

Analysis of Pusztai Study on GM Potatoes and their effect on Rats

Dr. Nina V. Fedoroff
Willaman Professor of Life Sciences and Evan Pugh Professor
Huck Institutes of the Life Sciences (<http://www.lsc.psu.edu/>)
201 Life Sciences Building
Pennsylvania State University
University Park, PA 16802

Chapter on Arpad Pusztai taken from her book:

Fedoroff, N. & Brown, N. (2004)

Mendel in the Kitchen, a Scientist's View of Genetically Modified Food Joseph Henry Press IS: ISBN-10: 0309092051 ISBN-13: 978-0309092050 pp 384

Her Website: <http://hils.psu.edu/lsc/fedoroff.html>

On August 10th, 1998, Arpad Pusztai of the Rowett Research Institute in Aberdeen, Scotland appeared on the British TV show "World in Action." In the course of the interview, he announced that his experiments showed that rats fed a diet of potatoes expressing a gene coding for a snowdrop sugar-binding protein showed stunted growth and reduced immune function (Enserink, Science 281.1184). He is further quoted as saying that he would not eat GM food and that he found it "very, very unfair to use our fellow citizens as guinea pigs" (Lee and Tyler, 1999).

The study made headlines around the world. According to Science's Martin Enserink, the Rowett Institute was flooded with calls from reporters even before the show aired. He quotes Rowett director Philip James saying that the Institute was faced with "a megacrisis we didn't remotely anticipate." James is said to have examined the experiments and found them a total "muddle." Pusztai's laboratory was sealed, his notebooks were turned over to an audit committee and Pusztai was put on indefinite leave – he was out of a job. The audit committee's report, released in October of 1998, concluded that Pusztai's data did not support the conclusion that the transgenic plants had a deleterious effect on growth, organ development, or immune function in rats.

Pusztai, whom Rowett had been forbidden to talk to the press, got in touch with a number of scientists and asked them to review the audit report and his rebuttal to it, as well as a transcript from the World in Action show (Enserink, Science 283:1094-5). On February 12 1999, Professors Edilbert van Driessche and Thorkild C. Bøgg-Hansen, colleagues who had collected the responses, issued a memorandum supported by more than 20 other scientists who had studied Dr. Pusztai's findings (Lee and Taylor, 1999).

Their memorandum stated (the following is largely verbatim from the WSWS website): "Those of us who have known Dr. Pusztai's work or have collaborated with him, were shocked by the harshness of his treatment by the Rowett and even more by the impenetrable secrecy surrounding these events. It is an unacceptable code of practice by the Rowett and its Director, Professor James, to set themselves up as arbiters or judges of the validity of the data which could have such a profound importance not only for scientists, but also for the public and its health." The memorandum concludes, "There is no doubt in our minds that the reviews will remove the stigma of alleged fraud and will restore Dr. Pusztai's scientific credibility."

One of the scientists who reviewed Pusztai's work, Dr. Vyvyan Howard, foetal and infant toxico-pathologist at the University of Liverpool, told the World Socialist Web Site, "I am working on some features of lectin toxicity and that is how I came to know Arpad Pusztai, who is certainly one of the world's experts in this field." Dr. Howard said that he believed Dr. Pusztai's data was (*sic*) sound. "We think it would pass peer review and be published and we are at a loss to really explain why the Rowett Institute came to the conclusion it did." Dr. Howard added that Pusztai's findings "are of considerable importance in the current debate on the safety and hazard assessment of genetically modified foods".

Professor S. Pierzynowski, from the Department of Animal Physiology, Lund University, Sweden, said, " I must stress that there is enough strong evidence that the work of the audit group was not objective and per se dangerous, not only for Dr. Pusztai, but generally for free and objective science." Joe Cummins, Emeritus Professor of Genetics at the University of Western Ontario, Canada described the Rowett Institute's treatment of Pusztai as "a great injustice", adding that the "Institute continues to look inward to cover up its mistakes".

These eminent scientists have not only raised serious concerns about the way research into GM food is being conducted, but that those who have dissenting voices are being suppressed and have had their careers ruined, and sometimes their health. Dr. Pusztai has suffered a mild heart attack brought on by the stress caused by trying to restore his scientific reputation and the credibility of his research. These concerns were echoed by Dr. Kenneth Lough, FRSE, a former principal scientific officer at the Rowett Institute between 1956 and 1987. He said, "In my view the evidence presented in the audit report must be considered as unsafe and is without justification for use against the scientific reputation of Dr. Pusztai. The Institute is at risk in sending the wrong signals to scientists in this field of research that any sign of apparent default will be treated with the utmost severity. The awareness will of course act as strong deterrent to those who wish to conduct research in this vitally important field." (end of stuff from WSWS).

But a committee of six eminent members of the British Royal Society, set up in April of 1999 to review the Pusztai data, reached the opposite conclusion. The committee sent out the material they received from Pusztai, the Rowett and other sources to scientists with expertise in statistics, clinical trials, physiology, nutrition, quantitative genetics, growth and development, and immunology. The

committee reviewed the opinions it received and issued a summary statement in June of 1999. The consensus of these experts was that the experiments were poorly designed, the statistical inappropriate, and the results inconsistent. Their recommendation was that the experiments be repeated and the results published.

Pusztai jumped to his own defense with a detailed response (<http://www.freenetpages.co.uk/hp/a.pusztai/>). He and a colleague with whom he had worked for some years published their study in medical journal Lancet (Ewen and Pusztai, 1999). Lancet, in turn, came under sharp criticism from a number of quarters, including U.K.'s Biotechnology and Biological Sciences Research Council, which called the journal "irresponsible." But Lancet's editor, Richard Horton, stood by the publication. Five of 6 reviewers had favored publication and he believed that it was appropriate for the information to be available in the public domain (Enserink, Science 286:656).

So what's this all about? Why this titanic battle of experts? Why is Pusztai, until this incident considered an authority on the plant proteins called lectins, under such fierce attack? He's written three books on lectins and published 270 research papers. Moreover, he'd worked at the Rowett Institute for 35 years. On the surface of it, his now-controversial research was perfectly straightforward: he fed genetically modified potatoes expressing a snowdrop lectin to rats and looked to see whether this food affected their physiology, particularly the gut, metabolic process and immune system. What are lectins? Should we worry about them? Should we share Pusztai's concern and conclusion that genetic engineering itself results in ".....possible gene silencing, suppression and/or somaclonal variation"?

The protein in question is called the *Galanthus nivalis* agglutinin after the Latin name of the snowdrop and it is abbreviated GNA. It was originally isolated from snowdrop bulbs and is a kind of protein that recognizes and bind to sugars on proteins. Such proteins are called 'lectins' as a group. Although lectins were first discovered in plants, they are now known to exist in animals in great profusion (Rudiger 2000). Many proteins – in all kinds of organisms – are decorated with sugar molecules – sometimes with long strings or branches of several sugar molecules. Such derivatized proteins are called glycoproteins.

Each glycoprotein has a different complement of sugar molecules, depending on what it does and where it does it. The sugar signature works like a zip code in the cell, determining where the protein is delivered by the machinery that produces it. When such decorations are on the surface – be it of a virus, a bacterium, or a cell – they serve as a recognition molecules. Lectins recognize the sugar molecules with such exquisite correctness and specificity that they have long been used to identify what sugars are present on a protein. Today it is increasingly recognized that the sugar 'codes' serve a large variety of internal functions. One of these is recognizing disease organisms.

So, for example, it has been known for a number of years that the AIDS virus HIV (human immunodeficiency virus) has mannose sugars on its surface and the ability of cells to recognize these surface sugars with their own lectins is part of the infectious process (Hammar 1995). Plant lectins like GNA, which

recognizes mannose, bind to the virus and inactivate it. They also interfere with its ability to infect cells (Hammar 1995). Because of its ability to bind to these surface sugars, GNA has been used to purify the HIV surface glycoproteins, which were in turn used to produce an immune response, albeit not much of one (Gilljam, 1993). Similarly, *Chlamydia trachomatis* has surface mannose-containing glycoproteins that allows the organism to infect cells by binding to a surface lectin (Siridewa 1993).

Plants – no less than animals – have mechanisms for defending themselves from microorganisms and insects. Plants produce lectins as one of their defense strategies against insects (Carlini 2002). Indeed, a good deal of evidence has accumulated that GNA, which binds specifically to a sugar called mannose, is rather toxic to certain kinds of insects pests of important crop plants, including rice (Du et al. 2000; Fitches et al., 2001). GNA does not seem to affect ladybird beetles, considered to be a beneficial insect (Down et al., 2000), although it does affect parasitic wasps, also considered to be beneficial insects (Romeis 2003). Some lectins, including ricin, are quite toxic because they're taken up by cells and block protein synthesis (Olsnes 2001). These are called ribosome-inactivating proteins or RIPs. But GNA doesn't have this activity (Batelli 1997).

Better yet, Pusztai's own studies showed that purified GNA wasn't toxic to rats (Pusztai 1990). In fact, he and his colleagues had shown that GNA had a protective effect against bacterial infection with *Salmonella*, a nasty intestinal bug (Naughton et al., 2000). All of this made the gene coding for GNA an attractive choice for increasing the insect resistance of crop plants. To test this possibility, the gene was introduced into a number of different crop plants, including potatoes and rice. And it does, indeed, increase their resistance to some important insect pests (Rao 1998; Foissac 2000). Because GNA binds to the surface cells of insects guts and enters their blood stream, it is also thought to have potential as a vehicle for delivering more toxic peptides to insects (Fitches 2002).

Sugar signatures are ubiquitous in biology – and as yet, we know rather little about what they do. It is known, for example, that there are two critical kinds of cells – the T and B cells – that must interact for the body's immune response to be activated. It has been reported that these interactions occur through a mannose-containing glycoprotein and that this interaction can be blocked by GNA (Savage 1993). Thus some of the same signature sugars central to important cellular functions. Pathogens take advantage of essential intercellular recognition mechanisms to gain a foothold, both by binding to the cell's own lectins and by evading the immune response because they resemble the cell's own molecules. So, for example, a lectin called DC-SIGN (dendritic cell-specific intercellular adhesion molecule-3 grabbing nonintegrin) binds sugars on the HIV envelope and facilitates infection of its target CD4 T cells (Geijtenbeek 2003).

The DC-SIGN lectin is referred to as an HIV 'receptor' because of this specific recognition of HIV, but it is actually a universal pathogen receptor (Geijtenbeek 2003). It normally captures viruses and other pathogens through their sugar-containing protein molecules and pulls them into the cell, where they

are broken down and displayed on the cell surface to trigger a protective immune response (Kooyk 2003). HIV hijacks this system. It stays intact when it binds to DC-SIGN and rides along to be presented to its target T4 cells in an infectious form. This is a rather effective evasion system. It makes it quite unlikely that the body will successfully fight back by making antibodies, the body's proteins that recognize and destroy pathogens. This is because the immune system learns early in life to discriminate between its own proteins and foreign proteins. But one particular HIV glycoprotein, gp120, has a dense cluster of mannose residues that has not been seen in any mammalian glycoprotein (Calarese 2003) and a few HIV patients make good antibodies to this protein. Recent work on one such antibody showed that it binds to the gp120 – the same protein to which DC-SIGN binds to promote viral infection – in a very unusual way. Antibodies generally recognize and bind to just one sugar residue, but this unusual antibody has an extended structure that permits it to recognize more than one mannose residue at a time. This is actually similar to the way that certain lectins recognize sugars because lectins consist of two or more identical proteins, each of which has a sugar-binding site (Hester 1996; Calarese 2003). The discovery of this unusual antibody raises new hope for stimulating the immune system to produce anti-HIV antibodies, immunizing people against AIDS.

But there are many kinds of lectins and they can have quite different effects. For example, Pusztai and his colleagues had reported 10 years earlier that a kidney bean lectin, phytohemagglutinin or PHA, caused the surface cells of rats' intestines to turn over more quickly (Pusztai 1993). The younger replacement cells on the tiny surface projections – called villi – of the intestinal cells had a high proportion of proteins with mannose sugars at the ends of their sugar signatures. This made the cells more susceptible to bacterial overgrowth with *Escherichia coli*, a common gut bacterium, because the bacterium has projections – called fimbriae – that recognize and bind to mannose. Including GNA in the diet reduced the extent of bacterial overgrowth because the GNA binds to the mannose on the intestinal cells.

PHA is a normal component of red kidney beans – and people get sick from eating too much of it. Allergist David Freed recounts an incident that occurred in 1988 when a hospital had a “healthy eating day” in its staff canteen at lunchtime (Freed 1999). He recounts that 31 portions of a dish containing red kidney beans were served that day and over the next several hours, 11 customers were experienced profuse vomiting, some with diarrhea – typical food-poisoning symptoms. All recovered by the next day, but no pathogen was found in the food. It turned out that the beans contained an abnormally high concentration of PHA.

There are many different kinds of plant lectins and they are present in most plants, especially abundant in seeds, including cereals and beans, and in tubers, including potatoes. They tend to survive cooking and digestive enzymes. Pusztai and many other investigators have shown that they affect intestinal cells. It isn't surprising that they occasionally cause symptoms of food poisoning (Freed 1999). As in insects, some can get into and through cells and into the blood stream. Some lectins are also potent allergens. So even though GNA appears

to be a relatively benign lectin as evidenced by rat feeding studies, there is absolutely no doubt that a food expressing such a protein needs careful testing, first in animals.

Sensibly, the Scottish Office Agriculture, Environment and Fisheries Department (SOAEFD) commissioned a 3-year study in 1995 titled "Genetic engineering of crop plants for resistance to insect and nematode pests: effects of transgene expression on animal nutrition and the environment." Its objective was "to identify genes encoding antinutritional factors which will be suitable for transfer into plants to enhance their resistance towards insect and nematode pests, but will have minimum impact on non-target, beneficial organisms, the environment, livestock fed on these plants, and which will present no health risks for humans either directly or indirectly through the food chain." The University of Durham and the Scottish Crop Research Institute were to provide the transgenic plants and the Rowett Research Institute was to do a chemical analysis of the transgenic plant materials. They were also to do both short-term (10 day) and long-term (3 months) rat feeding trials to determine whether the effect of the transgenic plant materials was similar to that of the parent lines.

The chemical analysis of the transgenic plants showed them to be quite different from the parent lines (<http://www.rowett.ac.uk/gmo/ajp.htm>) – although the audit report curiously concludes that they weren't (<http://www.rowett.ac.uk/gmoarchive/gmaudit.pdf>). The researchers measured total protein concentration, as well as the content of several relevant proteins, including GNA, potato lectin and several others. All of these differed between transgenic lines and in comparison with the parental lines. Rats in Pusztai's study were fed either raw or cooked potatoes. Non-transgenic potatoes were supplemented with GNA. The results showed that rats fed the transgenic potatoes had significantly lower organ weights. They found that GNA added to the potatoes made the animal's lymphocytes, which are cells in the immune system, more responsive to stimulation by other lectins. By contrast, lymphocyte responsiveness was depressed in the animals fed the transgenic potatoes expressing GNA.

What these studies basically showed was that the transgenic potato lines were different from each other, as well as from the parental potatoes. A later study on transgenic potatoes came to the same conclusion (Down 2001). Here Pusztai jumped to the conclusion that these differences must be attributable to the fact that the plants were transgenic – and he went public with his conclusion. What he probably didn't know – because he was neither a plant breeder nor a plant biologist – was that the very process through which the plants are put during the introduction of the transgene – culturing through a callus stage and then regeneration of the plant – can cause marked changes in both the structure and expression of genes.

The variation that arises as a result of passage through tissue culture is called "somaclonal variation" and is both a nuisance and a potent source of new materials for plant breeding. The variation is both genetic (single base changes, deletions, insertions, transpositions) and epigenetic – this means modifications that can affect expression of genes, but not their structure. For plant breeders,

this means that new materials and new varieties derived using culturing techniques must be evaluated for both their growth and their food properties. This is particularly important for potato breeding, because potatoes produce toxic substances called glycoalkaloids (Kozukue 1999). Glycoalkaloids are normally present in potatoes, can contribute to inflammatory bowel disease, and are concentrated by frying potatoes (Patel 2002). So potato breeders must carefully monitor these compounds, irrespective of the means by which new potato varieties are generated.

Unfortunately, Pusztai's analyses of the chemical composition of the transgenic lines were rather superficial. And his quick leap to the conclusion that the variation he observed was attributable to the fact that they were transgenic was simply unwarranted. This mistake has proved costly to Pusztai himself. And unfortunately, the expertise battle that sprang up around the experiments has obscured the importance of carrying out well-designed experiments to evaluate the food qualities of transgenic crop plants expressing proteins that have the potential of affecting human health. Lectins are clearly in this category.

Pusztai has been criticized severely for the quality of his experiments. His experiments have been attacked for their small sample sizes, the use of inappropriate statistical procedures, and the fact that a diet of raw – or even cooked – potatoes is a bad diet for rats (people too), even when supplemented with a bit of extra protein. But oddly enough, in all that has been written about these experiments, no one seems to have seen their central flaw, which was that he did not use appropriate controls. A “control” is the part of an experiment that allows the researcher to examine the consequences of just the change (in this case) or the treatment (in the case of a drug) under study. In Pusztai's experiments, the control potatoes had a different history than the transgenic potatoes and, in particular, that history included a culture procedure that induces somaclonal variation. The likeliest source of the variation he detected – and of the differences he attributed to the fact that they contained foreign DNA – was the culture procedure itself. In order to be able to attribute the deleterious effects of the transgenic potatoes to the newly introduced gene or to some other part of the introduced DNA, he would have had to make a comparison between potatoes that had the very same history, but either had or lacked the transgenic construct. This can be done, but the study that Pusztai participated in was simply not designed for such a test.

Battelli MG, Barbieri L, Bolognesi A, Buonamici L, Valbonesi P, Polito L, Van Damme EJ, Peumans WJ, Stirpe F. (1997) Ribosome-inactivating lectins with polynucleotide:adenosine glycosidase activity. *FEBS Lett.* 408:355-9.

Calarese DA, Scanlan CN, Zwick MB, Deechongkit S, Mimura Y, Kunert R, Zhu P, Wormald MR, Stanfield RL, Roux KH, Kelly JW, Rudd PM, Dwek RA, Katinger H, Burton DR, Wilson IA (2003) Antibody domain exchange is an immunological solution to carbohydrate cluster recognition. *Science* 300:2065-71.

Carlini CR, Grossi-de-Sa MF (2002) Plant toxic proteins with insecticidal properties. A review on their potentialities as bioinsecticides. *Toxicon* 40:1515-39.

Down RE, Ford L, Woodhouse SD, Raemaekers RJ, Leitch B, Gatehouse JA, Gatehouse AM. (2000) Snowdrop lectin (GNA) has no acute toxic effects on a beneficial insect predator, the 2-spot ladybird (*Adalia bipunctata* L.). *J. Insect. Physiol.* 46:379-391.

Down RE, Ford L, Bedford SJ, Gatehouse LN, Newell C, Gatehouse JA, Gatehouse AM (2001) Influence of plant development and environment on transgene expression in potato and consequences for insect resistance. *Transgenic Res.* 10:223-36.

Du J, Foissac X, Carss A, Gatehouse AM, Gatehouse JA. (2000) Ferritin acts as the most abundant binding protein for snowdrop lectin in the midgut of rice brown planthoppers (*Nilaparvata lugens*). *Insect. Biochem. Mol. Biol.* 30:297-305.

Enserink, M. (1998) Institute copes with genetic hot potato. *Science* 281:1184

Enserink, M. (1999) Preliminary data touch off genetic food fight. *Science.* 1999 283:1094-5

Enserink, M. (1999) The Lancet scolded over Pusztai paper. *Science.* 286:656.

Ewen SW, Pusztai A. (1999) Effect of diets containing genetically modified potatoes expressing *Galanthus nivalis* lectin on rat small intestine. *Lancet* 354:1353-4.

Fitches E, Woodhouse SD, Edwards JP, Gatehouse JA. (2001) In vitro and in vivo binding of snowdrop (*Galanthus nivalis* agglutinin; GNA) and jackbean (*Canavalia ensiformis*; Con A) lectins within tomato moth (*Lacanobia oleracea*) larvae; mechanisms of insecticidal action. *J Insect Physiol.* 47:777-787.

Fitches E, Audsley N, Gatehouse JA, Edwards JP. (2002) Fusion proteins containing neuropeptides as novel insect control agents: snowdrop lectin delivers fused allatostatin to insect haemolymph following oral ingestion. *Insect Biochem. Mol. Biol.* 32:1653-61.

Foissac X, Thi Loc N, Christou P, Gatehouse AM, Gatehouse JA. (2000) Resistance to green leafhopper (*Nephotettix virescens*) and brown planthopper (*Nilaparvata lugens*) in transgenic rice expressing snowdrop lectin (*Galanthus nivalis* agglutinin; GNA). *J. Insect. Physiol.* 46:573-583.

Freed, D. (1999) Do dietary lectins cause disease? *British Med. J.* 318:1023-4.

Geijtenbeek TB, van Kooyk Y. (2003) DC-SIGN: a novel HIV receptor on DCs that mediates HIV-1 transmission. *Curr. Top. Microbiol. Immunol.* 276:31-54.

Gilljam G. (1993) Envelope glycoproteins of HIV-1, HIV-2, and SIV purified with *Galanthus nivalis* agglutinin induce strong immune responses. *AIDS Res. Hum. Retroviruses.* 9:431-8.

Hammar L, Hirsch I, Machado AA, De Mareuil J, Baillon JG, Bolmont C, Chermann JC. (1995) Lectin-mediated effects on HIV type 1 infection in vitro. *AIDS Res. Hum. Retroviruses.* 11:87-95.

Hester G, Wright CS. (1996) The mannose-specific bulb lectin from *Galanthus nivalis* (snowdrop) binds mono- and dimannosides at distinct sites. Structure analysis of refined complexes at 2.3 Å and 3.0 Å resolution. *J. Mol. Biol.* 262(4):516-31.

Kooyk Y, Appelmelk B, Geijtenbeek TB. (2003) A fatal attraction: *Mycobacterium tuberculosis* and HIV-1 target DC-SIGN to escape immune surveillance. *Trends Mol Med.* 9:153-9.

Kozukue N, Misoo S, Yamada T, Kamijima O, Friedman M (1999) Inheritance of morphological characters and glycoalkaloids in potatoes of somatic hybrids between dihaploid *Solanum acaule* and tetraploid *Solanum tuberosum*. *J. Agric. Food Chem.* 47:4478-83.

Lee, K and Tyler, R. International scientists raise concerns over genetically modified food.
<http://www.wsws.org/articles/1999/feb1999/food-f17.shtml>

Naughton PJ, Grant G, Bardocz S, Pusztai A. (2000) Modulation of *Salmonella* infection by the lectins of *Canavalia ensiformis* (Con A) and *Galanthus nivalis* (GNA) in a rat model in vivo. *J. Appl. Microbiol.* 88:720-7.

Olsnes S, Kozlov JV (2001) Ricin. *Toxicon* 39:1723-8.

Patel B, Schutte R, Sporns P, Doyle J, Jewel L, Fedorak RN (2002) Potato glycoalkaloids adversely affect intestinal permeability and aggravate inflammatory bowel disease. *Inflamm Bowel Dis.* 8:340-6.

Pusztai A, Ewen SW, Grant G, Peumans WJ, van Damme EJ, Rubio L, Bardocz S. (1990) Relationship between survival and binding of plant lectins during small intestinal passage and their effectiveness as growth factors. *Digestion* 46 Suppl 2:308-16.

Pusztai A, Grant G, Spencer RJ, Duguid TJ, Brown DS, Ewen SW, Peumans WJ, Van Damme EJ, Bardocz S. (1993) Kidney bean lectin-induced *Escherichia coli* overgrowth in the small intestine is blocked by GNA, a mannose-specific lectin. *J. Appl. Bacteriol.* 75:360-8.

Rao KV, Rathore KS, Hodges TK, Fu X, Stoger E, Sudhakar D, Williams S, Christou P, Bharathi M, Bown DP, Powell KS, Spence J, Gatehouse AM, Gatehouse JA. (1998) Expression of snowdrop lectin (GNA) in transgenic rice plants confers resistance to rice brown planthopper. *Plant J.* 15:469-77.

Romeis J, Babendreier D, Wackers FL. (2003) Consumption of snowdrop lectin (*Galanthus nivalis* agglutinin) causes direct effects on adult parasitic wasps. *Oecologia.* 134:528-36.

Rudiger H, Siebert HC, Solis D, Jimenez-Barbero J, Romero A, von der Lieth CW, Diaz-Marino T, Gabius HJ. (2000) Medicinal chemistry based on the sugar code: fundamentals of lectinology and experimental strategies with lectins as targets. *Curr. Med. Chem.* 7:389-416.

Savage SM, Donaldson LA, Sopor ML. (1993) T cell-B cell interaction: autoreactive T cells recognize B cells through a terminal mannose-containing superantigen-like glycoprotein. *Cell Immunol.* 146:11-27.

Siridewa K, Froman G, Hammar L, Mardh PA. (1993) Characterization of glycoproteins from *Chlamydia trachomatis* using lectins. *APMIS* 101:851-7.