane of focus, but the two homologues are clearly still distinct and separate. We will see some other discontinuities in these images, probably because a region of the chromosome is out of the plane of focus—these are two dimensional optical slices through a three-dimensional process. That also explains the appearance of some additional colors in the images as parts of the chromosome come to lie on top of each other or in such close proximity that the microscope can't separate the labels.

There is a major transition between Figures B and C. Note that there is now only a single very large green region, but still two separate, distinct, and elongated red and blue regions. This single large green region is made up of the pairing centers of the two homologues, which have come together—so close together that they cannot be distinguished from each other. This shows the pairing process, that pairing really does initiate at this end as previous experiments had suggested.

Pairing begins with the green pairing centers in Figure C, but the homologues continue to come together in synapsis in the subsequent images. In Figure D, both the green pairing center and the red regions in the middle of the homologues are synapsed but the blue regions at the ends opposite the pairing centers are not yet synapsed. In Figure E, all regions of the homologues are synapsed so that is looks like a single thick chromosome, with three paired and synapsed regions. Figure F appears to show that the synapsis along the length may not be absolutely maintained, and that the homologues can de-synapsis or come apart before coming back together in full synapsis in Figures G and H.

Much more can be said about the processes of pairing and synapsis, and many, many aspects of these processes are not yet understood. But these images by Nabeshima et al. really speak for themselves in showing us what the processes may look like.