Home:

Dr. Lindeman maintains a research program to investigate the mechanisms of sperm motility, with special emphasis on the workings of the flagellar axoneme. A number of talented undergraduate students have been involved in the research, which is supported by the **National Science Foundation**. This work is supported by the Cellular Organization Program of the NSF (grant MCB-0918294). Presently, we have several Oakland University students participating in the work. The main contribution of the program is a series of reports which build a case for a **"Geometric Clutch"** mechanism to explain how cilia and flagella generate a beat. This hypothesis is tested in a working computer simulation. Much of the current experimental work in the lab is designed to test specific predictions of the Geometric Clutch model.

Any opinions, findings and conclusions or recomendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation (NSF).

Click here to see **Dr. Lindemann's research and publication history**

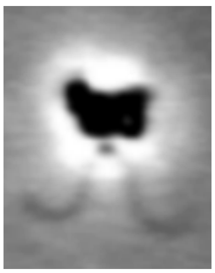
Dr. Lindemann's Cytoskeleton Research page

Click here to find out: **"What are cilia and flagella?"**

Geometric Clutch Computer Model

Dr. Lindemann has written programs that demonstrate the Geometric Clutch model. Here we present three different models for you to choose from. The first one is a Windows program that models a *Chlamydomonas* flagellum. The second Windows program models a bull sperm flagellum. The last program is a DOS program that has default settings for a 10-μM cilium. In order to run these programs, you need an IBM compatible computer.

NOTE: These are Executable files (.exe)



To download the Windows version of the**Geometric Clutch model** program for***CHLAMYDOMONAS***, click on the link below:
DOWNLOAD NOW

Do you want some instructions on how to run the *Chlamydomonas* program? If so, click on the link below:

INSTRUCTIONS

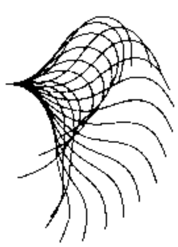
The Photo of an isolated flagellar apparatus of *Chlamydomonas* is courtesy of Danial Oberski

To download the Windows version of the**Geometric Clutch model** program for **BULL SPERM**, click on the link below:
DOWNLOAD NOW

Do you want some instructions on how to run the bull sperm program? If so, click on the link below:

INSTRUCTIONS

The baby bull photo is courtesy of Kathie Lesich



To download the DOS version of the **Geometric Clutch model** program for a **10-μM cilium**, click on the link below:
DOWNLOAD NOW

Do you want some instructions on how to run the Geometric Clutch model for a 10-μm cilium? If so, click on the link below:

INSTRUCTIONS

The beat pattern of a 10-μm cilium is courtesy of the Geometric Clutch model

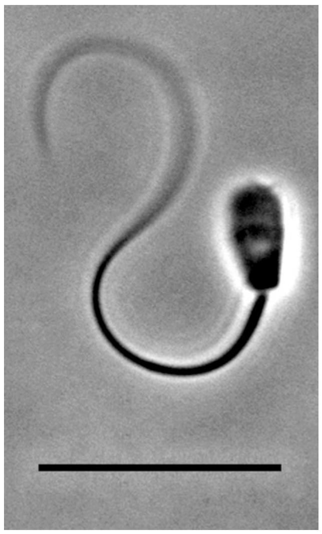
Interested in the source code for the **"original"**version of model? If so, click on the link below:
"ORIGINAL" MODEL SOURCE CODE

Interested in the source code for the **"upgraded"**version of model? If so, click on the link below:

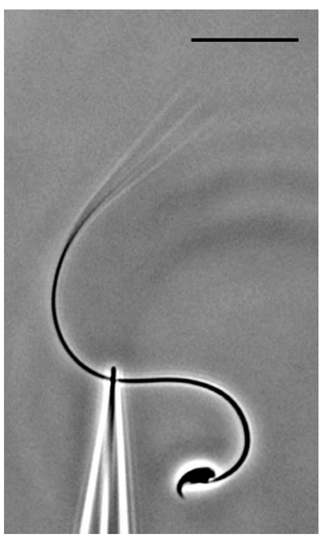
"UPGRADED" MODEL SOURCE CODE

Video Clips and Pictures:

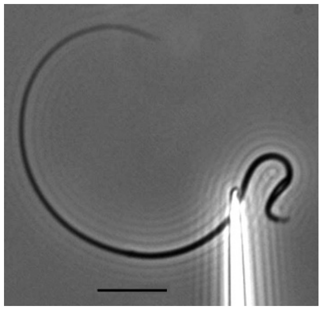
Here are video sequences from some of the finer experiments performed in our lab over the last few years. They are listed in chronological order. To shorten download times, these files have been compressed. Thus, the image quality is reduced. You can access the abstract and complete citation information related to each video clip by clicking on the word "reference" after each heading.



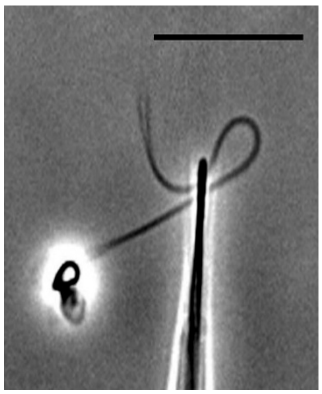
This picture shows a bull sperm cell. The bar represents 20 micrometers (millionths of a meter).



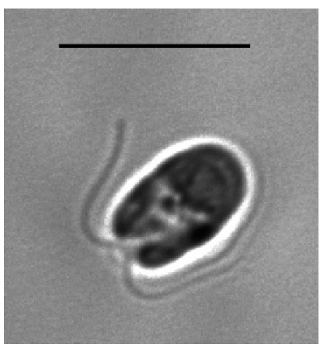
This is a mouse sperm cell. A glass probe is seen bending the tail and producing a counterbend. The bar represents 20 micrometers.



This is a rat sperm cell showing a counterbend. The bar represents 20 micrometers.



This is a sea urchin sperm cell showing a counterbend. The bar represents 15 micrometers.



This is an example of *Chlamydomonas* (green algae); a single-celled organism. The bar represents 10 micrometers.

Blocked bull sperm: **Reference**
Principal or "P" block
Reverse or "R" block

Force of bull sperm: **Reference**
Principal or "P" isometric stall
Reverse or "R" isometric stall

Counterbends:
Counterbend in Mouse sperm
Counterbend in Rat Sperm

Cut Bull Sperm still moves

Clipped bull sperm: **Reference**
An 18-µM flagellum still beats
Cut flagellum swims away

Force of a rat sperm calcium hook: **Reference**
Rat calcium hook force

Mouse Sperm Manipulation:
Vanadate-Treated, Reactivated Wild-Type Mouse Sperm
Vanadate-Treated, Reactivated SPAG16L-Deficient Mouse Sperm

Dr. Lindemann's Publications

Note: Clicking the author's link will take you to the abstract on pubmed.gov. All links open in a new window.

Lesich, K.A., C.B. Kelsch, K.L. Ponichter, B.J. Dionne, L. Dang and C.B. Lindemann. (2012) The calcium response of mouse sperm flagella: Role of calcium ions in the regulation of dynein activity. *Biology of Reproduction* 86(4):105.

Lindemann C.B. (2011) Experimental evidence for the geometric clutch hypothesis. *Current Topics in Developmental Biology* 95: 1-31.

Lesich, K.A., Z. Zhang, C. Kelsch, K. Ponichter, J.F. Strauss III and C.B. Lindemann (2010) Functional Deficiencies and a Reduced Response to Calcium in the Flagellum of Mouse Sperm Lacking SPAG16L. *Biology of Reproduction* 82: 736-744.

C.B. Lindemann and K.A. Lesich (2010) Flagellar and ciliary beating: The proven and the possible. *Journal of Cell Science* 123:519-528.

Lindemann C.B. (2009) Heart of the beat (the flagellar beat, that is) *Biophysical Journal* 97: 2865-6.

Lindemann C.B. and Lesich K.A. (2009) Detergent-extracted models for the study of cilia or flagella. *Methods in Molecular Biology* 586:337-53.

Pelle D.W., C.J. Brokaw, K.A. Lesich and C.B. Lindemann (2009) Mechanical properties of the passive sea urchin flagellum. *Cell Motility and the Cytoskeleton* 66:721-735.

Lorch D.P., C.B. Lindemann and A.J. Hunt (2008) The motor activity of mammalian axonemal dynein studied in situ on doublet microtubules *Cell Motility and the Cytoskeleton* 65:487-494.

Lesich, K.A., D.W. Pelle and C.B. Lindemann. (2008) Insights into the mechanism of ADP action on flagellar motility derived from studies on bull sperm. *Biophysical Journal* 95:472-482.

Lindemann C.B. and Mitchell D. R. (2007) Evidence for Axonemal Distortion During the Flagellar Beat of*Chlamydomonas*. *Cell Motility and the Cytoskeleton* 64:580-589.

Lindemann C.B. (2007) The Geometric Clutch as a working hypothesis for future research on cilia and flagella. *Annals of the New York Academy of Sciences* 1101:477-493.

Lindemann C.B., L.J. Macauley and K.A. Lesich (2005) The counterbend phenomenon in dynein-disabled rat sperm flagella and what it reveals about the interdoublet elasticity. *Biophysical Journal* 89:1165-74.

Lindemann C.B. (2004) Testing the geometric clutch hypothesis. *Biology of the Cell* 96:681-90.

Schmitz-Lesich K.A. and C.B. Lindemann (2004) Direct measurement of the passive stiffness of rat sperm and implications to the mechanism of the calcium response. *Cell Motility and the Cytoskeleton* 59:169-79.

Lindemann, C.B. and A. J. Hunt (2003) Does axonemal dynein push, pull, or oscillate? *Cell Motility and the Cytoskeleton* 56:237-44.

C.B. Lindemann (2002) Geometric Clutch model version 3: The role of the inner and outer arm dyneins in the ciliary beat. *Cell Motility and the Cytoskeleton* 52:242-254.

Moritz, M.J., K.A. Schmitz and C.B. Lindemann (2001) Measurement of the force and torque produced in the calcium response of reactivated rat sperm flagella. *Cell Motility and the Cytoskeleton* 49:33-40.

Lindemann, C.B. and K.A Schmitz (2001) Detergent-extracted models for the study of cilia or flagella in Cytoskeleton Methods and Protocols Edited by R.H. Gavin Humana Press, New Jersey. *Methods in Molecular Biology* 161:241-252.

Schmitz, K.A., D.L. Holcomb-Wygle, D.O. Oberski, and C.B. Lindemann (2000) Measurement of the force produced by an intact bull sperm flagellum in isometric arrest and estimation of the dynein stall force. *Biophysical Journal* 79:468-478.

Holcomb-Wygle, D.L., K.A. Schmitz, and C.B. Lindemann (1999) The flagellar beat of bull sperm arrests when t-force is reduced: a prediction of the Geometric Clutch Hypothesis is confirmed by micromanipulation experiments. *Cell Motility and the Cytoskeleton* 44:177-189.

Lindemann, C.B. and K.S. Kanous (1997) A model for flagellar motility. *International Review of Cytology* 173:1-72.

Lindemann, C.B (1996) Functional significance of the outer dense fibers of mammalian sperm examined by computer simulation with the geometric clutch model. *Cell Motility and the Cytoskeleton* 34:258-270.

Bird, Z., R. Hard, K.S. Kanous and C.B. Lindemann (1996) Interdoublet sliding in bovine spermatozoa: Its relationship to flagellar motility and the action of inhibitory agents. *Journal of Structural Biology* 116:418-428.

Lindemann, C.B. and K.S. Kanous (1995) "Geometric Clutch" hypothesis of axonemal function: key issues and testable predictions. *Cell Motility and the Cytoskeleton* 31:1-8.

Lindemann, C.B., J.M. Walker and K.S. Kanous (1995) Ni2+ inhibition induces asymmetry in axonemal functioning and bend initiation of bull sperm. *Cell Motility and the Cytoskeleton* 30:8-16.

Lindemann, C.B (1994) A "Geometric Clutch" hypothesis to explain oscillations of the axoneme of cilia and flagella.*Journal of Theoretical Biology* 168:175-189.

Lindemann, C.B. (1994) A model of flagellar and ciliary functioning which uses the forces transverse to the axoneme as the regulator of dynein activation. *Cell Motility and the Cytoskeleton* 29:141-154.

K.S. Kanous, C. Casey, and Lindemann, C.B. (1993) Inhibition of microtubule sliding by Ni2+ and Cd2+; evidence for a differential response of certain microtubule pairs within the bovine sperm axoneme. *Cell Motility and the Cytoskeleton*. 26:66-76.

Lindemann, C.B., A. Orlando and K.S. Kanous (1992) The flagellar beat of rat sperm is organized by the interaction of two functionally distinct populations of dynein bridges with a stable central axonemal partition.*Journal of Cell Science*Jun;102:249-60.

Lindemann, C.B., T.K. Gardner, E. Westbrook, K.S. Kanous (1991) The calcium-induced curvature reversal of rat sperm is potentiated by cAMP and inhibited by anti-calmodulin. *Cell Motility and the Cytoskeleton* 20:316-24.

Lindemann, C.B., J.S. Goltz, K.S. Kanous, T.K. Gardner, P. Olds-Clarke (1990) Evidence for an increased sensitivity to Ca2+ in the flagella of sperm from tw32/+mice. *Molecular Reproduction and Development* 26:66-77

Lindemann C.B. and K.S. Kanous (1989) Regulation of mammalian sperm motility. *Archives of Andrology* 23:1-22.

Lindemann, C.B., J.S. Goltz, T.K. Gardner and K.S. Kanous (1988) The interaction of pH and cyclic adenosine 3',5'-monophosphate on activation of motility in Triton X-100 extracted bull sperm. *Biological Reproduction* 39:1129-36.

Lindemann, C.B., J.A. O'Brien and F.J. Giblin (1988) An investigation of the effectiveness of certain antioxidants in preserving the motility of reactivated bull sperm models. *Biological Reproduction* 38:114-20

Lindemann, C.B. and J.S. Goltz (1988) Calcium regulation of flagellar curvature and swimming pattern in Triton X-100 extracted rat sperm. *Cell Motility and the Cytoskeleton* 10:420-31

Lindemann, C.B., J.S. Goltz and K.S. Kanous (1987) Regulation of activation state and flagellar wave form in epididymal rat sperm: evidence for the involvement of both Ca2+ and cAMP. *Cell Motility and the Cytoskeleton* 8:324-32

Lindemann, C.B., M. Lipton and R. Shlafer (1983) The interaction of cAMP with modeled bull sperm. *Cell Motility and the Cytoskeleton* 3:199-210

Lindemann, C.B., M. Fisher and M. Lipton (1982) A comparative study of the effects of freezing and frozen storage on intact and demembranated bull spermatozoa. *Cryobiology* 19:20-8

Lindemann, C.B., I. Fentie and R. Rikmenspoel (1980) A selective effect of Ni2+ on wave initiation in bull sperm flagella.*Journal of Cell Biology* 87:420-6

Lindemann, C.B. (1978) A cAMP-induced increase in the motility of demembranated bull sperm models. *Cell* 13:9-18

Lindemann, C.B. and I. R. Gibbons (1975) Adenosine triphosphate induced motilty and sliding of filaments

in mammalian sperm extracted with Triton X-100. *Journal of Cell Biology* 65:147-62

Lindemann, C.B., W.G. Rudd and R. Rikmenspoel (1973) The stiffness of the flagella of impaled bull sperm. *Biophysics Journal* 13:437-48

Lindemann, C.B., A.C. Jacklet, S.E. Oriss and R. Rikmenspoel (1973) Control of bull sperm motility. Effects of viscosity, KCN and thiourea. *Journal of Mechanochemical Cell Motility* 2:7-24

Lindemann, C.B. and R. Rikmenspoel (1972) Sperm flagellar motion maintained by ADP. *Experimental Cell Research*73:255-9

Lindemann, C.B. and R. Rikmenspoel (1972) Sperm flagella: autonomous oscillations of the contractile system. *Science*175:337-8

Presentations made by Dr. Lindemann or Kathleen Lesich

Dec 3-7, 2011

The American Society for Cell Biology 2011

The above link gets you to the abstract: **Axoneme distortion in sea urchin sperm flagella evaluated by a geometric analysis of bending and shear.**

Dec 11-15, 2010

The American Society for Cell Biology 2010

The above link gets you to the abstract: **The Effects of Calcium on the Switch-Point of the Beat in Reactivated Bull Sperm.**

Nov 4-5, 2010

2010 NSF-FRG Workshop Tulane University

The above link takes you to the presentations page.

Dec 5-9, 2009

The American Society for Cell Biology 49th Annual Meeting

The above link gets you to the abstract: **Functional defects in sperm from SPAG16L disrupted mice.**

Nov 1-4, 2009

Dynein 2009

The above link retrieves the abstract: **Nucleotide Regulation of Dynein Controls the t-force in the Flagellar Beat Cycle**.

Dec 1-5, 2007

The American Society for Cell Biology 47th Annual Meeting

The above link gets you to the abstract: **ADP increases the switching threshold of the bull sperm beat, an effect that can be explained by increased microtubule binding affinity of dynein.**

Dec 9-13, 2006

The American Society for Cell Biology 46th Annual Meeting

The above link gets you to the two abstracts: **Reduced Inter-doublet Sliding and the Response to Calcium in Mouse Sperm Lacking the Central Apparatus Protein, SPAG16L & An Investigation of the Mechanical Properties of Passive Sea Urchin Sperm Flagella.**

Feb 18-22, 2006

Biophysical Society 50th Annual Meeting

The above link gets you to the abstract: **The Interdoublet Elastic Component of the Sea Urchin Sperm Flagella.**

Dec 10-14, 2005

The American Society for Cell Biology 45th Annual Meeting

The above link gets you to the two abstracts: **The Counterbend Response of Mouse Sperm: Evidence that the Nexin Links have an Elastic Limit & Evidence that Ca2+ selectively affects dyneins on certain microtubule pairs in the mouse sperm axoneme.**

Oct 31-Nov 3, 2005

Dynein 2005

The above link retrieves the abstract: **Active Forces and Elastic Resistances within the Flagellar Axoneme**.

May 25-27, 2005

Microorganism Motility Workshop

This link takes you to the workshop's homepage. To access the abstract click on **"Mechanical considerations of flagellar beating"** which is the title of Dr. Lindemann's presentation.

Feb 12-16, 2005

Biophysical Society 49th Annual Meeting

The above link gets you to the abstract: **Microtubule Motility on Doublet Microtubules Isolated from Bull Sperm.**

Dec 4-8, 2004

The American Society for Cell Biology 44th Annual Meeting

The above link gets you to the abstract: **Physical Evidence for the Existence of Interdoublet Elastic Linkages in Rat Sperm Flagella.**

Oct 6-8, 2004

International Symposium on Interdisciplinary Science

The above link gets you to the symposium homepage. You can access the conference schedule from there.

Feb 14-18, 2004

Biophysical Society 48th Annual Meeting

The above link gets you to the abstract: **The Calcium response of Rat Sperm: Evidence for a dynein-based mechanism.**

Dec 14-18, 2002

American Society for Cell Biology 42st Annual Meeting

The above link gets you to the abstract: **The Magnitude of the Transverse-Force in Flagella at the Point of Beat Reversal.**

Dec 8-12, 2001

American Society for Cell Biology 41st Annual Meeting

The above link gets you to the abstract: **Measurement of the Effect of ADP on the Force Generated in Bull Sperm Flagella.**

Feb 17-21, 2001

Biophysical Society 45th Annual Meeting

The above link gets you to the abstract: **Measurement of the Passive Stiffness of Bull Sperm Flagella Using Force-Calibrated Glass Microprobes.**

July 24-26, 2000

National Science Foundation Workshop on Force Transduction in Biology

This link takes you to the homepage of the workshop. Select "abstracts" to read the abstract or select "program" to access the slides from the presentation.

January 25-29, 1999

The Institute of Mathematics and its Applications Computational Modeling in Biological Fluid Dynamics

This link takes you to the workshop's homepage. To access the abstract select the "workshop schedule". To access slides from this presentation click on the "material from workshop" link.

Dr. Lindemann's Cilia and Flagella Page

WHAT ARE CILIA AND FLAGELLA?

Cilia and flagella are whip-like appendages of many living cells that are used to move fluid or to propel the cells. Cilia beat with an oar-like motion and flagella have a snake-like motion as illustrated in Figure 1. The cilia in your lungs keep dirt and dust from clogging your breathing tubes (the bronchi) by moving a layer of sticky mucous along to clean out the airways. Sperm cells use a flagellum as a propeller to move the cell through the fluid of the oviduct to reach the egg. Thousands of animals and plants use cilia and flagella for swimming (example: paramecium), or feeding (example: clams and mussels) or mating (example: green algae). It is a curious fact that all of these cilia and flagella have a very similar internal arrangement of tubes (the outer doublets) and protein connectors (the nexin links and dynein arms) that suggest that there is something very special about this particular way of building a cell propeller. Figure 2 is a diagram of these internal parts of a flagellum. Nature tends to keep designs that work well. If we can possibly understand why this particular design works so well, we might be able to design miniature devices that use the same principles of operation!

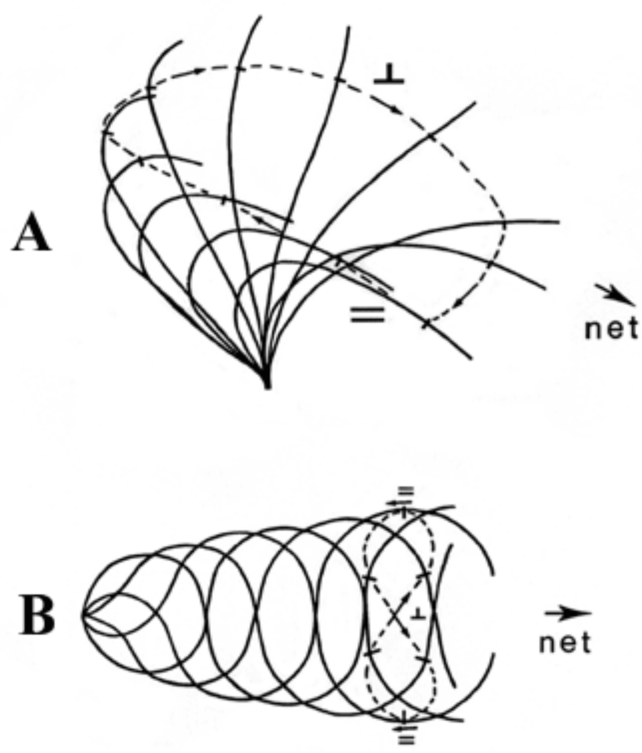


Figure 1

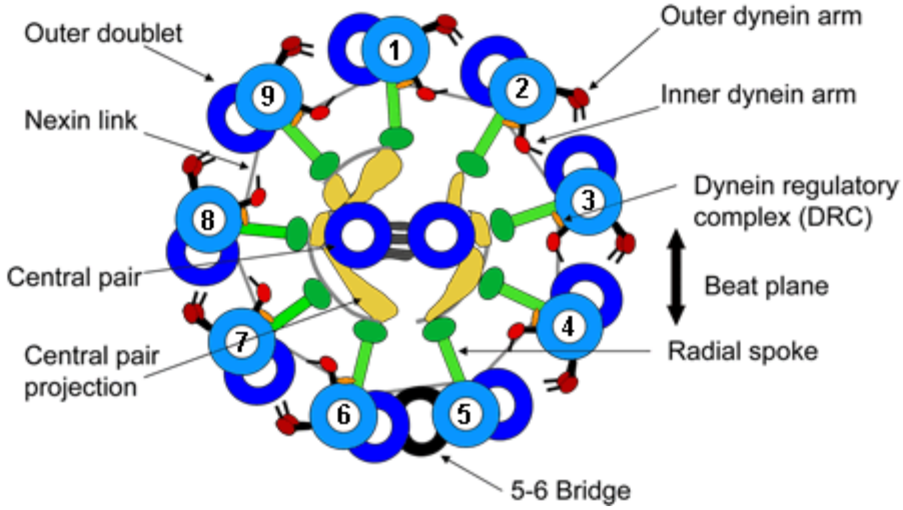
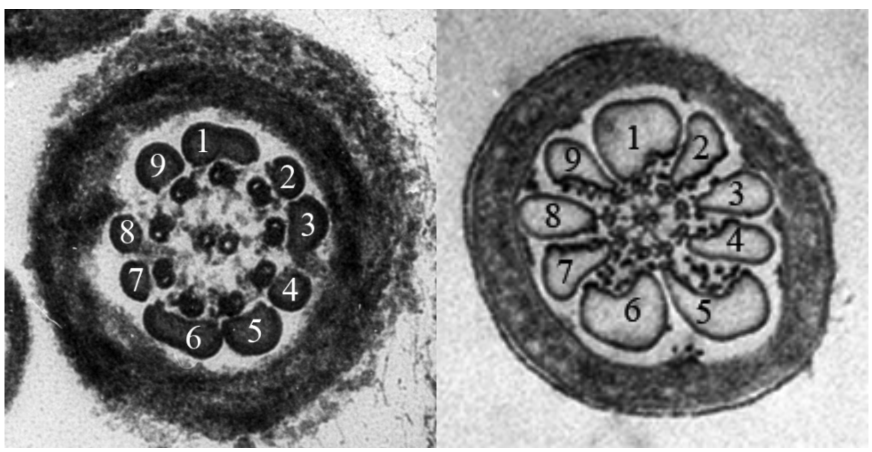


Figure 2



An electron-microscopy image of a numbered bull axoneme and mouse axoneme, respectively.

THE GEOMETRIC CLUTCH MODEL

The Geometric Clutch model of ciliary and flagellar beating is a hypothesis that attempts to explain the way that cilia and flagella work. A computer model based on this hypothesis can imitate a cilium or a flagellum. The basic underlying idea of the Geometric Clutch hypothesis is rather simple to understand. When the molecular motors (dynein arms in the picture) that power the beat of the cilium or flagellum are activated, they pull and push on the outer doublets and induce a strain on the structure that causes the cilium to bend. This part of the story of how cilia beat is agreed upon by all of the scientists that study cilia and flagella. (The Geometric Clutch idea is based on the ida that when the motors push and pull on the outer doublets the strain on each doublet creates a sideways force that is transverse to the doublet. This transverse force (or t-force) pushes some of the doublets closer together and others are pushed apart. The motors on the doublets that are pushed closer together go into action and generate force; the motors on doublets that are pulled apart are forced to stop pulling. In the Geometric Clutch model this is the working principle. The t-force controls the motors and acts like a "clutch", much as the clutch that engages or disengages the motor of your car. When this working principle is built into a computer simulation of a cilium or flagellum, the simulated flagellum can produce repetitive beats that look very much like those of a real cilium or flagellum. A working copy of the Geometric Clutch computer simulation can be downloaded from the "clutch model" page of this web-site (**HERE**). If you follow the instructions that are built in to the demonstration version you can make the model simulate a beating 10-micron long cilium (provided you are working from an IBM compatible PC).

Dr. Lindemann's Fun Sperm Facts!

Sperm are wonderful little cells and they can be loads of fun! For your enjoyment we've compiled some amazing facts about them.

See our **FAQ** page for additional fun information

A Wonderous Tale of a Sperm Tail - Originally published in the Fall 2010 issue (Issue 19) of The Oakland Journal

The **QUESTION** most frequently asked to Dr. Lindemann via e-mail: **How long can sperm live on environmental surfaces?ANSWER**: They die as they dry out, so it depends on how quickly they dry. They also are killed by fresh water due to osmotic shock. Soap and detergents such as those used for laundering and hand washing also kill them, as these substances strip off the cell membrane of the sperm. **Something to consider**: They are the haploid half of your life cycle so be careful where you leave them.

Please note, while sperm are relatively easy to kill on environmental surfaces, do not try to use water or detergents to kill them in the vagina or female reproductive tract. The female tract and the jelly-like consistency of human semen protect them from mixing well with water once inside the female body. In addition, water and detergent can be harmful to the tissues. This is not a good birth control strategy!

Animal	Average number of sperm per ejaculate (in millions)
Mouse	50
Rat	58
Guinea Pig	80
Rabbit	280
Man	280
Sheep	1000
Cow	3000
Pig	8000

Time between coitus and arrival of sperm in the Fallopian tube *

(In other words the amount of time it takes for sperm to get where they need to go)

Animal	Travel Time
Cow	2-3 Minutes
Rabbit	A few minutes
Mouse	15 Minutes
Guinea Pig	15 Minutes
Sow (Pig)	15 Minutes
Rat	15-30 Minutes
Hamster	2-60 Minutes
Dog	Minutes-Hours
Ewe (Sheep)	6 Minutes - 5 Hours
Woman	5 - 68 Minutes

Average volume and content of human ejaculate[#]

The volume and content of the ejaculate depend on the length of time between ejaculations. **The average volume of semen is 2.75 mililiters (ml)**, ranging from 2-6 ml, the higher volumes following periods of abstinence. An average human ejaculate contains about 180 million sperm (66 million/ml), but some ejaculates contain as many as 400 million sperm. Both quantity and quality of the sperm are important determinants of fertility. A man is considered clinically infertile if his sperm concentration falls below 20 million/ml semen. # (Just remember though- it only takes ONE to make a baby)

The average sperm count fell from 113 million sperm/ml of semen in 1940 to 66 million/ml in 1990. The volume of a single ejaculate has declined from 3.40 ml to 2.75 ml. This means that men on average are now ejaculating less than half the number of sperm as men did 50 yrs ago. A drop from more than 380 million sperm to about 180 million sperm per ejaculate. Furthermore, the number of motile sperm has also dipped. Importantly, the sperm count has not declined in the less polluted areas of the world during the same time period.[#]

Animal	Fertile Life of Sperm (hours)
Mouse	6
Rat	14
Guinea Pig	21-22
Human	24-48
Rabbit	30-32
Sheep	30-48
Cow	28-50
Horse	144
Bat	135 Days

Motile (moving) sperm have been found in the human fallopian tube up to 85 hours after coitus, although the ability to fertilize an egg is usually lost before motility is lost.

Does size matter?[^]

One would think that a big animal would have bigger gametes, but nothing could be further from the truth. The biggest sperm I have ever seen came from a fruit fly! The sperm of a fruit fly can be as long as the body of the male fly, about 1.1 mm. On the other hand, of the vast number of mammals humans have one of the smallest sperm cells, measuring only 40 microns long. Rats produce one of the largest sperm at 170 microns long. When we talk of mice and men we may be the bigger animals in the diploid phase of life, but it is the mice that have the bigger haploid phase of life with 80-micron long sperm.

How many is enough?[^]

This question always comes up in regard to human fertility. If it takes only one sperm to fertilize and egg, why does a low sperm count make a man infertile? A fertile male human ejaculates between 2 and 5 mililiters(ml) of semen (on average about a teaspoon). In each ml there are normally about 100 million sperm. If the concentration falls below 20 million sperm per mililiter there is usually some trouble with fertility. Twenty million still seems to be a lot, so why the problem? Only a small fraction of the sperm deposited in the woman's vagina end up in the uterus. From those that make it to the uterus, only a small fraction of those find their way to the oviducts. Usually the egg is all the way up at the other end of the oviduct(fallopian tube). Of those that are in the oviduct only a small fraction make their way from the lower to the upper oviduct. So, in fact, the number of sperm successfully arriving at where the egg is located is actually very small. Another problem is that the egg is not just waiting to be fertilized by the first sperm to come along. The egg is usually covered by a thick layer of cells called the corona radiata that serve as a blockade to restrict sperm from getting into the egg. Sperm cells contain enzymes that break this barrier down. It may actually require an assault of many sperm to break down the corona sufficiently to let one sperm get through to the egg. So the whole process is somewhat like a marathon run in a maze filled with mucus followed by breaking into a fortress. That one sperm that finally makes it is the champion of Mother Nature's triathlon. If you don't have enough competitors to start, none are left at the finish. We don't know for sure but this may be a way of selecting for a healthy sperm to do the job of passing genes to the next generation. Modern in-vitro fertilization techniques can by-pass this selection process and achieve fertilization with much fewer sperm. Successful fertilization is now even accomplished with sperm that can't swim. This is accomplished by directly injecting sperm into the egg with a tiny glass pipette (tube). Only time will tell what bypassing nature's triathlon will do to the human gene pool.

* Austin and Short (1982) Reproduction in mammals: Germ cells and fertilization. Cambridge University Press, NY, NY

Lauralee Sherwood (2001) Human Physiology: From cells to systems. Brooks/Cole, Pacific Grove, CA

^ Charles B. Lindemann

Dr. Lindemann's Lab Support

Lab Technician and Co-PI: Kathie Lesich
Lab Technician: Dr. Tania dePinho

Student Research Assistants since 1999:
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Frequently Asked Questions

Below are some examples of questions we frequently recieve regarding sperm and fertility. If you have a question that isn't answered here feel free to **contact us.** Remember, our advice does NOT replace that of a medical professional.

How long can sperm live on environmental surfaces?

They die as they dry out, so it depends on how quickly they dry. They also are killed by fresh(tap) water due to osmotic shock(they "explode"). Soap and detergents such as those used for laundering and hand washing also kill them, as these substances strip off the cell membrane("skin") of the sperm. These methods kill sperm very quickly.

Please note, while sperm are relatively easy to kill on environmental surfaces, do not try to use water or detergents to kill them in the vagina or female reproductive tract. The female tract and the jelly-like consistency of human semen protect them from mixing well with water once inside the female body. In addition, water and detergent can be harmful to the tissues. This is not a good birth control strategy!

Is there a possibility of getting pregnant even if the penis did not go completely into the vagina?

Yes, there is a possibility of getting pregnant even if the penis does not go completely into the vagina. And this is true even if no ejaculation occurred (in other words even if he didn't come/orgasm). Precum can contain sperm and since it only takes one sperm to fertilize an egg- that is technically all you need. Obviously, the chances of getting pregnant this way are much less than if full penetration with ejaculation occurred. This is because even though only one sperm cell is required to fertilize an egg it technically takes an "Army" of sperm to successfully get that one cell to the egg. **More information**

Does precum have enough sperm to get a woman pregnant? or Can I have sex without a condom at first then use one before finishing without getting pregnant?

Precum contains enough sperm to get pregnant. While it may not have millions of sperm like the ejaculate, it is technically enough for a woman to get pregnant. This is why the withdrawal method of birth control, which is the withdrawal of the penis prior to ejaculation (also known as the "pull and pray" method), is not very effective. It is also why not using a condom at first is not effective. If your desire is to NOT get pregnant, use a different form of birth control or use a condom the entire time.

I was in a jacuzzi/shower/bathtub/pool and I ejaculated, can my girlfriend get pregnant?

Not unless you ejaculated in her vagina without a condom.

I have had a lot of X-rays/CT scans/radiation therapy in my pelvis area, will my children have problems?

From beginning to end, a sperm cell takes around 64 days to be made by a normal human male. Radiation affects new sperm cells more than older ones. So, a man 2 months after any radiation exposure should have normal sperm again. That being said, there are no guarrantees that sperm after 2 months will be fine, or even that sperm less than 2 months will be affected. A few X-rays shouldn't have enough radiation to cause problems. Ask your doctor if you're thinking about having children while on radiation imaging or therapy.

What is the size of a sperm cell relative to the size of a human ovum (egg)?

A human sperm is about 55 micrometers (μm) in overall length (head-5 μm plus 50 μm flagellum). A mature ovum is between 120-150 μm in diameter. So the ratio would be 1:2 or 1:3 if you were comparing length of the sperm to the diameter of the egg. If you compare the width of a sperm cell (~3 μm) to an egg's diameter the ratio would be between 1:40 -1:50.

I have heard that male sperm swim faster and female sperm live longer, is this true?

There is some truth to this idea. There is a technique called "swim up" to help people have some control over the sex of their child, but it is not very effective (ratio from 50/50 to around 60/40 for males/females). It works like this: A sample of sperm cells is spun at a very high speed, which makes all the cells clump together at the bottom of the container. After the spinning is stopped, the sperm cells are allowed to swim freely again. The faster cells (the male sperm cells) swim up out of the clump faster than the female cells(generally) and are collected for use.

Another technique people try is timing sex with ovulation to influence the sex of their child. The arguement is that having sex soon after the woman has ovulated will increase the likelyhood that the faster male sperm will get to the egg first. Whereas sex slightly before ovulation male sperm will die off leaving only the female sperm around to fertilize the egg by the time it is ovulated. Once again, this technique isn't very effective.

How long can sperm live in the female reproductive tract?

Sperm are seldom able to fertilize an egg after 48 hours of storage in a woman. Sperm can be detected 5 days after sex, but there are generally not enough of them or they don't swim very well, so their ability to fertilize an egg is lost. It's still possible, because you only need one cell to fertilize an egg.

Links to other sites with relevant material...Enjoy!

Click here for links to other researcher's websites in the field of cilia and flagella

Cell Motility and Shape: Microfilaments - A brief, yet good summary of cell motility and shape. Contains good references for further information.

Cytoskeleton, Cell Motility & Motors - BioChemWeb - Excellent site containing anything you would ever want to know about everything cellular. Highly recommended.

Cytoskeleton Research Homepage

Wikipedia: Flagellum - Good site for general information regarding the flagellum.

Molecular Machines - Great site for illustrations and animations regarding cellular motility.

More Bacterial Flagellar Information - A great site about the motility of E.Coli

Sex, Wild-Style - an interesting article about animal sexual selection

Eyelashes Up Close - An article about cilia's role in disease

Sperm Sparring Spotted - An article about competition between sperm of different males

Sperm Motility Secrets Revealed -

Wikipedia entry on Don W. Fawcett - A noteable sperm researcher and founder of the American Society for Cell Biology(ASCB).

A Downside to Female Promiscuity

Along Came a Sadistic Spider - an article about traumatic insemination in spiders

Airway cilia taste toxins - an article about cilia in the airway that can detect toxic substances

Robocilia at work - an article about manmade cilia

What is Sperm Morphology? or **More about sperm morphology** plus some related **information about infertility**

Catch the Sperm - Use a condom gun to catch the sperm and diseases before they pass.

Contact Information

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Got Questions, Comments, or Complaints about the website?

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