The Case of the Dividing Cell: Mitosis and Meiosis in the Cellular Court

Part I—The First Day of Testimony

by
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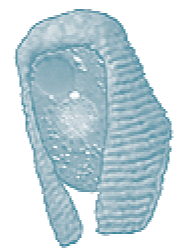
Mitosis Exposed



“Hear ye. Hear ye. The Honorable Judge Cellular now presiding. All rise.”

The judge in his black robes came silently into the courtroom amid the usual bustle that attended one of the special sessions. He slid into his high backed chair, glanced at the papers on the bench before him, and as was his habit, he gazed first at the defendant over his spectacles. Then giving the same attention to the prosecution, he looked over the jury. If he could have pursed his lips, he would have done so, for he wondered greatly at this particular jury that was filled with prokaryotic cells.

Prokaryotic cells? It hardly seemed fitting that they would be sitting in judgment of a eukaryotic matter. Hardly fitting at all. Oh, well, both the prosecution and the defense seemed to want it that way. So be it. He knew that the attorneys wanted to be impartial, but this was unseemly. Prokaryotes, what did they know about eukaryotes? Harrumph.

The judge adjusted his plasma membrane over his shoulders and began speaking with a voice that seemed to resonate from the bowels of his endoplasmic reticulum. “Ahem, let us see now. This is the case of the State vs. Egg Cell Number 6624223. This presents an unusual situation involving an alleged capital offence. The defendant is charged with being an undesirable mutant in the body politic. The penalty is death. This is the most serious of matters. It requires our undivided attention. So let us begin, but let us begin with the presumption of innocence. Please, now councilors, let us have the opening statements. But, please keep your comments brief and to the point. The prosecution first, arguing the position for the State. I believe it is Ms. Liv, is it not?”

“Yes, thank you, Your Honor. Members of the jury, I come to you today as a member of our cellular community. I come from a long line of cells that stretches back to a time when the world was once filled with only prokaryotic cells like yourselves. For over a billion years you ruled the world. We eukaryotic cells are but recent upstarts. For the most part we live in colonies making up the bodies of animals, plants, and fungi.”

“I, in fact, am a liver cell, one of several trillion cells living in a human I’ll call Martha. It is essential that we all live in harmony with one purpose in life—that is, survival. If Martha doesn’t survive, we all die—I, and the rest of the liver cells, the kidney cells, the muscle cells, the nerves, and all of the others that make up this grand human being.

"Yet, this is not all. Our individual survival is only part of the story. We would not be here except for the fact that we all are descendents of untold numbers of other organisms, many of them complex colonies of cells, for the last 700 million years. And we have relied on sex. Yes, I know that this concept is one that you asexual cells hardly understand. But as you have certainly read, in humans, like Martha, the cells in her ovary produce some unusual cells called eggs. And in Martha's husband there are some cells called sperm. If these two cells get together they will produce a fertilized egg that may grow up to be another colony of cells we call a baby.

"Now the point of all of this is that in order to produce a perfect baby, the sperm and the egg must be perfect. This brings me to the central issue of this crime. The defendant on the stand today is one of Martha's cells. We all love Martha—some of us have lived with her for years—but as we will show, she has been alive for 43 years and this has led to trouble. Many of her eggs are flawed. And this is exactly the case with our defendant, Egg Cell Number 6624223. SHE IS NOT PERFECT. It is our contention that she should be destroyed by apoptosis. She is not just contaminated by a simple point mutation. She is disfigured by having an extra chromosome 21. This invariably leads to Down Syndrome. *She should be destroyed so that a pure lineage can go on. We believe that you will see the wisdom of this solution by the end of the trial and trust in your good judgment.*"

"Thank you, Ms. Liv. Now, Councilor Oocyte, would you give your opening remarks?"

"Thank you, Your Honor. Cells of the jury, you have heard the remarks of my colleague. She argues that my client is flawed. She bases that on unsound logic. We will stipulate that my client is unusual, but that does not mean she is flawed or damaged. In every part of Martha's body there are unusual cells. Some cells in the lining of her digestive tract are triploid or have even higher numbers of polyploidy. Her liver cells, and perhaps Ms. Liv herself, are filled with unusual numbers of chromosomes. Some have three, four, five, six, seven, or more sets of chromosomes. Ms. Liv here appears in the pink of health! What's there to be troubled about? These cells are all living healthy lives and contributing to Martha's welfare. There is hardly a reason to get upset with my client who has a single extra chromosome 21. And, as is well known, even if a Down baby is the result, these children live happy, wholesome lives. We will clearly demonstrate to the jury that death is hardly a reasonable remedy, and that, in fact, there is no crime that has been committed at all."

"Thank you, councilor. Now Ms. Liv, you may call your first witness."

The First State Witness: Mr. Nuclear Membrane Explains the Secrets of Mitosis.

"Your Honor, I call Mr. Nuclear Membrane of the Epidermis to the stand."

"Bailiff, administer the oath."

"Do you swear to tell the truth, the whole truth, and nothing but the truth so help you DNA?"

"I do."

"I am calling Mr. Nuclear Membrane here as an expert witness on the process of cell division."

"I object Your Honor. Mr. Nuclear Membrane cannot serve in this capacity, as he is simply an expert in the topic of cell division that occurs in skin cells. This is hardly the same as that which occurs in the sex cells. And that is the subject of the case. Although cell division in the skin cells is just like cell division almost everywhere else in the body, cell division is entirely different in the ovaries and the testes where the sex cells are manufactured. The skin cells divide by mitosis. The sperm and eggs are produced by meiosis—an altogether different process."

"Ms. Oocyte objects. Councilor Liv, what do you say?"

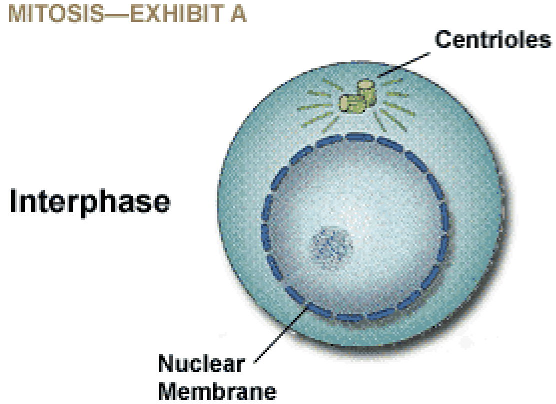
"I am not calling Mr. Nuclear Membrane as an expert in meiosis but as one on mitosis. I wish to lay the groundwork for making the distinction between the two."

"Then I withdraw my objection, Judge, and will so stipulate that the gentleman is an expert in mitosis and nothing else. Go ahead, this should be interesting."

"Now, Mr. Membrane, please describe the events of simple cell division that occurs in the skin. I believe you have some diagrams to show the jury that will help. Bailiff, would you please place the exhibits on the easel?"

"Yes, Ms. Liv, I do. First, I want to stress that the normal skin cell divides repeatedly in its life. Skin cells are always being wiped away when Martha's hands rub against anything. We do indeed have a busy time keeping up with the wear and tear of everyday living.

MITOSIS—EXHIBIT A

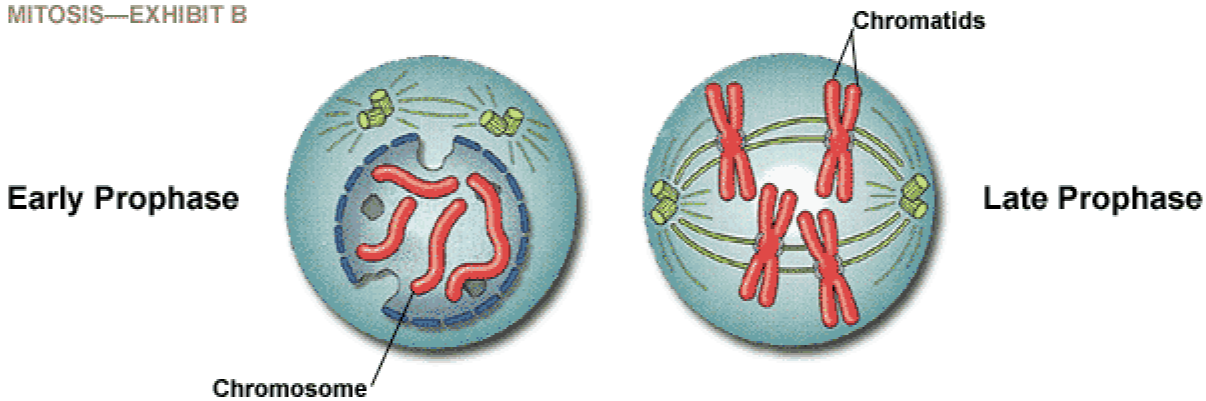


"When Martha's cells get ready to divide, the genetic information has to be copied. You know what I mean. If you're going to make another cell just like yourself, you've got to make sure that the next generation knows what to do; you've got to send the right information. Right? So the cell has to make a copy of the instructions in the DNA—you know, the genetic material. So here's the deal. The scientists that study this stage in our life call it 'Interphase,' and that's what's shown in Exhibit A. This is the time when we're really livin' it up, growing like crazy, making proteins like there's no tomorrow, and making little organelles. But then things change in a big way. The cell has gotten too big, you might say. It's got to divide. And that's when the DNA makes a copy of itself.

"Now take a look at the diagrams that show the next steps. All of 'em have special names. There's early and late Prophase, Metaphase, Anaphase, and my favorite, Telophase."

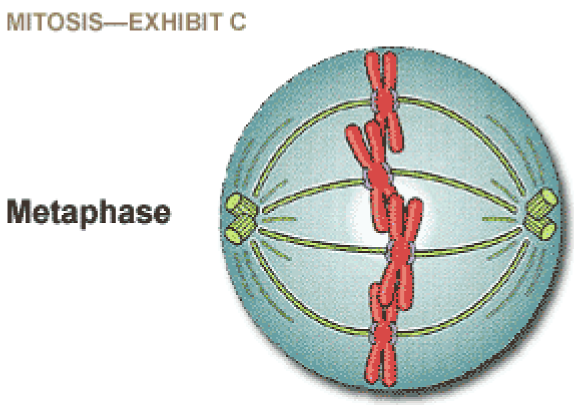
"Please, tell us the overall gist of what is happening."

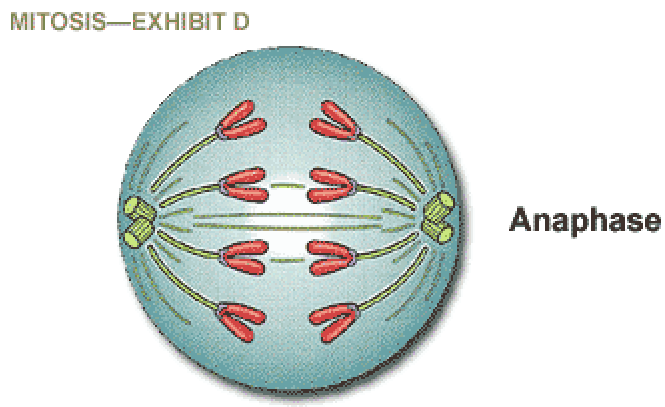
"Well, it's no mystery. Look here at Exhibit B. The DNA that has made an extra copy of itself gets all wrapped up into wads you call chromosomes. But each chromosome has two parts, you know, the original part and the copy. They're called chromatids—the parts, that is. The two parts of each chromosome are linked together at a point in their middles.



"So, what happens next?"

"Well, in Exhibit C you see the chromosomes lining up in the center of the cell, and then in Exhibit D the pairs of chromatids split apart and go off to opposite sides of the cell. They're pulled there by fibers. All of the chromosomes are doing the same thing, all at once. Half of their chromatids go to one side and half go to the other. That way, each side of the cell gets a complete set."





"Just a moment, Mr. Membrane, where did these fibers come from? It looks like they come from the centrioles."

"That's right, but I'm not quite sure as I never have really been around to see that part of the story. I've been told that…"

"Objection. That's hearsay, Your Honor."

"Objection sustained."

"Let's try this again, Mr. Membrane. What have you seen yourself?"

"The chromatids are separated and dragged to the opposite sides of the cell, and that's when I reappear—see, that's me, right here in Exhibit E—in two places, actually. I make a nuclear membrane that surrounds the chromosomes on both sides of the cell. You know, that's my job, to surround the DNA for the two new cells. I'm making two nuclei for the next generation of cells."

"Let me be sure I have this right. The chromosome material—the DNA—makes a copy of itself, then bundles itself up so it can move to the center of the cell more easily. The two copies of the DNA are wound into separate bundles called chromatids that are bound together. They line up in the center of the cell and then become separated by some fibers that seem to pull them apart. So one set of chromatids (I presume you call them chromosomes at this point) goes to one side of the cell and the other set goes to the other side of the cell."

"That's right. You see, when the cell starts to divide, that is, when the cytoplasm in the center of the cell begins to pinch off the two parts, both sides get a complete set of chromosomes. In humans, there are 46 chromosomes. So every time a skin cell makes a copy of itself, both cells get a complete set of 46 chromosomes. Then each cell reverts to Interphase. It's wonderful, don't you think?"

"Yes, I do. Thank you for your testimony. Now councilor Oocyte, the witness is yours for cross examination."

Ms. Oocyte Cross Examines

"Thank you, Judge. Now just to be sure I have this right, Mr. Nuclear Membrane, do I understand that you disappear during this process and reappear at the end?"

"That's right. I have to sort of break apart in the early Prophase so that the chromosomes can move to the center of the cell. They couldn't do this if I were in the way, could they?"

"No, I don't suppose they could, Mr. Nuclear Membrane. Then the next time you see anything is when you reassemble around the two new sets of chromosomes on opposite sides of the cell. That's the reason Telophase is your favorite time, isn't it? So everything else you have told us about in between these two times is mere scuttlebutt, isn't it?"

"I would hardly call it that. It is well known that…"

"Let's move on to another question, shall we? Tell me, when the DNA makes a copy of itself, is the copy always perfect?"

"Well, you know…, most of the time. It has to be…, otherwise the cell might be sick, become cancerous or something."

"But that isn't what always happens, is it?'

"Ah…, no. I guess not."

“Isn’t it true that many cells have so-called ‘imperfect copies’ of DNA during mitosis and things aren’t disastrous? In fact things are often pretty good, aren’t they? Sometimes these somatic mutations turn out well. I’m thinking of cases where a hair cell on the head of a person like Martha mutates and the person has a nice stripe of white running through their hair. That’s pretty striking, isn’t it? You wouldn’t say that is bad would you? Or abnormal? Or a reason to destroy Martha or her mutant cell? No? I thought not, it depends upon the situation, doesn’t it?”

“Yes, I guess so.”

“No further questions, Your Honor.”

“You may step down, Mr. Nuclear Membrane. And I believe we have had enough testimony for today. We will resume tomorrow at the same time. Court is in recess.”

Questions

1. What are the major events that occur during each of the stages in the life cycle of a cell such as a skin cell, i.e., Interphase, Prophase, Metaphase, Anaphase, Telophase, and Cytokinesis? Assume you are a court reporter that has to explain these stages to your readers with as little jargon as possible.

2. How does cell division differ in prokaryotes and eukaryotes? Clearly, these differences may be difficult for the prokaryotes in the jury to follow unless you show the similarities and differences.

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Part II—Court Is Back In Session

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Meiosis Exposed

The jury filed back into the courtroom, hardly visible to the spectators seated on the benches. Their tiny prokaryotic bodies seemed to bounce along to some inner music. It had been three days of testimony and the jury had now become comfortable with the routine. Once seated, they started whispering among themselves and court reporters could catch snatches of their conversations:

"God, I feel so small…. I know what you mean…. What do you think about that mitochondrion that testified? He looked sort of cool. Look at all of that stuff in their bodies. I mean really… to see all of those membranes inside. I mean, it grosses me out. I really shouldn't be prejudiced, after all they have invited us here, but it really is a bit too much…. Shh, here comes the judge."

"Hear ye. Hear ye…."

With preliminaries over, Judge Cellular peered over his glasses and stated, "I do hope we can move this trial along more rapidly, councilors. We really don't have to burden the jury with hearing from every organelle in the eukaryotic galaxy; surely the testimony is quite adequate to show how mitosis works. And, no, we don't have to hear from the plant cell witnesses. I'm sure we all understand it sufficiently well. Now, Councilor Liv, at our last session we left off with the witness for the prosecution having been sworn in. Was it Mr. Spermatocyte?"

"Yes, Your Honor. He is a primary spermatocyte and the defense has already stipulated that they will accept him as an expert witness for the process of meiosis. You will recall that he comes from Martha's husband Sam and his testes. He has been involved with the meiosis process ever since Sam's puberty."

"Very well. Mr. Spermatocyte, please come back to the stand. Come on sir, don't hang back. No need to swear you in again. Let's get on with it, Ms. Liv."

State Witness: Mr. Spermatocyte Explains How Sperm Are Formed

"Now, sir, I believe you were explaining the cell division process that occurs in the testes. It is different than in the skin and other parts of the body. Right?"

"That is quite correct, Councilor. The cell division in the sex glands doesn't lead to two identical cells like we typically find in mitosis. No, indeed—it leads to four sperm cells, each absolutely unique. Quite special. Quite."

“How so, Mr. Spermatocyte?”

“Let me remind you that all cells in the human body start out with 46 chromosomes, but actually these are not really 46 completely different chromosomes. No, sir. They are two sets of 23 chromosomes; one set has come from Sam’s mother and the other set from his father. Put them together and you have Sam’s 46 chromosomes all jumbled up in the nucleus running the business of his cells.”

“But if it is the case that all cells in Sam’s body have the same set of chromosomes, how come the cells act differently? Why do skin cells act like skin and nerve cells act like nerves and not *visa versa*. I should think that…”

“I object to this line of questioning, Your Honor. This is immaterial and irrelevant to the case.”

“Overruled, Ms. Oocyte. It is necessary for the prokaryotic jury to understand how the cells in the colony differ from one another even though they have the same set of instructions. You may answer the question, Mr. Spermatocyte.”

“Gladly. You see, even if all cells have the same chromosomes and the same genes, not all of the same genes are turned on! A muscle cell has only the genes for being a muscle working, while the skin has only skin genes working. That’s all there is to it.”

“That’s fine Mr. Spermatocyte. Now continue with what happens when the sperm cells are formed.”

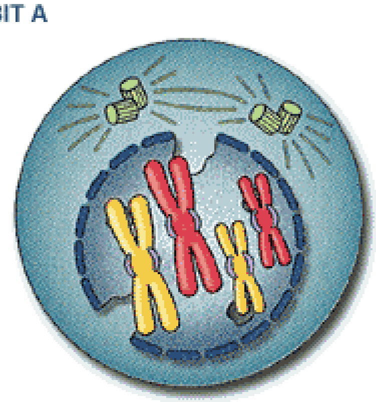
“Certainly. Now, you will remember when Mr. Nuclear Membrane testified, he said that during mitosis all of the chromosomes moved to the center of the cell in a line. Well, the chromosomes also line up during meiosis, but THEY-LINE-UP-IN-A-DIFFERENT-WAY! In fact, everything is different when we sex cells do it! We are the only ones in the body that go through meiosis. We have a special job to do. We have to make sperm and eggs. We are certainly not your run–of–the–mill sort of cells. All the other cells go through mitosis; they are simply making clones of themselves. We, however, are out to make something unique! It is rather clear, isn’t it… how special we are? Let me illustrate what happens when the sperm are formed. Naturally, I have brought my own set of diagrams along. They show what happens in my human, ‘Sam.’

“You might know.”

“I’ll have none of that nonsense in my courtroom, Ms. Oocyte. The bailiff will set the diagrams up on the easel for you, Mr. Spermatocyte.”

MEIOSIS—EXHIBIT A

Prophase I



"Very well. I'll continue. Now you really have to notice this. Take a look at how the chromosomes line up during meiosis. Just look at that, won't you! See, it isn't random at all. There aren't 46 chromosomes in a row. No sir, there are 23 pairs of chromosomes in a row, although I can only show two pairs in Exhibit A. But look how Sam's chromosomes from his momma have paired up with his dad's set; the number 1s are together, and 2s, and 3s and so on. And if you look closely you can see that each chromosome is composed of two chromatids, just exactly like we saw for the skin cell demonstration."

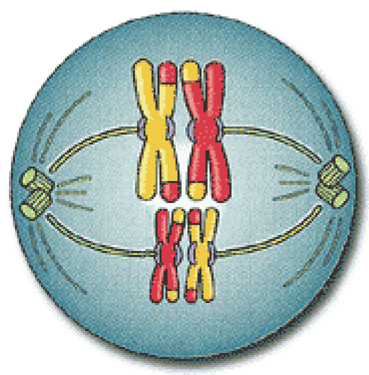
"I need a little clarification here for my poor judge's brain. Are you saying that when sperm are going to be made, the cell starts off in pretty much the same way as when a skin cell or a muscle cell is going to be made? That is, each chromosome's DNA first makes a copy of itself and the nuclear membrane disappears during Interphase?"

"That's absolutely correct, Your Honor."

"And what you're telling me I see in Exhibit B is that the chromosomes move to the center of the cell, but this time they're lining up with the mother's and the father's side by side. That is, I could look inside and see the two #2 chromosomes next to each other and a little further along I could see the two #16's and so on down the line? Why, if I looked close enough, I would see the chromatids. In fact, they would look like teams of four chromatids."

MEIOSIS—EXHIBIT B

Metaphase I



"That's it, Your Honor! You have it precisely!"

"And, so…? Please explain the relevance of that arrangement to me and the jury. I can see them puzzling along with me."

"Yes, indeed. But I must digress a moment. I need to…"

Ms. Oocyte Objects: What Has This to Do With Eggs?

"I do object, object, object! What is this, a biology lesson? Surely, we have listened patiently about all of this coming and going long enough. We all get it. Mitosis is different than meiosis. Isn't that sufficient? Let's move the trial along. My client is different than other little gametes. We have granted that. She is on trial for her life! Why are we listening to this lecture about sperm? My client is an egg cell, for God's sake!"

"Sit down, Ms. Oocyte. I will have no further outburst in my courtroom or I will cite you for contempt. Do you understand?"

“Yes, Your Honor. But this is extremely frustrating, and I am sure that the jury is as disturbed as I. Just look at them. My objection still stands. What is your ruling, if you please?”

“Ms. Oocyte, your point is well made. Councilor Liv, are you going to connect this up in some way? Why are we talking about sperm instead of eggs?”

“The formation of sperm and eggs are essentially the same, Your Honor. But it is easier to explain if we first look at the simpler sperm formation. We will make the connection in a moment.”

“Very well, then. Continue with your testimony, Mr. Spermatocyte. I will withhold my ruling for the present.”

“Thank you. The point I was making is that when these pairs of chromosomes lie side by side they touch at many points. That’s when they sometimes swap parts, and you can see that represented too in Exhibit B. Pieces of Sam’s mother’s chromosome #7 can exchange pieces with Sam’s father’s #7. It’s quite like a mix and match affair. You see it gives variability to the chromosomes. This is called ‘crossover’ by the geneticists.”

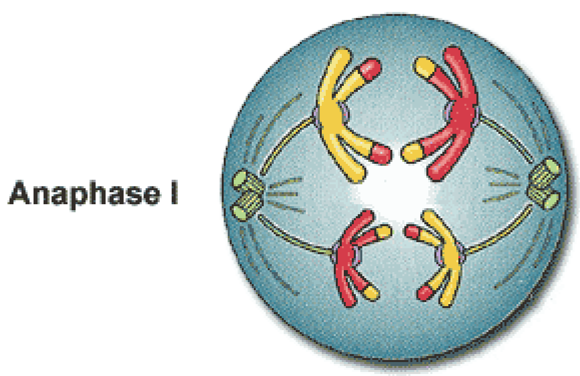
“Does it occur often?”

“Oh, absolutely! In fact, in humans at every meiotic tetrad (that’s what the four chromatids are called) there are about 10 crossovers. So by the time that crossover is finished, the individual chromatids can hardly be thought of as mother’s or father’s any more. They are a hybrid of the two.”

“Let us now return to the main point, Mr. Spermatocyte. What is the result of this peculiar arrangement of the chromosomes?”

“Well, just like in mitosis, there are some threads that are formed in the cell that attach to the chromosomes. These are the spindle fibers. They act to pull the sets of chromosomes apart—look at Exhibit C. This time though the chromatids of the chromosomes won’t be separated. Only the pairs of mother and father chromosomes are separated.”

MEIOSIS—EXHIBIT C



“Do you mean that all of the mother’s chromosomes go one way and the father’s go another and end up in different cells?”

“Oh, dear me, no. Did I say that? No, no…. Oh, I see where the trouble is! I didn’t make a crucial point, and the diagram might be slightly misleading. When the father and mother’s chromosome pairs lie together that doesn’t mean that they line up so that all of the mother’s are on one side and the father’s are on the other. Nothing could be further from the truth. No, they can be on either side. It is just chance that the mother's #10 is on the right side of the cell and the father's is on the left. It could have just as easily been the opposite. So the end result is that it is simply a mixture. The only thing that counts is that each side gets a complete set of chromosomes."

"That's this variability point again. It sounds like each cell is going to be a pretty unique collection of genes. What happens next? Complete sets of chromosomes are on each side of the cell; does that mean that the cell is going to divide?"

"You are quite correct, Ms. Liv. Two cells are formed each with its own collection of 23 chromosomes, as represented in Exhibit D. But wait, things are not over. The chromosomes still have their chromatids. Remember them? Now the cells go to work to pull these apart."

MEIOSIS—EXHIBIT D

"An excellent explanation, Mr. Spermatocyte. I surmise that you are about to tell me that they now go through the same steps as mitosis—that the chromosomes line up in the center of the cell and then the spindle fibers pull the chromatids apart so that…."

"Hold it, hold it, I object. Your Honor, I've been patient long enough. Who is the witness here and who is the attorney? It's a cute routine that they're putting on, but come on now, this is clearly leading the witness."

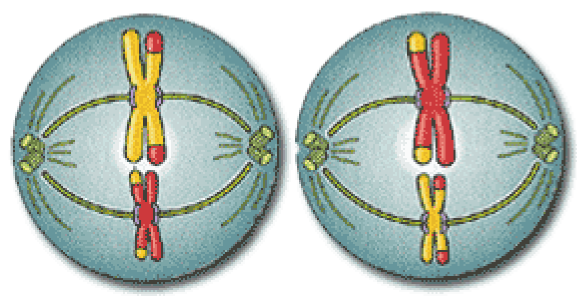
"I agree, Councilor Oocyte. Objection sustained. Ms. Liv. Please do not lead the witness. Rephrase your statements."

"All right. Mr. Spermatocyte, please tell us what happens next."

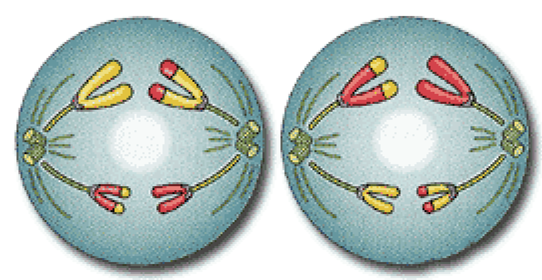
"Well, you definitely are correct. In Exhibit E you see the nuclear membranes again disolving, and in Exhibit F the chromosomes are lining up in the middle of the cell, just like in mitosis and it doesn't matter how they get into a line as long as they do it. Then the spindle fibers attach to their chromatids and Exhibit G shows the fibers pulling them apart. This way each side of the cell gets a complete set of instructions. Then, the cell divides. That's it. Meiosis is finished. If everything is perfect, each cell at the end has one complete set of instructions. Each sperm has 23 chromosomes. And, of course, there are four of them produced. In the first stage of meiosis we produced two cells, and then in the second stage each of these divided again and produced two. That makes four, doesn't it?

MEIOSIS—EXHIBIT E **Prophase II**

MEIOSIS—EXHIBIT F **Metaphase II**



MEIOSIS—EXHIBIT G **Anaphase II**



"After all, that really is the basic idea of meiosis, isn't it? To have a normal cell with 46 chromosomes go through duplication and then instead of dividing only once, it divides twice. This makes four cells, each with a set of chromosomes instead of dividing only once and having a cell with two sets of chromosomes, and that's what you see in Exhibit H."

MEIOSIS—EXHIBIT H

"Yes, indeed."

"Your witness, Councilor Oocyte."

Ms. Oocyte Cross Examines: What About Mutations?

“I hardly know where to begin. This explanation is so confusing that I don’t wonder that the jury is baffled about what is going on here. You are telling us that meiosis leads to four cells, not two like we saw previously in mitosis. Right? And you seem to be suggesting that, with all of this crossover and mixing of chromosomes, each sperm cell is unique. If that is so, am I correct in saying that one variation is just as normal as the next?”

“Well, I’m not sure I would say that…. I guess I would say that some cells are more normal than others. If there is a mutation, I would say that cell is, uh…, suspect.”

“Why is that?”

“Because most mutations decrease the chances that a sperm will survive. Most mutations are bad.”

“But not all. Right?”

“Right.”

“Fine, now let’s get the picture of what happens in the egg. In the formation of sperm, meiosis leads to four cells, each with a set of chromosomes. I take it that these four cells are really called sperm when the process is finished. Sperm, is that right?”

“Absolutely. They are sperm with great wonderful tails and great potential, I must say. In fact, I’ve got some more fascinating diagrams…”

“No! I mean, no, that’s quite all right. I think we’ve seen quite enough of those. Please conitnue.”

“Oh. Okay, well, in the formation of the egg, exactly the same process happens. The primary oocyte, rather like you, Ms. Oocyte, will eventually form an egg. You will go through the two steps of chromosome shuffling and at the end four cells will be formed. The only real difference is that three of the cells will be tiny and one will be huge, rather like your client there. The tiny ones are called polar bodies and they just disintegrate. The huge one is the egg and it has all of the nutrients and cytoplasm saved for itself. See for yourself how loaded the defendant is with nu….”

“PLEASE, Mr. Spermatocyte confine your remarks to the general situation and refrain from making personal asides…. Now, one more question, sir. Is it true that many egg cells that develop in an older woman like Martha don’t go through exactly the same steps? That lots of times there are differences?”

“You are definitely correct. Older men and women seem to have more mutations and…”

“That will do for the moment, Mr. Spermatocyte. Now, tell me what were the events that have lead to the special chromosome pattern that we see in the defendant, Egg Cell Number 6624223?”

“As I understand it, she has an extra chromosome 21. This can happen in a woman’s egg as it is developing, especially an older woman. It is a simple mistake…”

“PLEASE, don’t refer to it that way as there are thousands of women that produce these eggs each year.”

"I object to Councilor Oocyte leading the witness. If the witness says it is a mistake, then that is what he means. He has been certified as an expert witness, Your Honor."

"Objection sustained."

"Please, tell us then how this situation occurs to millions of women each year."

"It is simple, really. Everything is fine through the first stage of meiosis. The chromosomes make copies. They line up in the center and the pairs of chromosomes separate. We now have two cells with 23 chromosomes with chromatids. Then the trouble starts. When the chromosomes line up again in the center, this time for the chromatids to separate, all goes well except that chromosome 21 doesn't always separate completely. If this happens to the egg, then it will end up with an extra copy of 21."

"It sounds like if this egg is fertilized by a normal sperm cell with its 23 chromosomes, then the baby that results will have an extra chromosome 21."

"Yes. The condition is called trisomy and leads to a baby that has Down Syndrome. About one baby in 600 hundred has three copies of 21, but in women over the age of 45, one baby out of 50 will have Down Syndrome."

"This sounds pretty common to me. It's hard to imagine that one would want to…."

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The transcript of the trial stops here. Missing is the testimony of the remaining witnesses for the prosecution and the all important defense witnesses. Newspaper accounts of the proceedings indicate that there continued to be fireworks between the two attorneys. Most importantly, there was a surprise character witness for the defense, a population geneticist who was a prokaryote. Here was a bacterial cell speaking about the value of mutations in the course of evolution. Councilor Liv tried to discredit him, but only succeeded in alienating the jury, according to some accounts. Unfortunately, the final decision of the jury is not recorded as the courthouse files of the proceedings have been destroyed in a mysterious fire that some blame on an anarchist movement that claimed that eukaryotic cells are nothing more than a symbiotic collection of prokaryotes. So we are left with mere speculation as to the verdict in this trial.

Faithfully recorded by Researcher E. coli #536^{23}.

Questions

1. Record the stages of meiosis in eukaryotic cells realizing that there are two cell divisions involved, each having their particular terms and characteristics.

2. List the key differences between mitosis and meiosis.

3. Do prokaryotes have mitosis or meiosis?

4. Crossover occurs between homologous pairs of chromosomes, but can it occur between two different chromosomes, say between #1 and #17?

5. Was it an evolutionary necessity that meiosis evolved at the same time as sexual reproduction?

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