A history of layer breeding in Cuxhaven since 1959: from serendipity to sustainability

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serendipity: a gift for discovery by accident and sagacity while in pursuit of something else[1]

1949-1959: Serendipitous introduction of RRS by Art Heisdorf

During the recovery period after World War II, European poultry breeders were busy rebuilding pre-war structures and resumed conventional herdbook breeding with egg-type and dual purpose breeds. Meanwhile, poultry breeders in North America had discovered the benefits of crossing different breeds or lines of the same breed. The scientific foundation of the poultry breeding program in Cuxhaven can be traced back to the **"Heterosis Conference"** at Iowa State College, where plant and animal geneticists met in 1949 to discuss different theories and potential utilization of "heterosis" for plant and animal improvement. Among the participants was Art Heisdorf, a young poultry geneticist who had recently started his own breeding company Heisdorf & Nelson Farms. Mr. Heisdorf was keen to get a better general understanding of "heterosis" and was especially attracted by alternatives to the concept of inbred-hybrids, introduced by Hy-Line in the 1940s.

At the heterosis conference, Comstock *et al.* (1949) presented **"reciprocal recurrent selection"** (RRS) as an alternative to crossing inbred lines. The basic idea of this theory is that superior crosses can be further improved by "recurrent" (i.e. repeated in each generation) selection based on the performance of cross-line relatives (daughters or half-sisters), while pure-line information should be completely ignored. This theory assumes that overdominance can be an important part of heterosis, i.e. within-line selection would always favor heterozygotes and keep gene frequencies intermediate. RRS, on the other hand, should drive the frequencies of relevant alleles in opposite direction, thus increasing the frequency of heterozygotes in the commercial cross. Heisdorf returned home convinced that the theory behind RRS was sound and decided to test it on two of his White Leghorn lines, which happened to "nick" well from the start and continue to respond to RRS even 60 years later.

As shown later in a review by Bell (1972), other selection experiments failed to demonstrate the superiority of RRS, either because the lines used did not differ sufficiently in allele frequencies when the selection started or the experiment was terminated prematurely. Art Heisdorf's decision to apply RRS on a suitable set of lines and the subsequent success of the breeding program in Cuxhaven is an illustration of "serendipity": we may not be celebrating 50 years layer breeding in Cuxhaven this year, had it not been for the lucky combination of four factors: (1) the decision to test and verify RRS theory in a long-term breeding program; (2) availability of a set of non-inbred White Leghorn lines with superior combining ability and genetic variation responding to RRS; (3) providing a stimulating research environment to attract and inspire a team of qualified geneticists who believed in RRS; and (4) cooperating with business partners who share similar values and are dedicated to serve the egg industry and egg consumers with highly efficient layers.

Not only did the original two White Leghorn lines used by H&N "nick" well, Lohmann and Heisdorf were also a perfect match. Art Heisdorf's German ancestry probably helped him to trust Heinz Lohmann as a business partner when Lohmann asked for access to pure-lines and complete know-how in modern breeding and management as a basis for the license agreement which was signed in 1958. The H&N "Nick Chick" had won more random sample tests in the USA than any other strain, but when the **"HNL Nick Chick"** was first tested in Germany, it was soon recognized that a higher egg weight was desirable to satisfy European preferences – an additional argument to justify a stand-alone breeding program in Germany.

[1] One of several explanations of serendipity found on the website http://livingheritage.org/three_princes-2.htm

1959-1969: Dr. von Krosigk and Dr. Pirchner as geneticists in Cuxhaven

Max von Krosigk played an important part in setting up the HNL breeding program in Cuxhaven as a replicate of the RRS breeding scheme at Hollywood Hills in Washington, which by then already consisted of two replicates – the "A" and "B" populations, to supply the growing demand year-round. Franz Pirchner, whom I first met in 1962 during the World Fair in Seattle, was hired by H&N to replace Max von Krosigk, but decided to pursue a University career after two years in Cuxhaven (1963/64). Before I was hired to succeed Max von Krosigk as geneticist in charge of the HNL breeding program in Cuxhaven, I had met both on various occasions and found out more about our common background as PhD students of Prof. Lush at Iowa State University.

Not only the first three geneticists hired by H&N to supervise the HNL breeding program in Cuxhaven, but also my successors Rudolf Preisinger and Matthias Schmutz started with a dairy cattle breeding project for their PhD thesis before changing to layer breeding. The extensive experience analyzing large data sets was very helpful, and as Max von Krosigk would say: all you need for a start is a solid theoretical background in genetic statistics, design of experiments and mathematical probability; all else can be learned from available data and in open discussions with colleagues and business partners.

The RRS program involved three main steps every year:

(1) summarize performance records of pedigreed paternal and maternal half-sisters, calculate genetic parameters and rank their pure-line brothers and sisters on a "selection index"; select the best males and females on the productivity of their cross-line sisters (ignoring pure-line data);

(2) assign reciprocal matings of 100 males x 10 females each to produce the next generation of 2000 pedigreed cross-lines families, avoiding close relation among females mated to the same male;

(3) switch males between lines after cross-line reproduction, avoiding mating of related males and females, to produce non-inbred pure-line progeny for sib selection in the next generation.

In addition to the RRS routine, Pirchner initiated several experimental programs. He compared different lighting programs, estimated genetic parameters of feed efficiency and started to develop inbred sublines by full-sib matings. His interest in poultry breeding continued after he left Cuxhaven to accept positions as University professor in animal breeding in Vienna, Austria and Weihenstephan, Germany. The inbred lines he started were abandoned after I became responsible for the HNL breeding program.

The idea to **select directly for improved feed efficiency** was contrary to the widely accepted opinion of Nordskog *et al.* (1973) that selection for higher egg mass and lower body weight would achieve the same goal without the extra cost of measuring individual feed consumption. Von Krosigk and Pirchner (1964) presented first estimates of genetic relationships between feed consumption and productive traits in laying hens at the British Poultry Breeders' Roundtable, but it took another 10 years and high feed prices in the mid 1970s before we introduced testing for feed efficiency on a larger scale in our breeding program. Several of Pirchner's graduate students (Damme, Heil, Wang) worked with feed efficiency data from a long-term selection program at Weihenstephan, involving two brown-egg lines (Rhode Island Red and Sussex) of H&N origin.

I first met Art Heisdorf in 1966 after the World Poultry Congress in Kiev/USSR, when I was interviewed as potential successor of Max von Krosigk. Art's personality and the image of Heisdorf & Nelson and Lohmann as research oriented, progressive breeding companies convinced me to accept a challenging job in the industry, a decision I never regretted.

Genetic progress and **limits to selection** were popular topics during the 1960s, and we tried to separate genetic and environmental trends with appropriate statistical methods. In a joint publication with Henderson, Kempthorne and Searle (1959), von Krosigk compared statistical approaches developed at Ames and Cornell, using field data from milk recording in Iowa herds. At H&N and Lohmann, a **"repeat mating design"** was introduced to compare progeny from two generations in the same environment. Although not completely unbiased, the estimates published by von Krosigk *et al.* (1972) confirmed that our selection produced predictable results. In subsequent years, I discontinued the repeat mating controls and focused on the results of random sample tests to monitor the rates of change in different strain crosses (Flock and Heil, 2002).

1969-1979: Analysis of part records; selection for Marek's resistance

When I presented my first paper at a franchize hatchery meeting in Cuxhaven (1969) and asked the audience whether they agreed with the performance profile defined in our breeding goals, our distributors appeared to be completely happy with the HNL Nick Chick and only worried the new geneticist may try something stupid like reducing age at sexual maturity or lowering body weight to improve feed efficiency.

To get a better understanding of variation in egg production and potential for genetic improvement, we collected and analyzed egg production data from pedigreed test crosses in 4-week periods to determine the optimum length of testing period (Willeke, 1972; Flock, 1977). As a result, we started to put **more emphasis on persistency** and tried to hold age at sexual maturity constant instead of selecting on cumulative part records. Following the same reasoning, we later extended the testing period and the generation interval from 12 to 14 months.

Marek's disease (MD) was known from other areas and selection for MD resistance discussed as a possibility. But our veterinary colleagues predicted that vaccines would solve the problem before we could develop genetically resistant layers, and we geneticists did not understand the important difference between MD and Leukosis (LL) at that time. In retrospect, it was a prudent decision to **select a set of sub-lines for MD resistance** (mortality on problem farms in Spain), while genetic improvement of the main lines continued in the MD-free environment of our pedigree farms in Germany.

When MD vaccines became available in the early 1970s, interest in the more MD-resistant lines soon vanished. The cumulative changes during the 5-year period demonstrated that MD resistance can be substantially improved – if we sacrifice other traits: the main lines were 20 eggs and 2 kg egg mass per HH ahead of the 'resistant' lines, which had about 20% lower mortality under challenge conditions (Flock, 1974; Flock *et al.*, 1975). Had we included MD resistance in the selection index for the main lines, we may have been out of business after MD-vaccines became available.

Once we understood the basic difference between MD and LL, we focused on **eradicating Leukosis viruses** from all our pure-lines. Although HNL had the image of low mortality due to LL, we started to test 100% at the pedigree level and gradually eliminated LL from all parent flocks. This eradication contributed significantly to reaching 300+ eggs in 500-day random sample tests (Flock, 1984; Flock and Kühne, 1985) and became essential for the introduction of a feather-sexing White Leghorn cross in subsequent years.

After Pfizer acquired H&N in the early 1970s, it was agreed not to renew the license agreement beyond 1978. Lohmann continued to use the original H&N lines, but changed the trade name from "HNL Nick Chick" to **"Lohmann Selected Leghorn"** (LSL), while H&N became a competitor in the global market.

In 1978, Lohmann AG acquired Hy-Line from Pioneer - mainly to gain access to the US market - and expanded the breeding activities in Cuxhaven to develop competitive white-egg and brown-egg crosses for world-wide distribution. For many years, both sides benefitted from a productive exchange of ideas between geneticists with independent backgrounds. The Hy-Line and LTZ gene pools remained completely separate, which adds to the security for the EW Group.

1979-1989: Change from RRS to mRRS; LSL-F and LB as new products

RRS theory assumes that overdominance is important. This potentially valuable part of variation could not be utilized with traditional pure-breeding and would be lost if we paid any attention to pure-line production. The pure-line candidates for selection were therefore kept in large floor pens while their cross-line sisters were tested in single cages. With this system, we were unable to monitor changes in heterosis.

To learn more about genetic variation and heterosis in our White Leghorn lines, we produced simultaneously pure-line and cross-line progeny from all selected sires to be tested under identical conditions in cages. Results from generation 1973/74 including all F2 and backcross combinations were presented at the European Poultry Conference in Hamburg (Flock, 1980). The experimental design to produce all possible combinations required artificial insemination (Stöve, 1980). Having performance-tested pure-lines in cages opened the possibility to select on a combination of cross-line and pure-line information (mRRS) and to monitor how this would affect progress in pure-line and cross-line performance.

With high selection intensity it is not possible to avoid inbreeding completely, but in our RRS breeding program we **minimized inbreeding by keeping large populations**. In connection with the analysis of inbreeding during 25 years from pedigree data of our lines (Ameli, 1989; Flock *et al.*, 1991), we generated new data to estimate heterosis and inbreeding effects in generation 1986/87. As documented in a later paper (Flock, 2000), some heterosis for egg production was indeed "lost" after we introduced mRRS (as predicted from theory if overdominance is important), but the "loss" can be explained by the ceiling of 1 egg per day: more potential for improvement in the pure-lines (peaking initially around 80%) than in the F1 crosses (already peaking around 95%).

As shown in table 1, we estimated 43 eggs and 3.15 kg egg mass heterosis after 22 generations of RRS, of which only 30 eggs and 2.42 kg egg mass were left after 13 additional years of mRRS. Perhaps we could have made a little more progress in the commercial layer and even increased heterosis by ignoring pure-line information, but our general breeding goal was to produce saleable chickens, not to maximize heterosis. If deleterious genes in the pure-lines are the cause of dominance and overdominance, we should not hesitate to eliminate them by family selection. Improved pure-line performance actually helped us to increase selection intensity, and correlated improvement of parent performance reduced chick production cost for our distributors.

In a non-commercial long-term selection experiment we should have continued to apply RRS in its pure form to see how much more heterosis can be added, but commercial breeders have to focus on competitive parents and commercial layers, "heterosis" is not saleable.

Table 1: Estimates of heterosis in generations 1973/74 vs. 1986/87 (Flock, 2000)

	Livability %		Egg number/HH		Egg mass kg/HH	
	1973/74	1986/87	1973/74	1986/87	1973/74	1986/87
F1 crosses	91.8	97.8	292	318	17.67	19.37
Purelines	88.6	93.6	249	288	14.52	16.95
Diff. F1-PL	+3.2	+4.2	+43	+30	+3.15	+2.42
% Heterosis	4.5	4.5	17.1	10.2	23.1	14.3

During the 1970s, brown-egg and feather-sexing White Leghorn strains were gaining market shares. To benefit from the expanding world market, Lohmann Tierzucht expanded the R&D program, focusing on the development of a competitive brown-egg layer and feather-sexing White Leghorns to replace the vent-sexing HNL. In order to develop a feather-sexing variety of LSL, we started with introgression of the slow feathering gene K from an experimental White Leghorn line into our LSL female line, followed by 10 generations of backcrossing and balanced selection. Before field-testing the new LSL-F variety, Leukosis virus was eradicated from all lines.

Convinced that our white-egg layer LSL was superior to any brown-egg layer in terms of egg production, feed efficiency and egg quality, Lohmann started later than other breeders to invest into sufficient additional facilities for a strong brown-egg breeding program. We briefly tried to introduce a RIR x Sussex cross under the name "Lohmann Super Brown". After replacing the Sussex line with a more productive White Rock female line, "Lohmann Brown" started to catch up in terms of all major traits of interest: optimal egg size, attractive shell color, high number of saleable eggs, efficient feed conversion, low mortality, competitive parent performance.

Breeding goals were adapted to the increasing competition between white-egg and brown-egg layers: we focused on shell strength in white-egg layers and feed conversion in brown-egg layers in response to the common belief that white-egg layers are more efficient, while brown eggs have stronger shells. Within a few generations, LSL entries in German random sample tests exceeded 40 Newton in shell breaking strength, and Lohmann Brown entries approached 2.00 feed conversion ratio.

In 1989, when we celebrated “30 years egg-type breeding in Cuxhaven” **Art Heisdorf** was a prominent guest speaker on our program and told us “how it was in the olden days” (Heisdorf, 1969, 1990). He was obviously happy to see LTZ continuing a strong layer breeding program and H&N International part of the Lohmann group, and I am sure he would be even happier to see the continuing development to this day.

<u>1989-1999:</u> Increasing emphasis on sustainability

Sustainable breeding of laying hens is focused on long-term contributions to the quality of life for egg consumers and producers worldwide, with appropriate attention to bird welfare and natural resources.

With increasing international sales of brown-egg and white-egg layers, Lohmann Tierzucht was confronted with different regional priorities and sometimes opposite ideas of customers, especially when it came to optimum egg weight and how to assess feed efficiency. Intensive communication with customers during periods of changing egg and feed prices or new disease problems helped us to understand the global egg industry better and to adjust priorities of our selection programs. It soon became obvious that we needed more than one white-egg and one brown-egg cross to satisfy different regional demand.

During my first decade in Cuxhaven (1969-79) we focused on one product for the European white-egg market: the HNL Nick Chick. During the second decade (1979-89) we introduced the feather-sexing LSL, entered the global brown-egg market, focused on feed efficiency and adapted egg weight to market needs. During my third decade in Cuxhaven (1989-99) Rudolf Preisinger joined our genetics team and helped to refine our routines, introduced new techniques and fresh ideas. I could then afford to spend more time reading and listening to people outside our mainstream business.

Sustainability became a public issue, and we as primary breeders were confronted with the question whether our breeding methods were compatible with society demands such as: (1) transparency of food production from farm to fork and from primary breeder to the commercial product; (2) husbandry conditions compatible with ethical standards of society; (3) minimal pollution of the environment; (4) preservation of genetic diversity; (4) long-term perspectives for adequate nutrition of a growing world population and increasing competition for land to be used for food, feed or fuel production. Selection for improved feed efficiency has made a substantial contribution to optimize the use of resources and minimize pollution of the environment. Selection against cannibalism has made egg production in non-cage systems easier. Our work on the genetics of osteoporosis in laying hens also suggests a reduction of bone breakage (Fleming *et al.*, 1997).

Active participation in public research is a “give and take” and more can be gained by transparency than by secrecy. Details of our breeding programs in Cuxhaven have been published extensively over the years (e.g. recently by Flock *et al.*, 2008). Sustainable farm animal breeding as defined in the European FABRE TP project (2008) for different species of farm animals includes principles we have been following for decades in our breeding programs (Flock, 1994; Flock and Preisinger, 2002).

Developments during the most recent ten year period from 1999 - 2009 will be reviewed in a follow-up paper by R. Preisinger in a future issue of Lohmann Information.

Zusammenfassung

Ein Rückblick auf die Legehennenzucht in Cuxhaven von 1959-2009: glückliche Startbedingungen und gute Aussichten für die Zukunft

Beim Beginn der Zucht 1959 konnte Lohmann auf 10-jährige Erfahrungen im amerikanischen Zuchtbetrieb H&N aufbauen. Im Rahmen eines Lizenzvertrages wurde das komplette Know-how einschließlich reiner Linien importiert. Bis Mitte der 1970er Jahre war das HNL-Zuchtprogramm in Cuxhaven eine Kopie der Basis in den USA, lediglich das Leistungsprofil sollte sich am deutschen Eiermarkt orientieren. Nach Ablauf des Lizenzvertrages wurden die züchterischen Aktivitäten erweitert und neue Wege in der Züchtung beschritten. Wesentliche Entwicklungen waren (1) wettbewerbsfähige braune Legehybriden; (2) federsexbare weiße Legehybriden; (3) nach Eigewicht differenzierte weiße und braune Linienkombinationen; (4) verbesserte Elterntierleistungen; (5) Freiheit von übertragbaren Krankheitserregern (Leukose-Viren, Mykoplasmen, Salmonellen); und (6) erweitertes Kommunikationsnetz mit Kunden.

In dieser Übersicht werden Schwerpunkte der Züchtung aus den vergangenen fünf Dekaden dargestellt. Wer sich ausführlicher in deutscher Sprache über die Entwicklung der modernen Legehennenzucht informieren möchte, sei auf das Kapitel „Praktische Legehennenzüchtung“ (Flock, Schmutz und Preisinger, 2008) in Brade, Flachowsky und Schrader (Ed.) verwiesen.

Literature

Ameli, H., 1989: Inzucht- und Heterosiseffekte sowie genetische Parameter in zwei langjährig reziproker rekurrenter Selektion unterworfenen Weißen Leghornlinien (LSL) und ihren reziproken Kreuzungen. Diss. Göttingen.

Ameli, H., D.K. Flock and P. Glodek, 1991: Cumulative inbreeding in commercial White Leghorn lines under long-term reciprocal recurrent selection. Brit. Poultry Sci. 32: 439 – 449.

Bell, A.E., 1972: More on reciprocal recurrent selection. Proc. Nat. Breeders' Roundtable, Kansas City.

Cole, .F. and F.B. Hutt, 1973: Selection and heterosis in Cornell White Leghorns: A review, with special consideration of interstrain hybrids. Animal Breeding Abstr. 41, 103-118.

Comstock, R.E., H.F. Robinson and P.H. Harvey, 1949: A breeding procedure designed to make maximum use of both general and specific combining ability. Agronomy Jour. 41, 360-367.

Dickerson. G.E., 1955: Genetic slippage in response to selection for multiple objectives. Cold Spring Harbor Symposia on Quantitative Genetics and Biology XX

Fleming, R.H., S.C. Bishop, H.A. McCormack, D.K. Flock and C.C. Whitehead, 1997: Heritability of bone characteristics affecting osteoporosis in laying hens. Brit. Poulty Sci. 38, 521 – 523.

Flock, D.K., 1969: Genetische Arbeit am HNL Nick Chick. Nov. 1969.

Flock, D.K., 1974: Recent results on advantages of reciprocal recurrent selection (RRS) within split populations of White Leghorn strains. Proc. 1st World Congress on Genetics Applied to Livestock Production. Madrid, 925-930.

Flock, D.K., 1977: Genetic analysis of part-period egg production in a population of White Leghorns under long-term RRS. Zeitschr. für Tierzüchtung und Züchtungsbiologie 94, 89 – 103.

Flock, D.K., 1980: Heterosisschätzungen in einer Population von Weißen Leghorn nach langjähriger RRS. Proc. VIth European Poultry Conference, 57-63.

Flock, D.K., 1984: The new target - 300 eggs per year. Lohmann Information Int'l. No.6/1984, 1 – 5.

Flock, D.K., 1990: Recent progress in white-egg vs. brown-egg layers: shell quality and efficiency of egg production. Lohmann Information Int'l. 14/1990, 9 – 15.

Flock, D.K., 1991: Utopie oder greifbare Wirklichkeit: 20 kg Eimasse pro Henne und Jahr bei 2,00 Futterverwertung? März/April, 1 – 4.

Flock, D.K., 1994: Umweltschonende ('sustainable') landwirtschaftliche Produktion: was kann die Geflügelzucht dazu beitragen? Mai – Aug., 7 – 10.

Flock, D.K., 1998: Genetic-economic aspects of feed efficiency in laying hens. World's Poultry Science Journal, 54, 225-239.

Flock, D.K., 2000: Heterosisverlust durch Reinzucht nach langjähriger RRS in einer Population Weißer Leghorn (LSL). Züchtungskunde 72, 153-158.

Flock, D.K., H. Ameli and P. Glodek, 1991: Inbreeding and heterosis effects on quantitative traits in a White Leghorn population under long-term reciprocal recurrent selection. Brit. Poultry Sci. 32, 451 – 462.

Flock, D.K. and G. Heil, 2002: Eine Langzeitanalyse der Leistungsentwicklung weißer und brauner Legehybriden anhand von Ergebnissen der amtlichen deutschen Legeleistungsprüfungen von 1974/75 bis 1997/99. Archiv für Geflügelkunde 66, 1-20.

Flock, D.K., C.M. v. Krosigk, F. Pirchner und H. Landgraf, 1975: Genetische Veränderungen hinsichtlich Marek-Resistenz und Produktionseigenschaften in Leghornkreuzungen. Archiv für Geflügelkunde 39, 21 - 28

Flock, D.K. und W. Kühne, 1985: Deutsche Legeleistungsprüfungen 1984/85: Aussagefähigkeit durch Boykottversuch kaum beeinträchtigt. Nov./Dez., 7 – 10.

Flock, D.K. and R. Preisinger, 2002: Breeding plans for poultry with emphasis on sustainability. Proc. 7th World Congress on Genetics Applied to Livestock Production, Montpellier.

Flock, D.K., M. Schmutz und R. Preisinger, 2008: Praktische Legehennenzüchtung. In: Brade, Flachowsky und Schrader (Ed.) Legehuhnzucht und Eiererzeugung – Empfehlungen für die Praxis. S. 70-92.

Goodwin, K., G.E. Dickerson and W. Lamoreux, 1960: An experimental design for separating genetic and environmental changes in animal populations under selection. Biom. Genetics 117, Pergamon Press, New York.

Havenstein, G.B., 1969: A repeat mating control for estimating the genetic changes made by reciprocal recurrent selection. Proc. 18th National Breeders' Roundtable, Kansas City.

Heisdorf, A., 1969: Twenty years experience with reciprocal recurrent selection. Proc. National Breeders' Roundtable, Kansas City.

Heisdorf, A., 1990: What was it like in the olden days? Lohmann Information International 13/1990.

Henderson, C.R., O. Kempthorne, S.R. Searle and C.M. von Krosigk, 1959: The estimation of environmental and genetic trends from records subject to culling. Biometrics 15, 192-218.

Nordskog, A.W., H.L. French, C.R. Arboleda and D.W. Casey, 1972: Breeding for efficiency of egg production. World's Poultry Science Jour. 28, 175-188.

Pirchner, F., 1983: Genetics of feed efficiency in layers. Proc. Brit. Poultry Sci. Conf., Edinburgh.

Stöve, K., 1980: Die künstliche Besamung beim Huhn: Optimierung im Zuchtbetrieb. Diss. Göttingen.

Von Krosigk, C.M., G.B. Havenstein, D.K. Flock and C.F. McClary, 1972: Estimates of response to selection in populations of White Leghorns under reciprocal recurrent selection. 4th European Poultry Conference, London.

Willeke, H., 1972: Maximierung des Selektionsfortschrittes in der Züchtung von Legehybriden durch den Einsatz von Teillegeleistungen. Diss. Göttingen.

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