EXPERIMENT #8

CELL DIVISION: MITOSIS & MEIOSIS

<u>Introduction</u>

Cells, the basic unit of life, undergo reproductive acts to maintain the flow of genetic information from parent to offspring. The processes of mitosis and meiosis are cellular events in which a parental cell will ultimately pass on its genetic information (encoded within genes on chromosomes) to daughter cells, thus insuring the continuation of that information. In today's lab, you will be observing mitosis, in which the daughter cells will contain the same number of chromosomes as the parent cell. You will also be introduced to meiosis, in which the daughter cells will contain exactly have the number of chromosomes as the parent cell.

<u>Goals</u>

At the end of this laboratory, you will:

1. Be familiar with the stages of both mitosis and meiosis

2. Be able to identify the stages of mitosis in both animal and plant cells via the microscope

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A. Mitosis

Mitosis, the process of cell division, is actually a part of a much larger process called the CELL CYCLE. The cell cycle is composed of 4 stages: G1 (growth or gap), S (synthesis of DNA), G2 (growth or gap), and M (mitosis). In order for a parental cell to divide into two daughter cells, it must be “prepared” for this division. The growth phases occur both before and after the DNA synthesis stage and are involved in producing the necessary cellular components for the act of division. The S phase is involved in duplicating the DNA so that each daughter cell will receive one set of chromosomes. The stages of G1, S, and G2 are collectively referred to as INTERPHASE. As soon as the cell exits G2, mitosis begins and the following events occur: Prophase, Metaphase, Anaphase, and Telophase. These are the four stages of mitosis, and very specific cellular events occur during each stage to insure that the cell divides properly. The following slides will illustrate and characterize each of these four stages of mitosis, as well as the starting interphase stage.

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A. Mitosis (continued)

1. Interphase

G1, S, and G2 stages compose interphase. This stage is a period of growth and DNA duplication. Visually, the cell looks like a typical cell with a defined cell and nuclear membrane. The contents of the nucleus are diffuse and appear to contain millions of stained dots (nuclear material). The following slides depict interphase in both an animal cell (whitefish) and plant cell (allium root tip)

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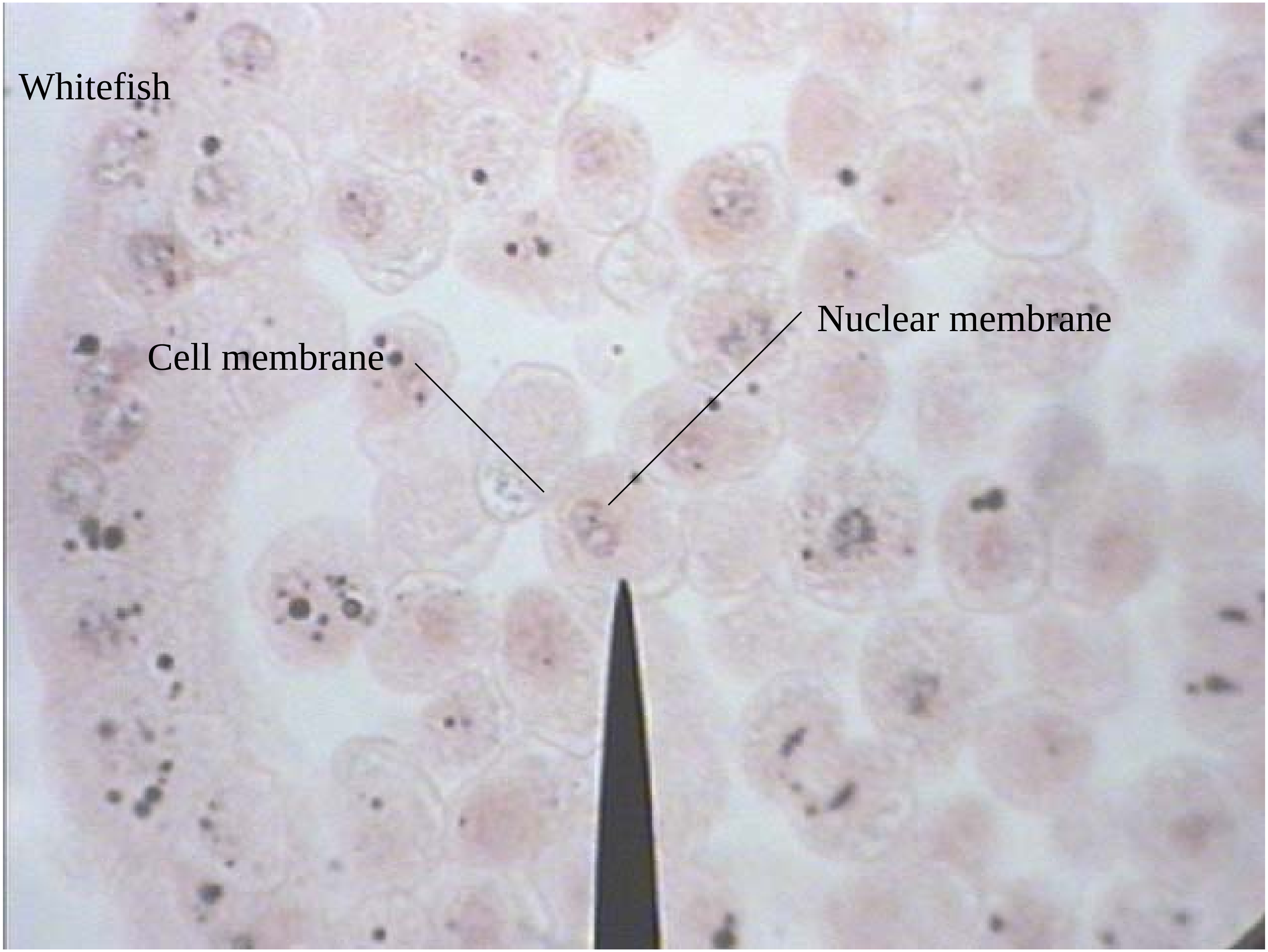

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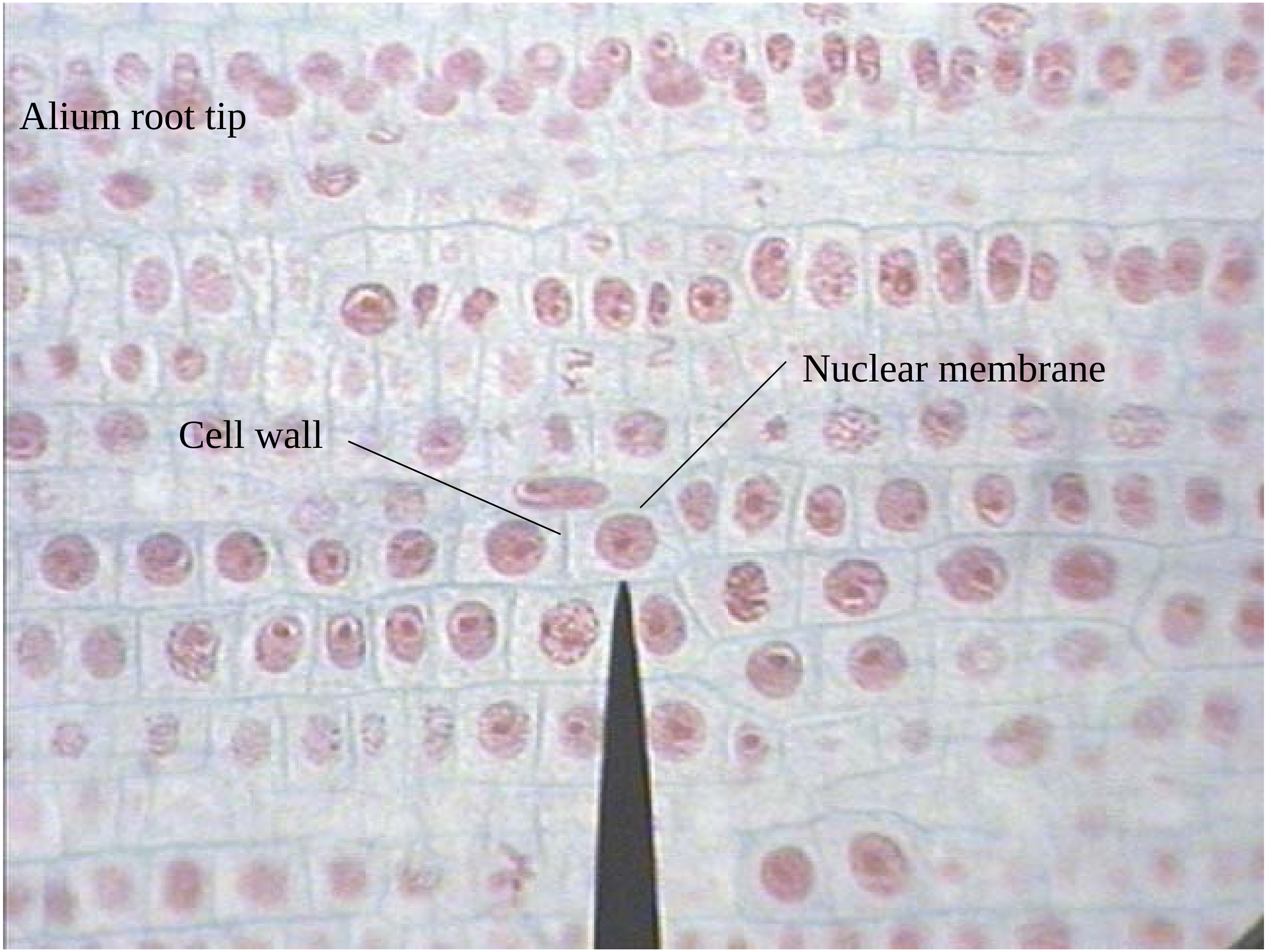

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A. Mitosis (continued)

1. Prophase

Prophase is characterized by the condensation of the diffuse chromatin into visible "strand-like" chromosomes. Even though you cannot visualize it, the condensed chromosomes are arranged as sister chromatids attached at their centromeres. The cell pictured on the following slides do not have an intact nuclear membrane. Another characteristic which is not visible on the following slides are the centrioles (only in animal cells), which migrate to opposite poles and will become the core of the the microtubule organizing center (MTOC)

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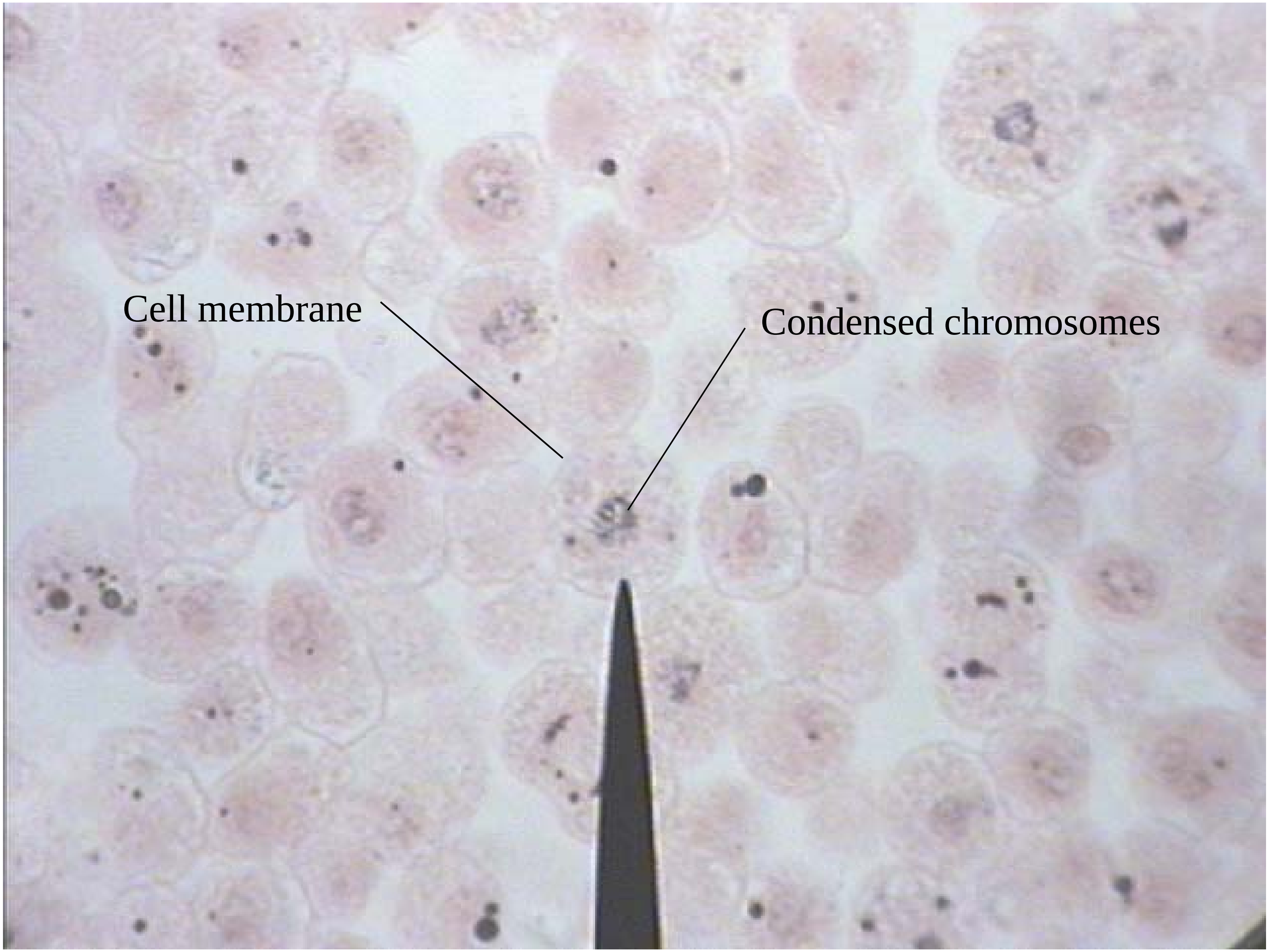

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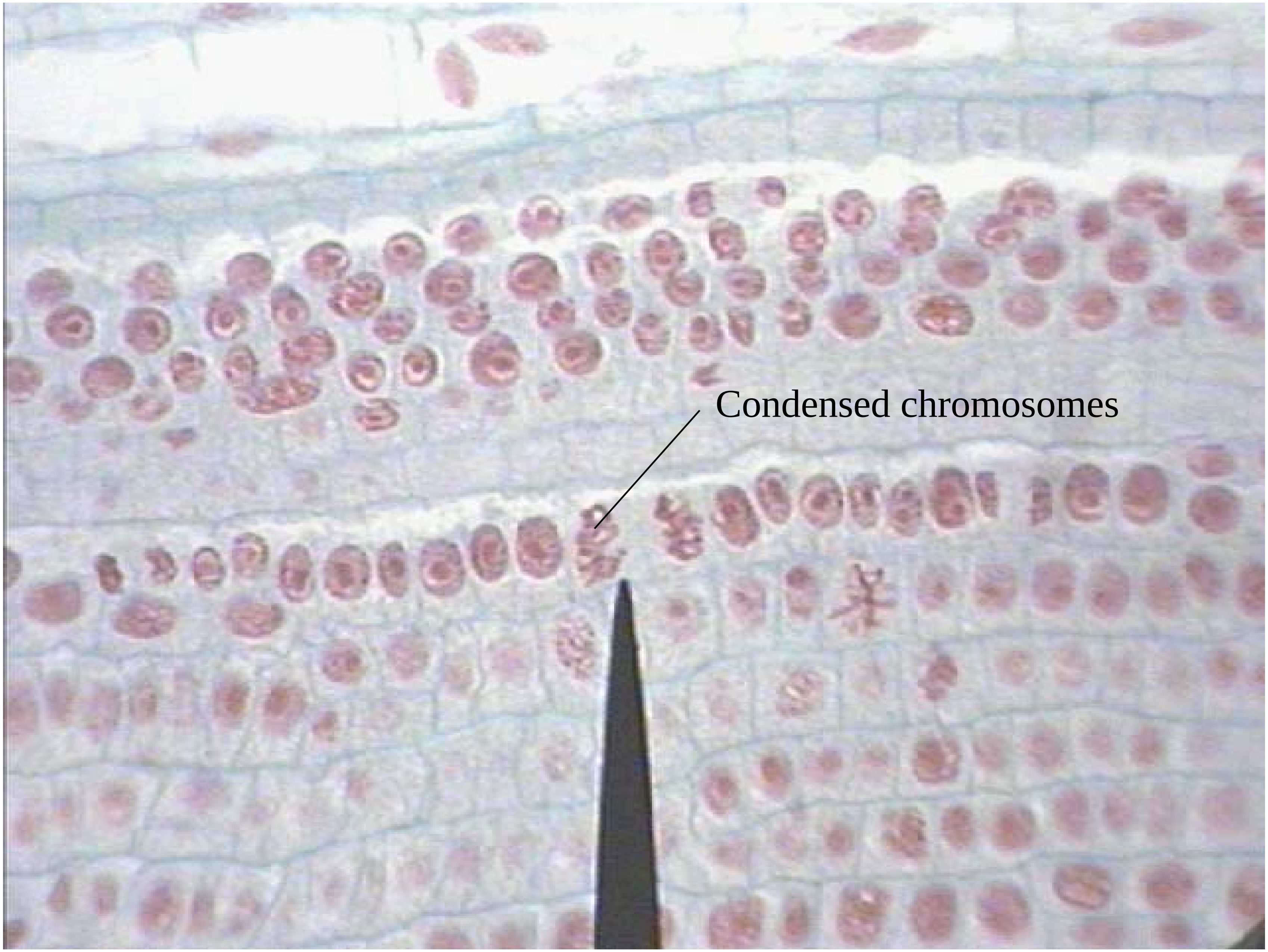

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A. Mitosis (continued)

1. Metaphase

The simplest phase of mitosis to identify is characterized by the “lining up” of the chromosomes along the metaphase or equatorial plate. Spindle fibers may or may not be visible connecting the centromeres of the sister chromatids to opposite ends of the cell.

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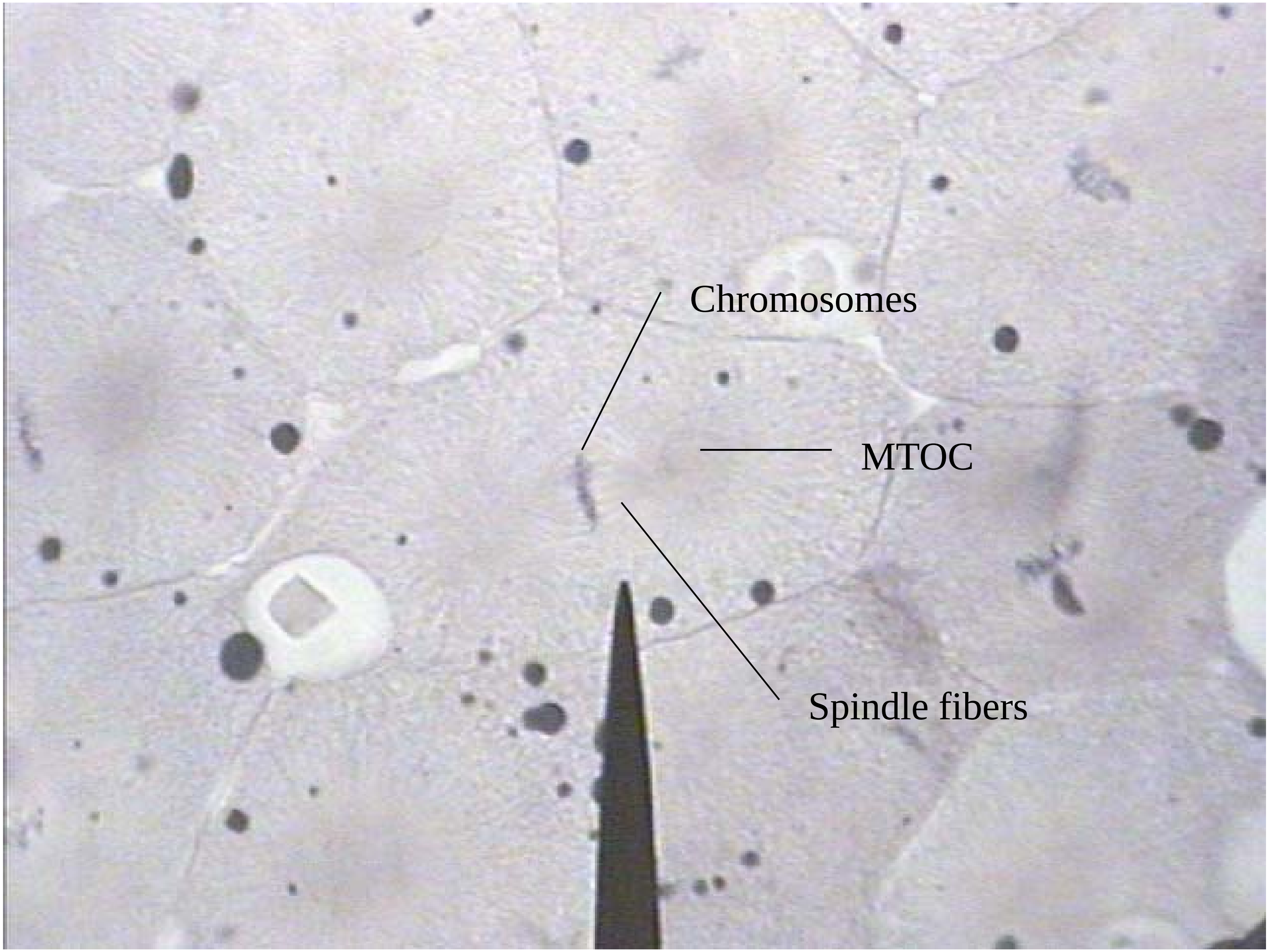

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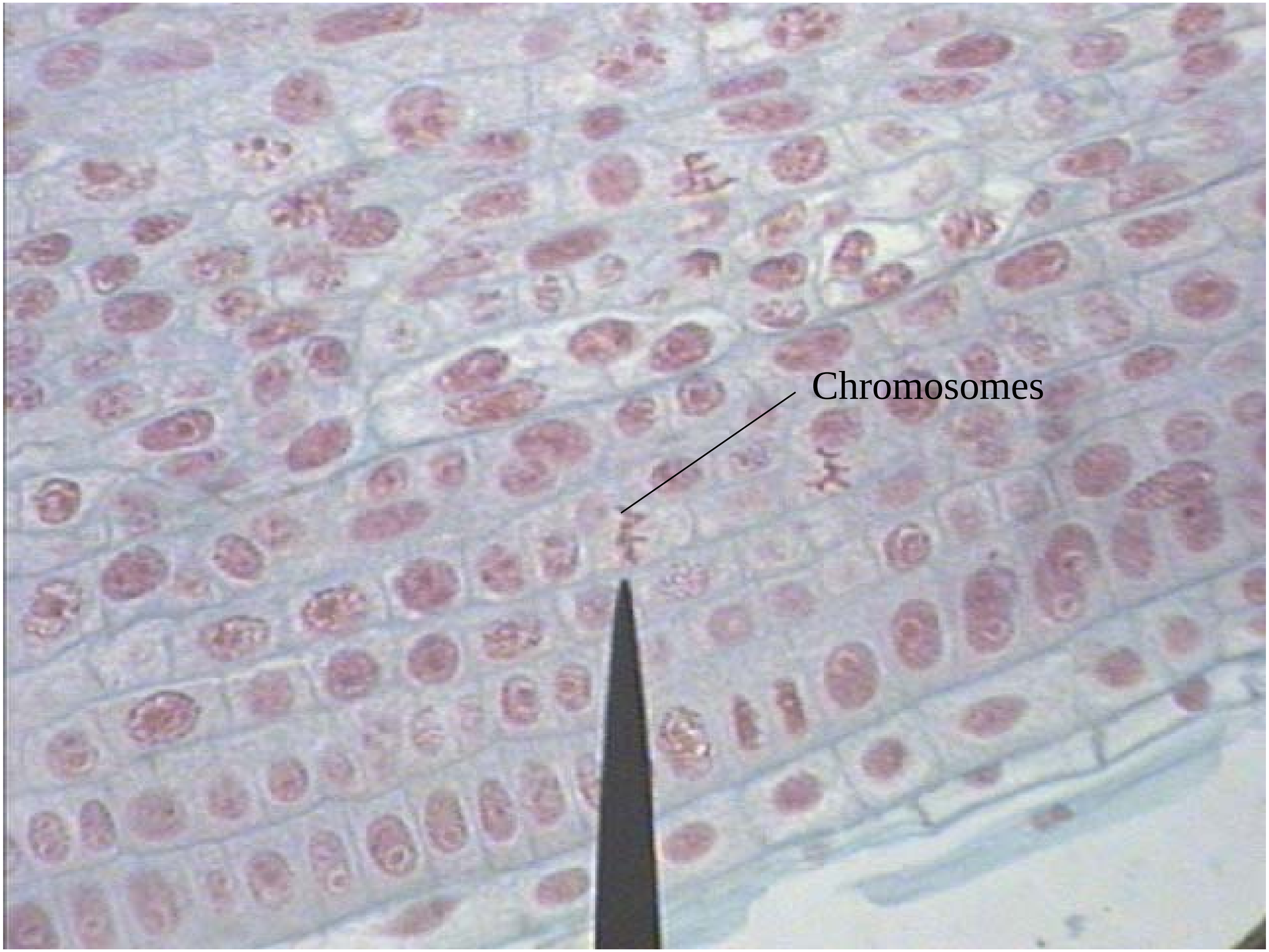

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A. Mitosis (continued)

1. Anaphase

Anaphase is characterized by the separation of the sister chromatids into individual chromosomes. Kinetochore fibers attached to the kinetochore region of the centromere facilitates the movement of the chromosomes toward opposite ends of the cell. The kinetochores ride the kinetochore fibers like a train on railroad track, but as they move along the kinetochore fibers the kinetochores disassemble “destroy” the tracks that they have just passed over. This division of the nuclear material is known as karyokinesis.

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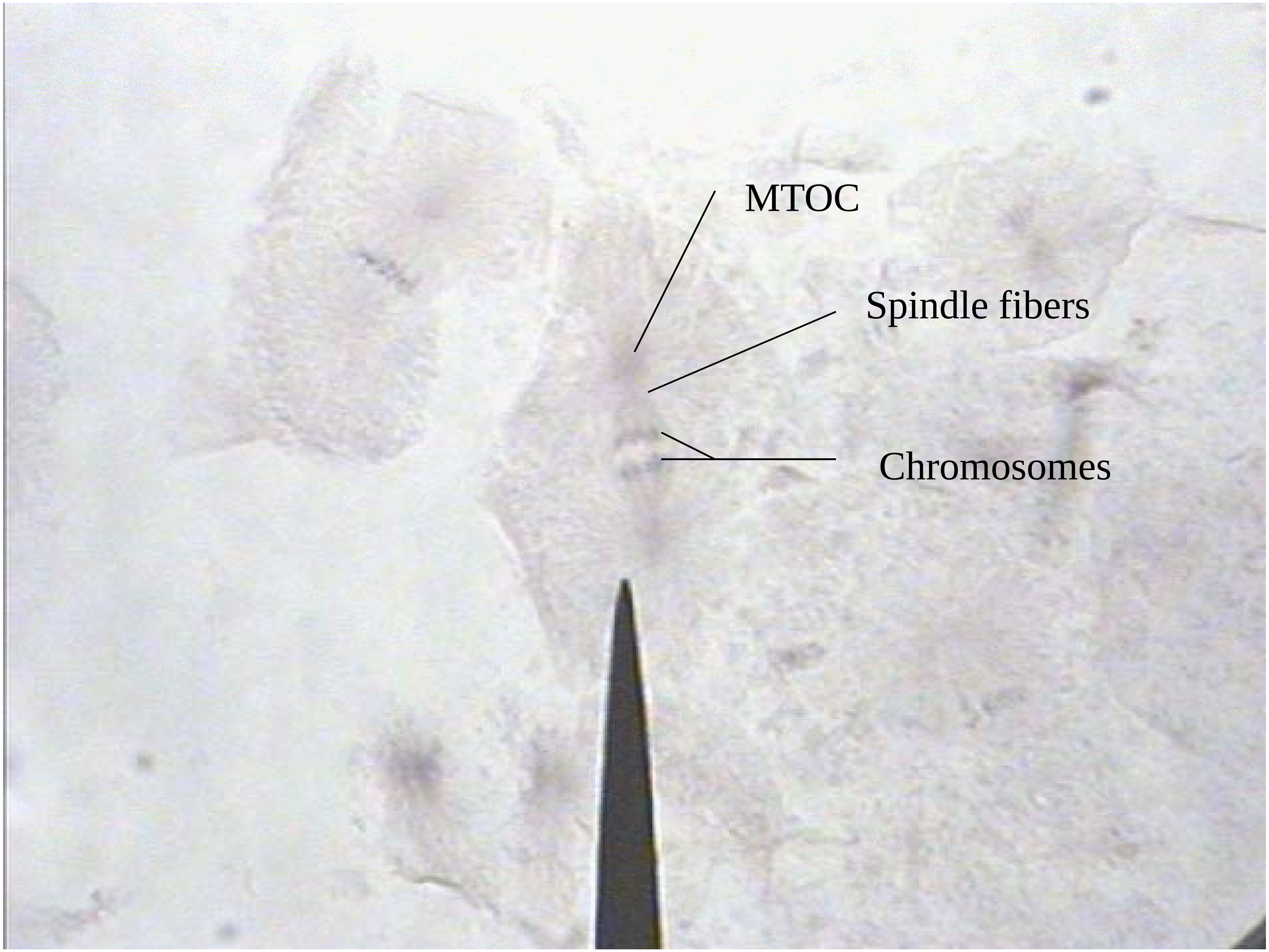

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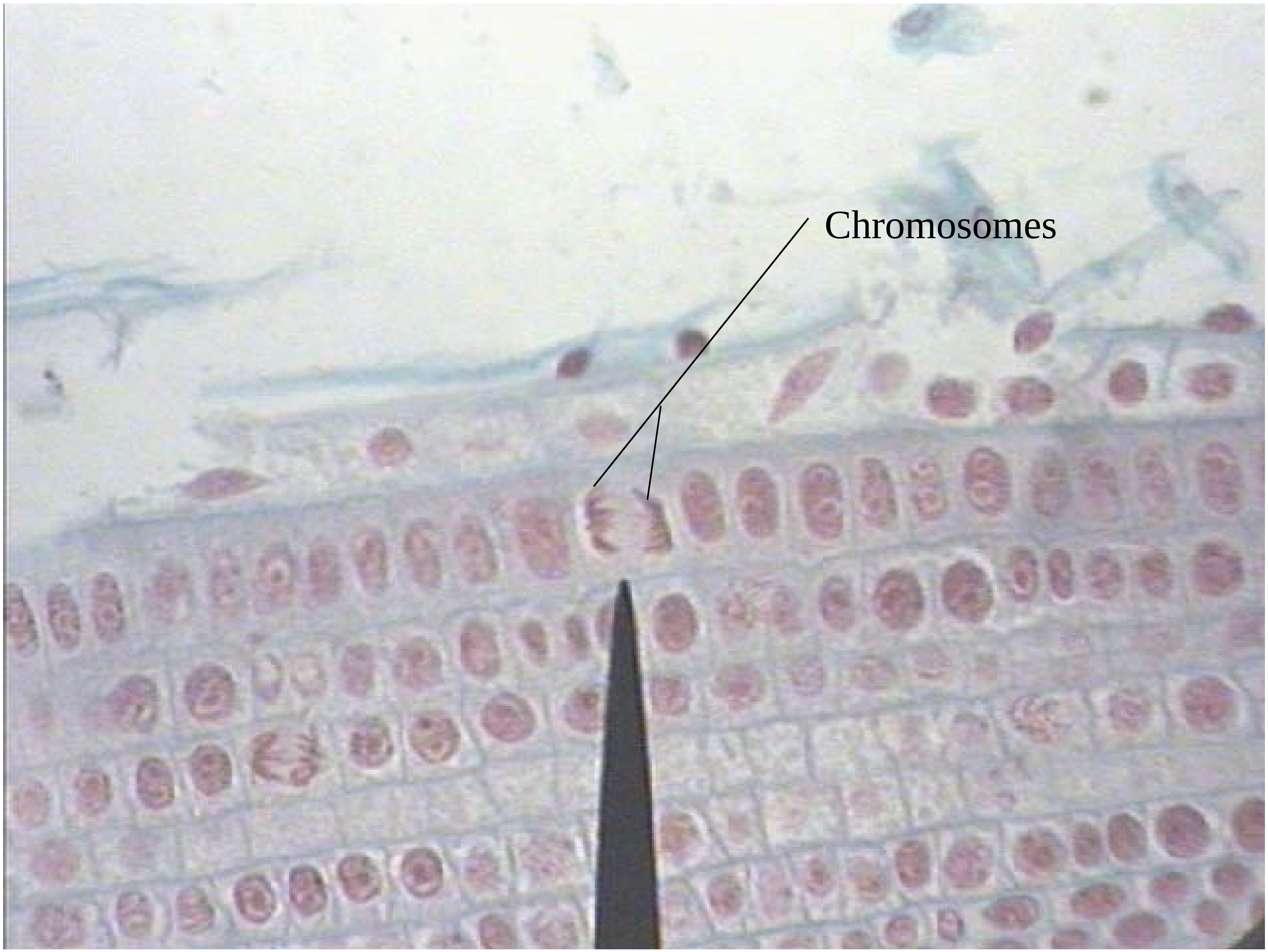

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A. Mitosis (continued)

1. Telophase

Telophase is characterized by the completion of chromosome migration and the reformation of the nuclear membrane. Cytokinesis, the process of dividing the cytoplasm, began in anaphase and is now leaving some definitive characteristics during telophase. In animal cells, the appearance of the cleavage furrow is a good indication that the cell has entered telophase. The cleavage furrow is an invagination of the cell membrane at the point at which the cell will be split at. In plant cell, the appearance of the cell plate (a precursor to the cell wall) is a characteristic of telophase.

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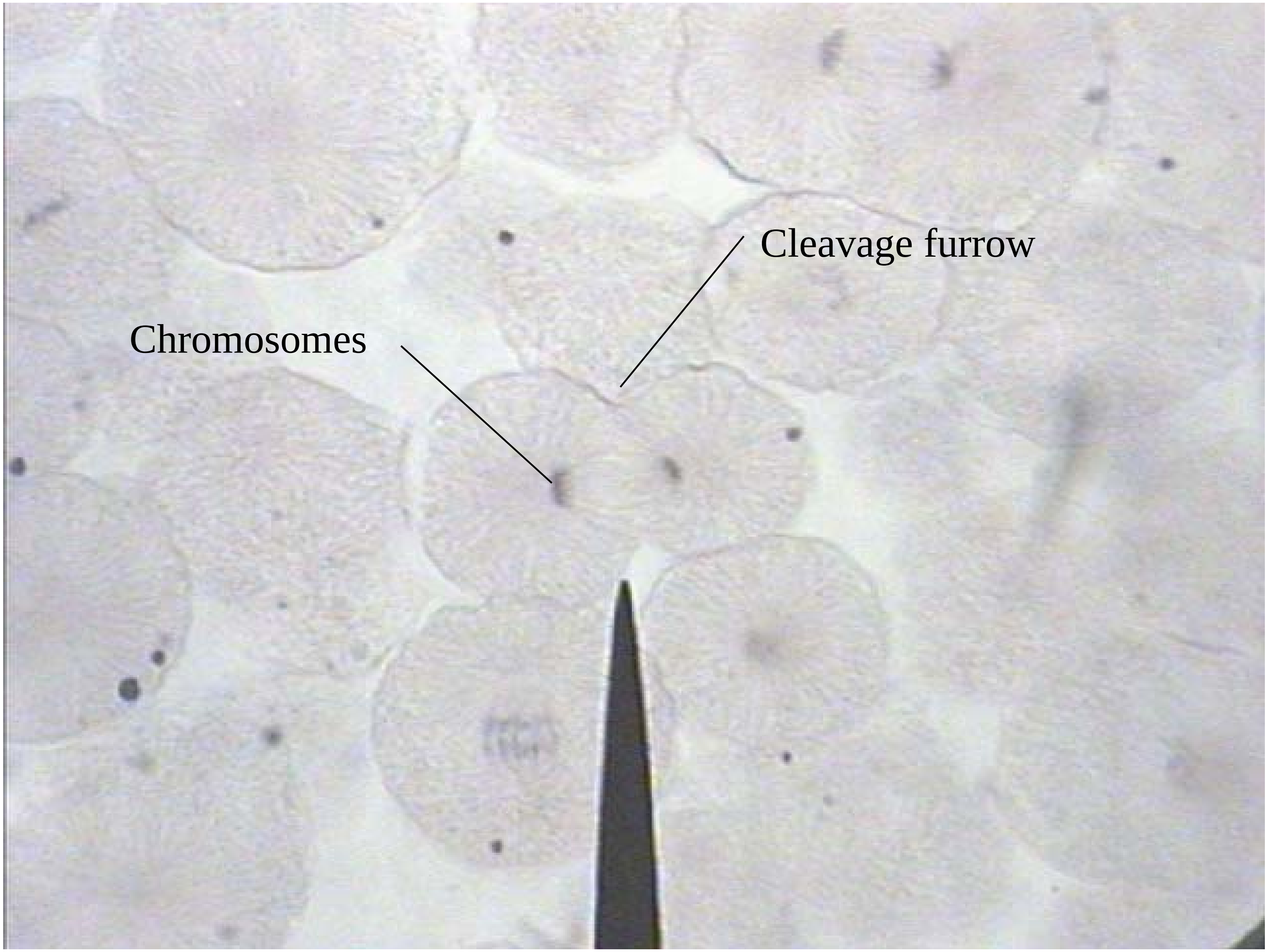

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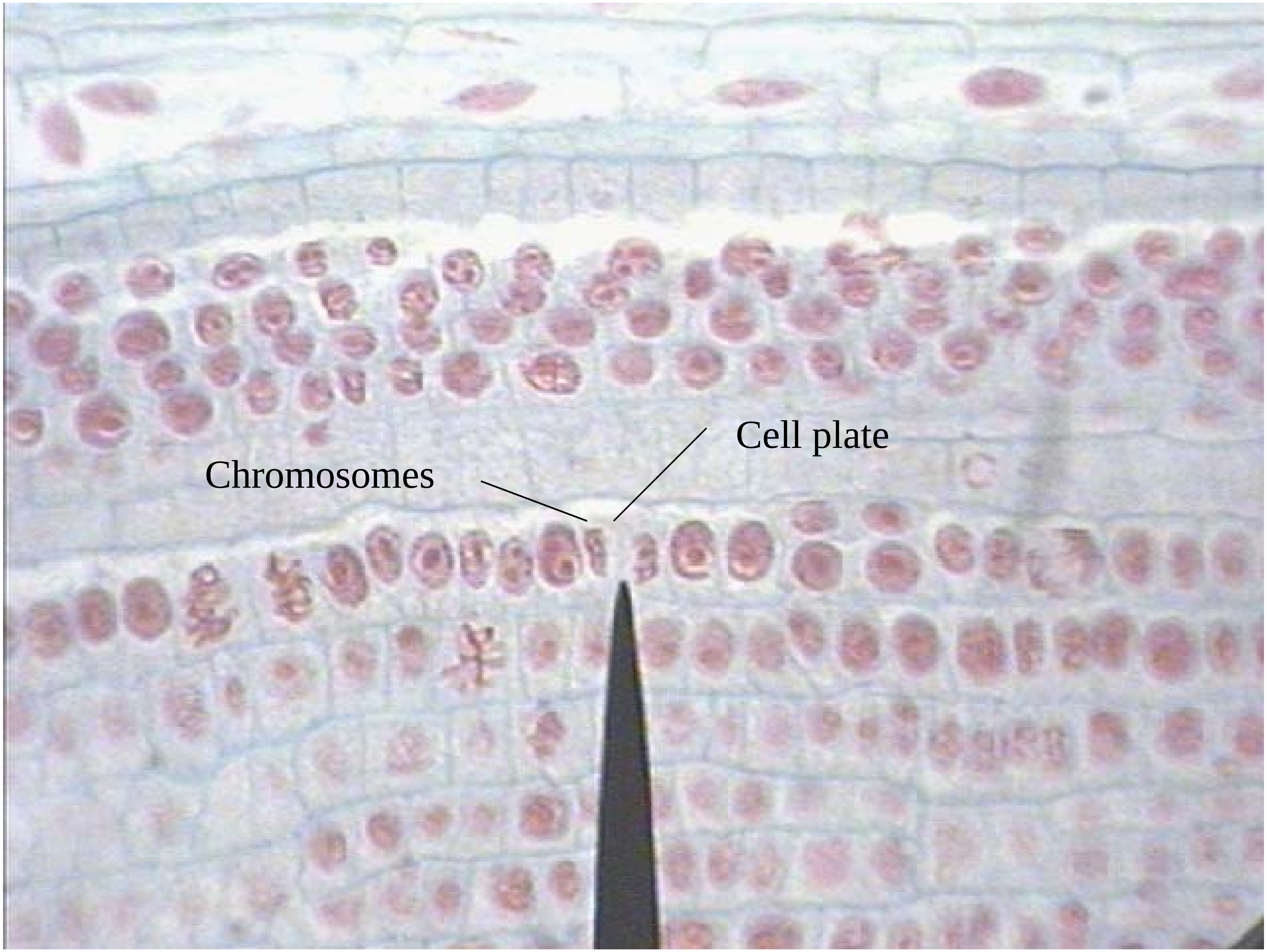

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B. Meiosis

Meiosis is also a process by which there is a division of nuclear material, but instead of producing two daughter cells which contain the same number of chromosomes as the parent, four haploid daughter cells are produced. Each containing only half the number of chromosomes as the parent. The reduction of the chromosome number in these sex cells or gametes is critical for the process of sexual reproduction. When male and female gametes combine with each other during fertilization, a zygote containing the proper number of chromosomes for that organismis produced. This single fertilized egg will then undergo mitotic divisions to become a complex multicellular organism with each cell containing the same genetic information encoded for by a set of chromosomes

Meiosis is divided into two steps: Meiosis I and Meiosis II. Each step of meiosis is divided into the appropriate Prophase, Metaphase, Anaphase, & Telophase stages with the number I or II following it to identify meiosis I or meiosis II. Let us look at the stages of meiosis in order beginning with prophase I.

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B. Meiosis - Prophase I

Prior to prophase I the cell completed a typical interphase stage where the cell grew and DNA was synthesized. During prophase I, the same events that occurred in mitosis also occur here. The chromatin condenses into visible chromosomes, the nuclear membrane disintegrates, and centrioles migrate toward opposite poles. The unique event that occurs during prophase I is synapsis where homologous chromosomes line up and fuse together. This fusion allows the exchange of genetic material between two chromosomes in a process called crossing over. The following pictures are examples of prophase I and synapsis.

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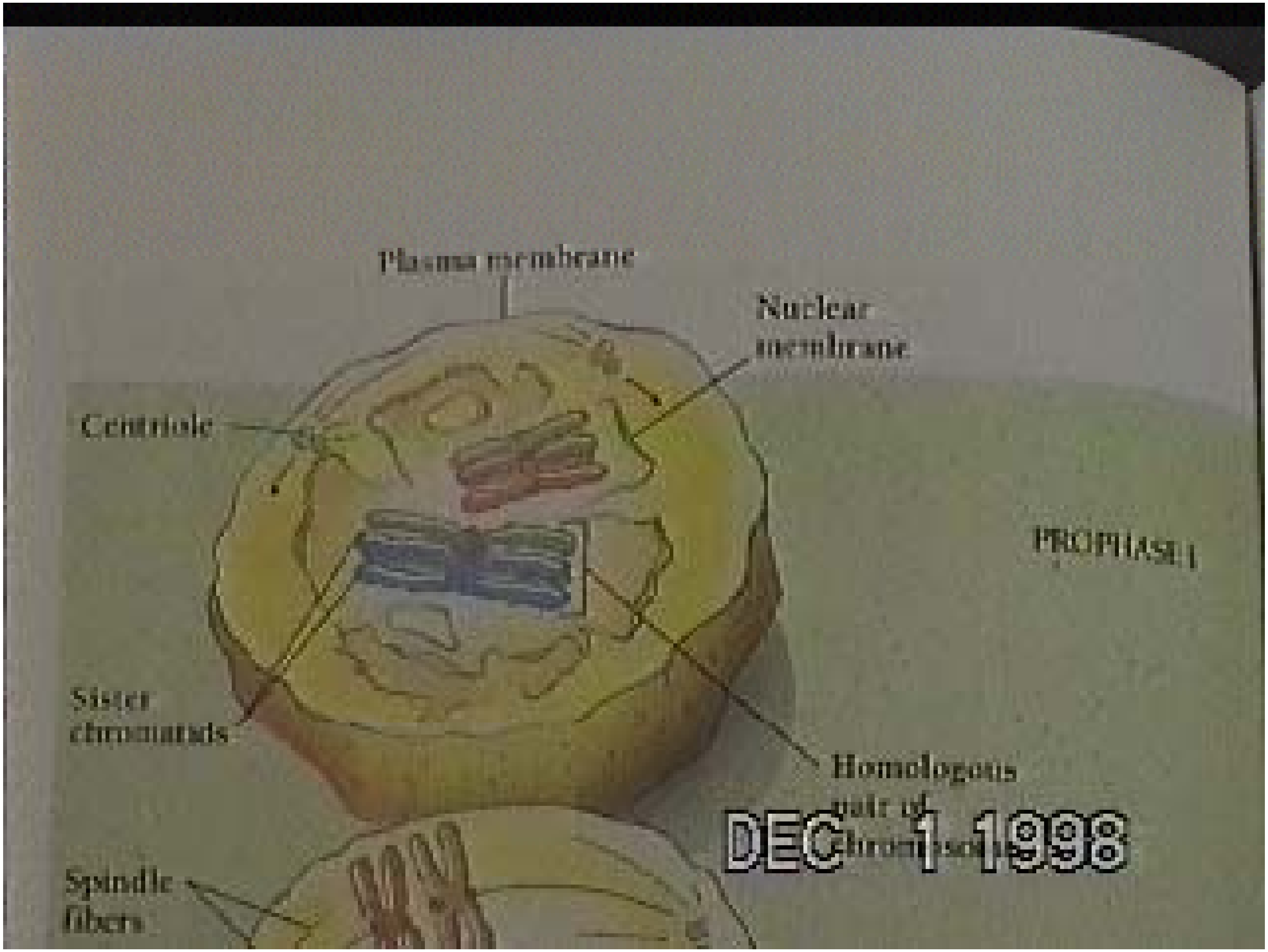

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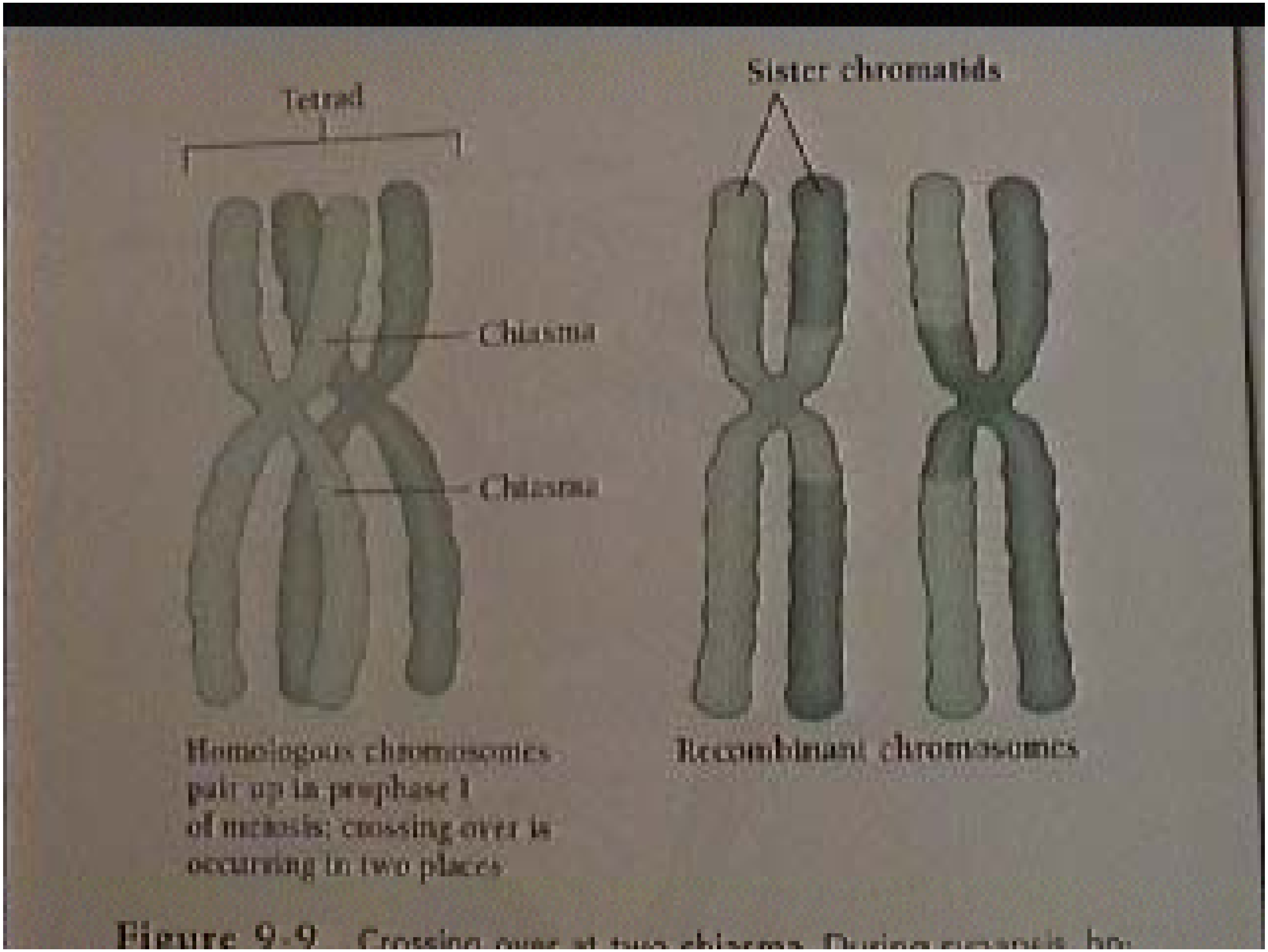

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B. Meiosis - Metaphase I

During metaphase I, the pairs of homologous chromosomes line up on the metaphase plate. This is distinct from mitosis, where each replicated chromosome lines up by itself on the metaphase plate. This is due to the synapsis event during prophase I.

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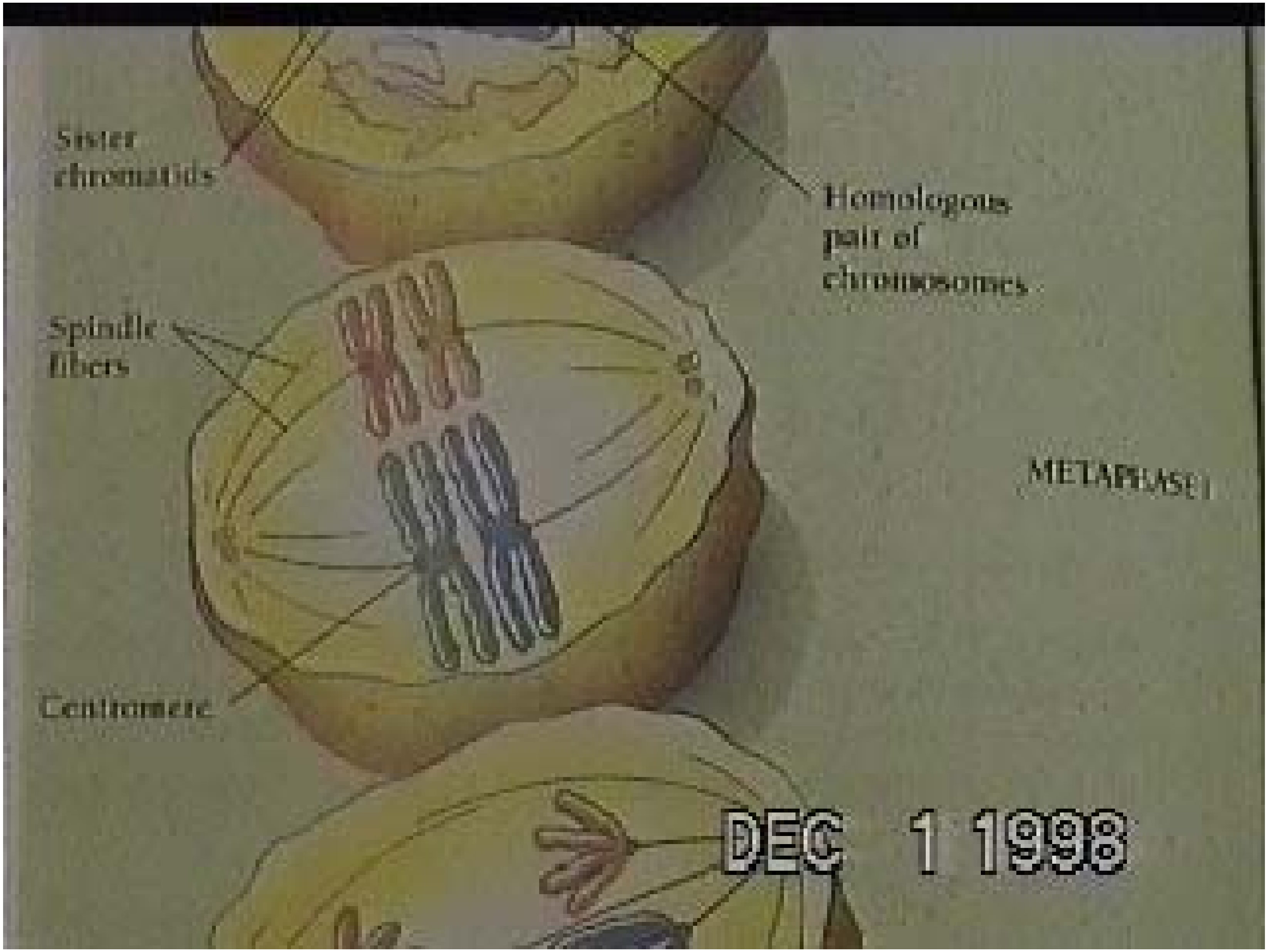

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B. Meiosis - Anaphase I

A pair of sister chromatids are separated from there homologous pair during anaphase I. Again this is different from mitosis in which individual sister chromatids are moved to opposite ends of the cell.

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B. Meiosis - Telophase I

Telophase I involves the division and separation of two daughter cells. The genetic make-up of these daughter cells is haploid. Even though they contain the same number of sister chromatids that you would find in the original parent cell, chromosomes are counted based on the number of centromeres present in the cell. Since the sister chromatids are attached at the centromere, they contain only half the number of centromeres present in the parent cell and thus half the chromosomes = haploid.

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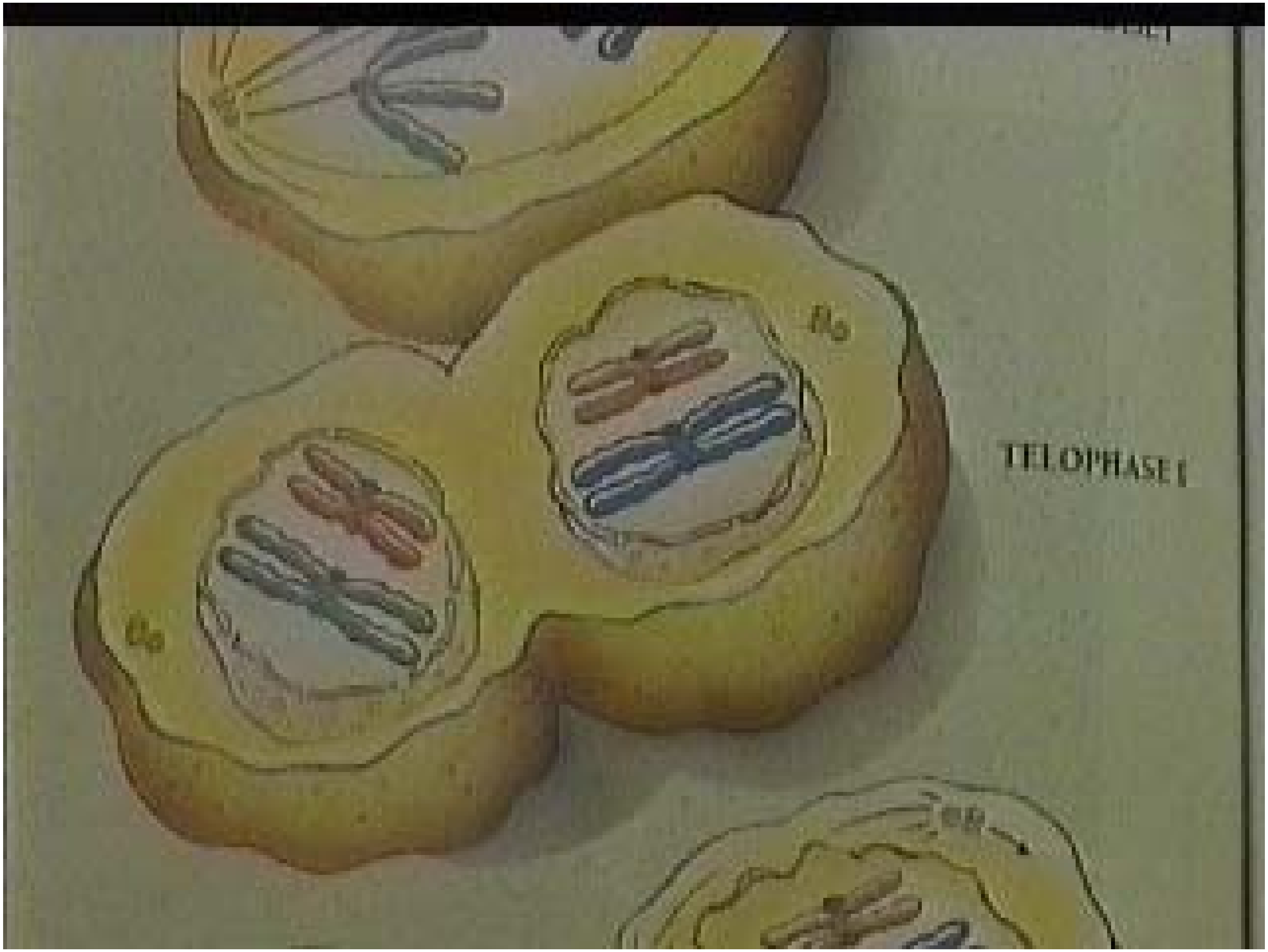

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B. Meiosis - Prophase II and Metaphase II

Essentially another prophase stage, without the synapsis event. The same cellular events that take place during prophase of mitosis occur. During metaphase, replicated chromosomes line up on the metaphase plate just like in mitosis.

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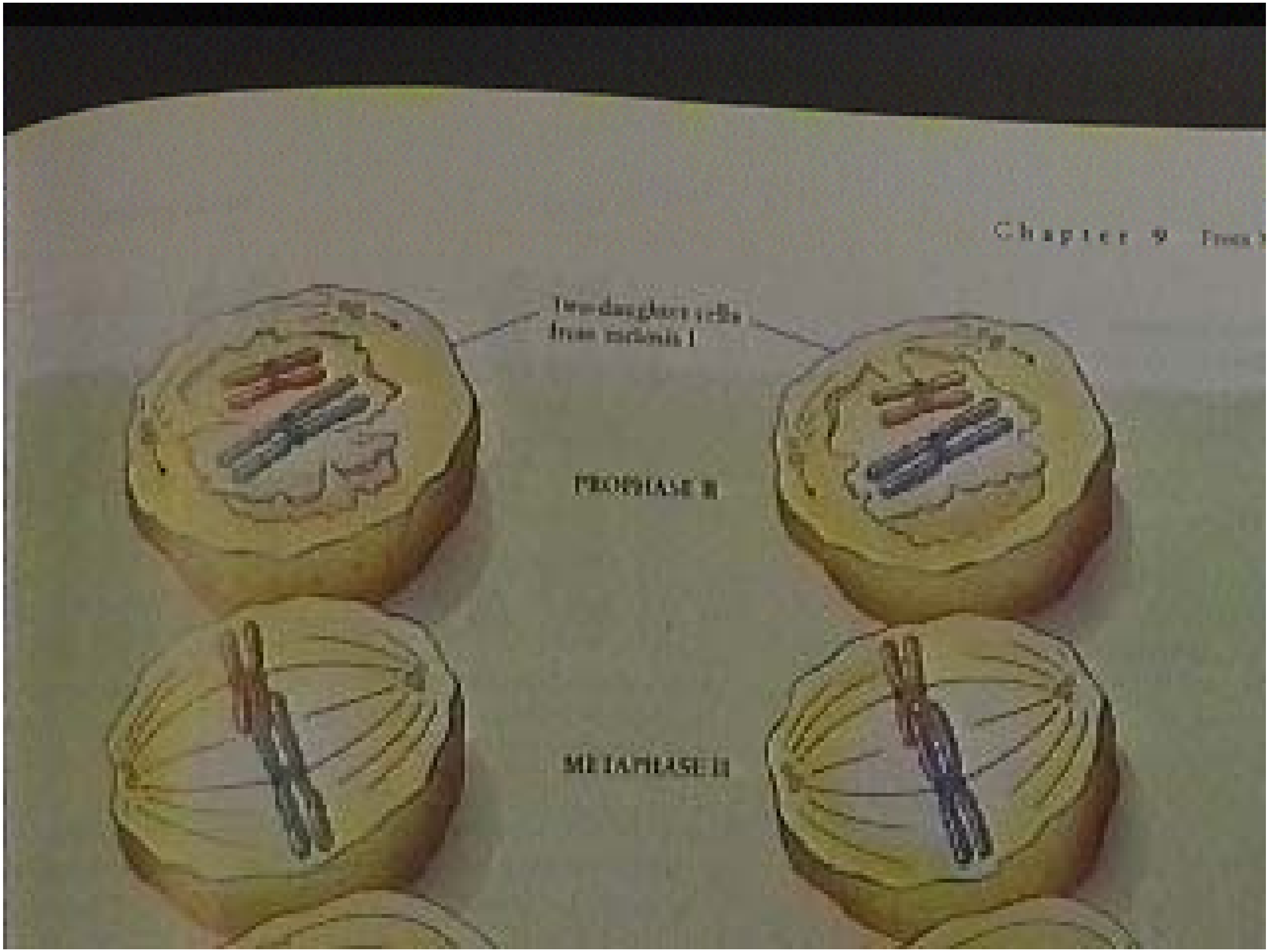

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B. Meiosis - Anaphase II and Telophase II

Anaphase II involves the separation of sister chromatids and Telophase II deals with packaging them into distinct gametes (sex cells) which contain half the number of chromosomes as the parent cell.

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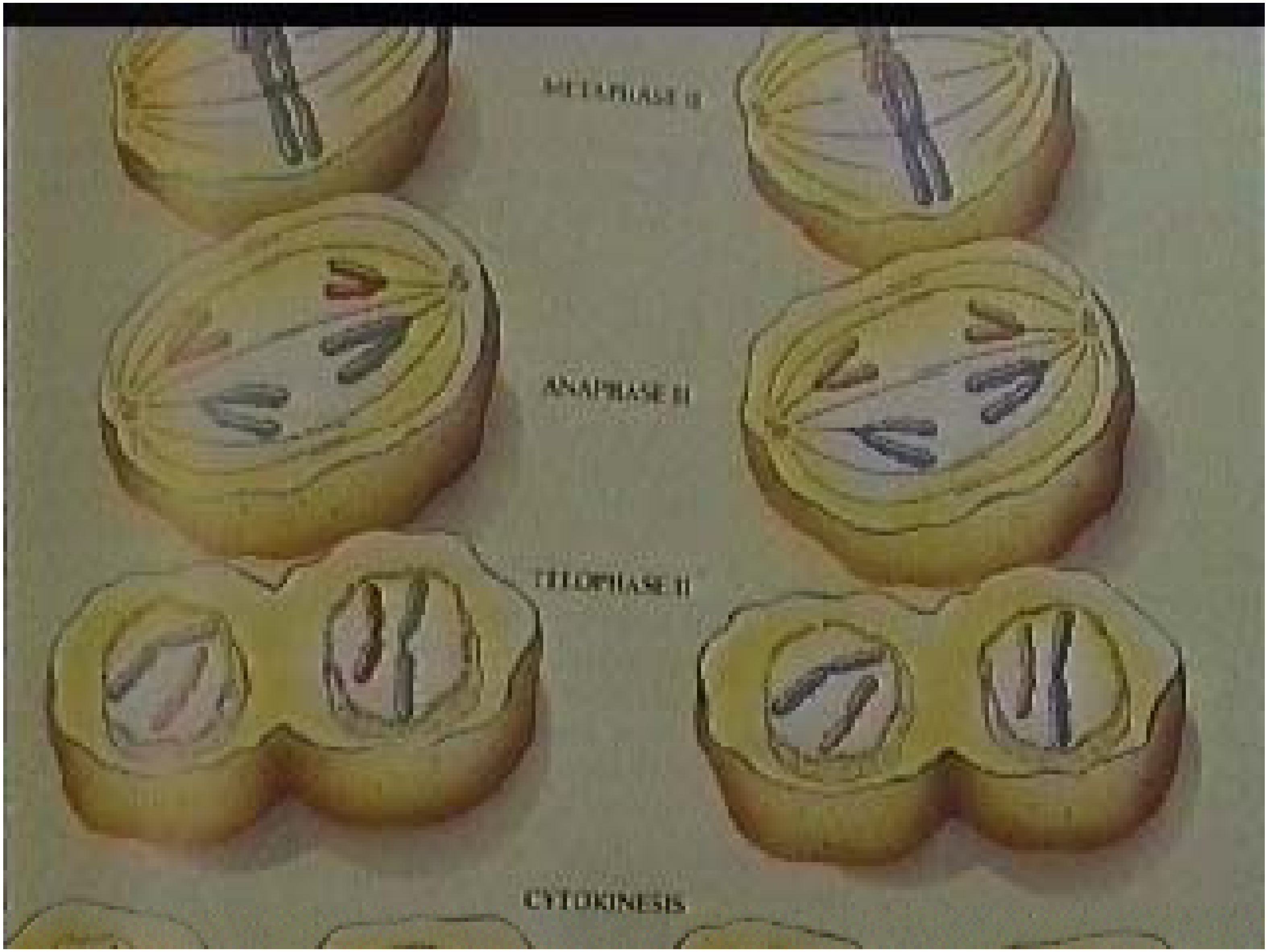

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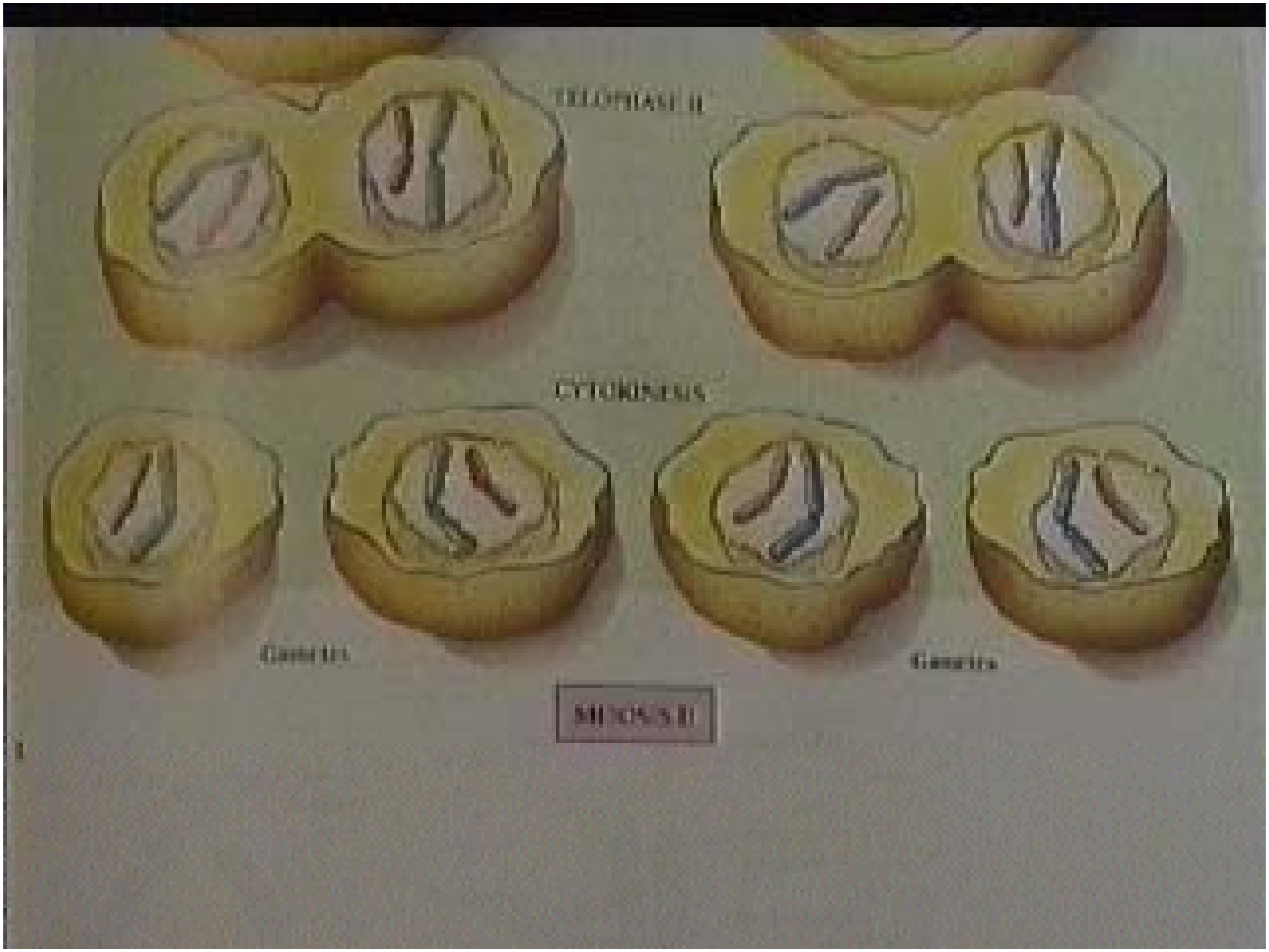

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C. Aberrations in Meiosis - Non-disjunction

The ability of organisms to produce viable offspring lies in the proper re-establishment of the diploid number of chromosomes. Human cells possess 46 chromosomes arranged in 23 pairs. Each parent contributes 23 chromosomes via their sperm or egg to re-establish this diploid number. If there is a defect in the meiotic processes in the male or female, aberrant gametes can be produced which contain abnormal numbers of chromosomes.

Non-disjunction is the failure of homologous chromosomes to separate during anaphase I or anaphase II. This result in the production of gametes containing 1 extra or 1 less chromosome. When combined with a normal gamete, the resulting fertilized egg and hence the offspring would contain 1 extra or 1 less chromosome (i.e. 45 or 47). Possessing one extra or one less chromosome can lead to serious birth defects or miscarriages. The information carried in exactly 46 chromosomes is so precise that possessing one extra or one less can inhibit the developmental processes of the child to be.

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Conclusions

Hopefully, this tutorial has been insightful for the upcoming laboratory. You should be prepared for the following tasks:

1. Identification of the mitotic stages in both animal and plant cells

2. Understand the overall cell cycle and how mitosis is a phase of it.

3. Understand the similarities and differences between mitosis and meiosis.

4. Understand the consequences of errors in meiosis, specifically non-disjunction.