Livestock genetics

The Livestock Breeding/Genetics sector focuses on breeding material (e.g., live animals, semen, embryos) and reproductive technologies for industrial production. The dominant species include chickens, turkeys, pigs, cattle, and high-value farmed fish and seafood (salmon, tilapia, trout and shrimp). The industry typically selects for genetic traits to maximize production (i.e., rapid growth and high yields) and to facilitate production, processing and transport of uniform animal protein products on a massive scale. Industrial breeds can't survive without high-protein feeds, expensive medications and climate-controlled housing.

Leading Livestock Genetics Companies, 2020

Company/ Headquarters	Ownership and 2020 Sales, US$ million, where available	Species Activity / Subsidiaries
CP Group (Thailand) Charoen Pokphand Group Co., Ltd. is the major shareholder of Charoen Pokphand Foods (CP Foods)	The Chearavanont family, owners of CP Group, rank among the richest families in the world. CP Foods reported sales of 18,867 in 2020.[1]	One of the world's biggest industrial ag firms, including breeding, production and processing of poultry, pigs and shrimp. Operates in China, Vietnam, Taiwan, India, Turkey, Russia, Cambodia, Philippines, Laos and Poland.
Tyson Foods (USA)	Publicly-traded; 43,185 (all segments); Tyson doesn't report its genetics revenue separately; total chicken segment revenue 13,234[2]	Giant, vertically-integrated meat grower & packer. **Cobb-Vantress** subsidiary is leading breeder of chicken broilers; production capacity 47 million chickens per week (2021).[3]
Mowi (Norway)	Publicly-traded; 4,288[4]	World's largest producer of Atlantic salmon (estimated 20% global market share). Mowi claims "full internal control of our own genetics."[5] Presence in 25 countries,12,000 employees.
EW Group GmbH (Germany)	Private, family-owned holding group with 277 companies. EW Group generates an estimated 3,250 in annual sales (all companies).[6]	World's largest poultry breeding and genetics firm. Broilers/turkeys: **Aviagen** and its subsidiary, **Hubbard**. Layers: **Hy-Line International**; acquired **Novogen** from Groupe Grimaud, 12/2021. Leader in aquaculture genetics, especially salmon, trout, tilapia. **AquaGen**, farmed salmon and trout breeding. Largest tilapia breeder: **GenoMar Genetics**, **Aquabel, AquaAmerica**, **AquaPorto**, **Vaxxinova**.

Genus, plc (UK)	Publicly-traded, 708[7]	Swine and cattle genetics; acquired 39% stake in **Xelect,** aquaculture genetics company; acquired **Sergal** (boar genetics).
Groupe Grimaud (France)	Private	Specialty poultry, rabbit breeds. **Choice** (swine division) present in 37 countries. **Blue Genetics** (shrimp genetic selection).
Hendrix Genetics (Netherlands)	Private; 50% owned by private equity firm Paine Schwartz, with investment from Mitsui & Co. (Japan)	Turkeys, layers, traditional poultry, swine, salmon, trout and shrimp. Brands include: **Hybrid**, **ISA**, **Dekalb**, **Bovans**, **Shaver, Babcock**, **Hisex**, **SASSO, Hypor**, **Kona Bay**, **Troutlodge** and **Landcatch.** More than 3,500 employees; operations in more than 25 countries.

Source: ETC Group, from company reporting and industry news

Trends: chew on this

ETC finds:

- Ever increasing concentration in livestock genetics; multi-species breeders and private equity firms flock to aquaculture and fish genetics.
- China's supersized stake in livestock production/consumption/genetics.
- Widespread applications of digital technologies; genomics and gene editing research.

Despite the explosive growth in animal protein consumption worldwide and the massive contribution of industrial livestock to greenhouse gas emissions, very few are monitoring the degree to which a handful of transnational firms supply the breeding stock and reproductive technologies for an ever-increasing share of the world's industrial meat, milk, eggs and farmed fish/seafood.

Smaller and less visible than any other sector of the industrial food chain, the global market for livestock genetics will reach an estimated US$8.9 billion by 2024.[8] However, market intelligence on this sector is notoriously unreliable because many of the biggest players are privately held, highly secretive and rely on proprietary genetics. The threat of virulent diseases (e.g., highly pathogenic avian influenza, African swine fever) also requires stringent biosecurity measures that further shroud the livestock genetics industry in secrecy.

Globally, the widespread adoption of industrial livestock genetics is the primary driver of the loss of farm animal genetic diversity. With the introduction of industrial breeding stock, native animals are subject to rapid replacement or genetic dilution.

Although the value of the livestock genetics sector is relatively tiny (less than one-fifth the size of the global seed industry, for example), its proprietary genetic stock underpins a massive animal protein industry that has far-reaching impacts on greenhouse gas emissions and the environment (including water and soil pollution and the import of feed from countries with high levels of deforestation), livestock diversity, animal welfare and more. In this report we focus on three sub-sectors of industrial livestock genetics: poultry, swine and aquaculture.

INDUSTRIAL POULTRY BREEDERS

With an estimated market value of US$311 billion in 2020, poultry is the world's most popular animal protein, and consumption is growing at a faster rate than any other animal protein sector.[9] Analysts predict that the poultry meat market will hit US$422 billion by 2025.[10] Globally, poultry is expected to account for 41% of all the protein from meat sources by 2030.[11]

Poultry: Who Rules the Roost?

Commercial Poultry Genetics – Leading Companies by Sector, 2020

Broilers	Layers	Turkeys
EW Group (Germany) Hendrix Genetics (Netherlands) Tyson Foods (USA)	EW Group (Germany) Hendrix Genetics (Netherlands) Novogen (France) – *acquired by EW Group in 2021*	EW Group (Germany) Hendrix Genetics (Netherlands)

Source: ETC Group

Globally, just three companies control commercial poultry genetics, making it the most concentrated sector in the industrial food chain.

EW Group and **Hendrix Genetics** are both family-owned dynasties that focus on multi-species livestock genetics. (As of November 2021, Hendrix Genetics is 50% owned by private equity firm Paine Schwartz Partners.[12]) **Tyson Foods** (US$43 billion sales, 2020[13]) is the world's 5th largest food & beverage firm, and its wholly-owned subsidiary, **Cobb-Vantress**, is one of the world's three largest chicken meat (broilers) breeders.

Layers (chickens raised for eggs)
Two privately-held companies dominate worldwide:
(1) EW Group's **Hy-Line Genetics**; 2) **Hendrix Genetics**. The third multinational breeder of layer genetics, **Novogen** (formerly owned by France-based Groupe Grimaud), was acquired by EW Group in December 2021.[14]

China, the world's largest egg market, accounts for more than 40% of world egg production. In 2009, China's small farmers, not factory farms, produced over 75% of China's eggs.[15] Today, China's layers are rapidly industrializing. The vast majority of China's breeding stock for industrial laying hens comes from EW Group and Hendrix. In 2019, EW Group's Hy-Line Genetics estimated that its genetics accounted for a 60% share of the total Chinese layer market.[16]

Broilers (chickens raised for meat)
Two companies dominate industrial breeding worldwide: 1) **Tyson Foods** subsidiary: **Cobb-Vantress**; 2) EW Group (subsidiaries: **Aviagen; Hubbard**). In 2020, China produced 18.6 million metric tons of chicken, virtually all of it sourced from imported breeding stock.[17]

Turkeys
Two companies overwhelmingly dominate: **Hendrix Genetics** and **EW Group**. Smaller breeders that specialize in heritage breeds exist, but they do not compete on the same scale. The global turkey meat market peaked at almost US$13 billion in 2019.The U.S. accounts for about 45%, by volume, of worldwide production.[18]

Market Concentration in Poultry Genetics Breeds Dependence & Vulnerability

- Some countries and even continents depend on just two industrial breeders to provide the genetic stock for their chicken broiler industry.[19] According to Australia's Chicken Meat Federation, "almost all" of the country's broilers are based on two hybrid strains (commonly referred to as Ross and Cobb) that are owned by two companies (EW Group and Tyson, respectively).
- Even countries that are self-sufficient in production of chicken meat recognize that their dependence on imported breeding stock raises serious food security concerns. In 2020, Russia imported 98% of its broiler breeding stock from multinational firms.[20] Already in 2020, the Russian government feared "that possible sanctions affecting the import of crossbreeds could drive the Russian poultry industry to the edge of collapse."[21]
- In 2020, China produced 18.6 million metric tons of chicken, virtually all of it sourced from imported breeding stock. In December 2021, Chinese breeders unveiled three new domestically bred varieties that they hope will end the country's 17-year reliance on imported genetic resources.[22]

Industrial livestock genetics is penetrating all regions of the globe, even under the guise of "sustainable agriculture." For example, in some African and Asian countries, where indigenous birds still account for up to 80% of the poultry population, imports of poultry breeding stocks could be imminent.[23] In 2019 Hendrix Genetics was awarded a multi-year grant from the Bill & Melinda Gates Foundation for the Sustainable Access to Poultry Parental Stock to Africa (SAPPSA) program.[24] The goal is "to provide better breeding stock and genetic solutions" for poultry farmers in Sub-Saharan Africa (e.g., Mozambique, Zambia, Zimbabwe, Burkina Faso and more). According to Hendrix, the company provides disease-free breeding stock and instruction on how to build biosecure poultry housing that will allow for export of quality genetics.[25] The project claims that it will introduce crossbreeds that are suited to challenging environments[26] and even contribute to achieving the UN's Sustainable Development Goals.[27] The concern is that the introduction of imported stock and technologies will ultimately create greater dependence on capital intensive inputs, marginalize local livestock producers and accelerate the loss of indigenous breeds.

Fast-Growing Broiler Breeding Backfires

Today's industrial chicken broilers have become the world's most prolific and popular protein. But industrial breeding is also undermining the birds' fitness. The consolidation of industrial chicken breeding in the hands of just two companies has resulted in two fast-growing hybrid lines that account for 90% of all broiler chickens worldwide: 1) EW Group's Ross 308; and 2) Tyson's Cobb 500.[28] Despite their spectacular feed-conversion rates, the altered genetics of these birds has spawned a number of physical maladies that degrade the texture of chicken meat and harm animal welfare.[29] Many industrial chickens (including both Ross and Cobb) suffer from muscle myopathy, resulting in conditions such as "spaghetti breast," "woody breast" and "white striping disease." When the birds gain weight too quickly their circulation systems can't keep pace. Portions of the breast become dead tissue because they don't have adequate blood supply. Woody breast syndrome causes muscle tissue to harden. (In 2016, the *Wall Street Journal* reported that 5-10% of boneless chicken breast fillets worldwide were affected by woody breast.)[30] Spaghetti breast results in soft and mushy muscle fibre that comes apart in stringy sections. When birds are affected with these muscle disorders, the low-quality meat must be discarded or sold at a discount. Some heavy, large-breasted birds are developing an additional health problem: subcutaneous cellulitis, a condition that results from sitting in damp manure.[31] Food processors are now under increasing pressure from the public to sell "humanely raised meat" – including demand for "slower growing broilers." But it takes time to modify global flocks; according to one industry spokesperson, there's a three-to-five-year gap between genetic selections made at the pedigree level and the chicken on your plate.[32]

The Weakest Link

Almost 10 years ago, FAO warned that "livestock health is the weakest link in our global health chain."[33] Over 70% of novel human diseases that have emerged in recent decades are of animal origin,[34] and factory farms are incubators for zoonotic diseases (those transmitted from animals to humans). The genetically-uniform traits that underpin the spectacular growth of industrial livestock breeds is precisely what makes these flocks and herds exceptionally vulnerable to disease outbreaks. One veterinarian describes the threat of avian influenza to industrial chickens: "They all have the same immune system, or lack of an immune system, so once a virus gets inside a barn, it's going to spread like wildfire."[35] If a virus that emerges on a factory farm mutates, it can pose dire threats to human health. A 2018 study examining the emergence of 39 highly pathogenic avian viruses found that all but two came from industrial poultry farms.[36]

Gene Editing for Ethical Eggs?

Gene editing research is underway in the poultry sector worldwide, especially related to the development of vaccines (e.g., avian influenza, Marek's disease and infectious bursal disease). To sidestep public resistance to a controversial genetic engineering technology, advocates of gene editing are touting it as the key to improving animal welfare for factory farm animals.[37] Ironically, this means addressing standard industry practices that are now deemed "unethical." For example, the layer chicken industry disposes of 4 billion day-old male chicks per year.[38] Research teams in the UK, Australia and Israel are exploring the use of CRISPR gene editing to control the sex of chicken offspring to dramatically reduce culling in the poultry industry.[39] If hens produce only female chicks, it would prevent the killing of billions of unwanted, day-old male chicks that are culled after hatching.[40] Germany and France have already passed laws to ban the culling of day-old chicks beginning in 2023. However, alternative methods of embryo sexing (e.g., sorting based on sex hormones; MRI scans) are being developed that do not involve genetic engineering.[41]

INDUSTRIAL SWINE GENETICS

Most swine genetic companies are privately-held, with limited financial disclosure requirements. That makes it hard to assess company-level performance and the sector's level of concentration. The UK's **Genus Plc**, which owns PIC (Pig Improvement Company) and is among the few publicly-traded animal genetics companies, claims 16% global market share for pig genetics.[42] Just like poultry breeders, pig breeders rely on a narrow range of uniform breeds to facilitate increasingly intensive livestock operations (because uniform breeds imply uniform feed and infrastructure requirements).[43]

Pig Virus Provides Pandemic Preview

In January 2020, when WHO began reporting on Covid-19, a highly transmissible and potentially deadly virus circulating in China,[44] the country's pork industry had been dealing with its own highly transmissible virus for more than a year. African Swine Fever (ASF) – a hemorrhagic disease in pigs that is almost always fatal – broke out in August 2018 and quickly spread; there is no vaccine and no effective treatment for ASF. The virus decimated China's pig population. In the first year of the virus outbreak, researchers estimate that more than 43 million pigs in China died of ASF or were culled to prevent AFS-transmission.[45] By the time the epidemic was (mostly[46]) reined in, in 2020, the toll amounted to as much as 60% of China's pig herd.[47] The world's biggest pork-consuming and pork-exporting country responded to the crisis, first, by securing imports for domestic consumption, then by restocking its breeding herd to recoup production capacity – at an estimated cost of US$60 billion.[48]

Throughout 2020, thousands of breeding sows and boars flew to China by chartered plane; it was a welcome lift to an airline industry languishing due to Covid-related travel restrictions.[49] China's record imports brought rewards for the biggest pig breeders outside China, though not indefinitely. **Axiom** (France), **Genus Plc** (UK), **Topigs Norsvin** (Netherlands) and **Genesus** (Canada) exported in record numbers; at the same time, Chinese companies began expanding their own production-capacity as pork prices peaked in late 2019 and early 2020.[50] By September 2020, China's **Muyuan Foods** had opened the world's largest pig production facility near Nanyang. The multistorey site can house 84,000 sows and aims to produce more than 2 million pigs per year.[51]

Fattening China's Pig Farms

The ASF epidemic also catalyzed a drastic reduction in the number of China's small-scale, family-owned pig farms,[52] a shift that had been on the government's agenda before the ASF outbreak and was already underway.[53] Just before the turn of this century, China was home to more pig diversity than any other country (with 72 breeds),[54] but, by 2005, 74% of China's pigs were raised in industrial systems.[55] With industrialization, one hybrid breed replaced breeds of different sizes and attributes previously raised on small family farms.[56]

In 2021, Canada's **Genesus** updated its rankings of the world's top 40 "mega producers" – that is, pork producers with more than 100,000 sows – based on late 2020 counts.[57] China has more companies on the list than any other country (15 of the 40), including all of the list's top five: **Muyuan Foods**, **Wens Group**, **WH Group (Smithfield Foods)**, **Zhenbang Group** and **New Hope Group**; state-owned **COFCO** is #18. Five of the 15 Chinese firms are on the list for the first time, suggesting the breakneck pace of industrialization and the breathtaking speed with which China re-stocked its herd, with an aim to (eventually) wean itself from foreign breeding stock. (**Genus Plc** claims it sells breeding material to one third of the top 50 pork producers in China[58] and receives royalties from its proprietary genetics based on "key performance variables," such as pig weight at slaughter.[59]) China's blockbuster swine market enticed Thailand's **CP Foods** to amass 43 swine-related firms in the country (39 swine farming operations and four pork processing companies) in a deal valued at more than US$4 billion.[60] The acquisitions give CP Foods a capacity of 7.2 million pigs annually in 22 of China's provinces.[61] CP Foods' massive investment in China follows its 2019 acquisition of Canadian pork processor **HyLife** for US$272 million.[62]

Smart Swine?

Pig farming's intensification also intensifies challenges to feeding, containing, monitoring, processing and sanitation, and, of course, new technologies are proposed to help overcome those challenges. A package of artificial intelligence technologies that process massive amounts of data in real-time includes electronic tagging, facial and voice recognition (to identify distressed piglet squeals) and heat-sensing. AI packages – such as Alibaba's "ET Agricultural Brain"[63] – are being used in the world's biggest swine operations.[64]

> "Given the computation time, the data required, the hardware infrastructure needed, and the cost, it currently makes sense to utilize AI only if you are raising millions of pigs, not just one or two… The logic is striking. A demand for pork drives industrialized farming of pigs, which increases disease transmission. The constant emergence of diseases drives the implementation of new technologies like AI pork farming. These technologies go on to make pork cheap, driving even more availability and demand… AI is not the balm to any problem—it is just one piece of the ever-hungry quest for scale." – from Xiaowei Wang, *Blockchain Chicken Farm and Other Stories of Tech from China's Countryside*

While companies apply artificial intelligence technologies to enable bigger and bigger swine operations, some companies are also aiming to apply genetic technologies to alter the pigs themselves. New 'gene-editing' technologies like CRISPR-Cas9 make it possible to delete or rearrange pieces of an animal's genetic material in order to 'engineer' particular traits, such as disease-resistance or heat-tolerance. Genus's PIC has produced hundreds of gene-edited pigs – with thousands of progeny – that have been engineered to resist the virus that causes Porcine Reproductive and Respiratory Syndrome (PRRS). PRRSv is highly infectious and affects pig farms in the U.S. particularly.[65] While Genus reports that its edited pigs are making their way through the regulatory process in both the U.S. and China, company researchers admit that newborn edited piglets exhibit the 'correct' edit only about 20 to 30% of the time.[66]

AQUACULTURE GENETICS /BREEDING

Industrial livestock breeders, as well as private equity investors,[67] are flocking to fish farming and genetics because aquaculture is booming worldwide, and the potential to apply genetic selection and genomics to high-value species is relatively untapped.

- Globally, since 2016, aquaculture has been the primary source of fish available for human consumption.[68] From 1990 to 2018, global aquaculture production shot up 527% and is projected to keep growing.[69]
- The global aquaculture market was valued at an estimated US$204 billion in 2020 and analysts predict it will reach US$262 billion by the end of 2026.[70]
- Asia is by far the world's largest and most diverse aquaculture producer, and China alone accounted for 58% of the global aquaculture volume and 59% of its value in 2017.[71]
- Multinational livestock genetics firms that conduct R&D in aquaculture are focusing on a handful of high-value aquaculture species: primarily salmon, shrimp, trout and tilapia. By contrast, aquaculture globally encompasses around 425 farmed species (fish, shellfish and seaweeds).[72]
- Only 11% of the world's total aquaculture harvest is traded internationally,[73] and it focuses on relatively few species from just a handful of countries. Salmon, shrimp, catfish and tilapia collectively account for about one-third of internationally traded seafood by value, but only 8% of global seafood production.[74]

Atlantic salmon is industrial fish farming's most profitable and high-tech superstar – generating an estimated US$18 billion in annual sales.[75] Norway and Chile are the world's largest producers. Similar to terrestrial factory farms, industrial salmon operations have become massive breeding grounds for environmental pollution, diseases and parasites.[76]

Big Data and Genomics

The application of genetics and genomics technologies to industrial aquaculture is the focus of both public and private sector research. Gene-editing (CRISPR Cas 9) experiments are underway worldwide, with most of the focus on traits such as faster growth, disease resistance and sterility.[77]

One target of gene editing is the goal of developing parasite-resistant salmon. Industrial salmon operations worldwide are plagued by parasites that feed on fishes' skin and blood, causing lesions and mass mortality in crowded pens. A team of Canadian and Japanese researchers are focusing on genes that confer resistance to sea lice in wild Pacific salmon, with the goal of using gene editing to engineer the same trait in farmed Atlantic salmon.[78]

Perhaps more fanciful, Chinese scientists are using gene editing to develop "bone free" carp species.[79] The prospect of "genetically filleted fish" is a complex, longer-term goal, but Chinese researchers have reportedly knocked out at least two genes that control boniness.[80]

CRISPR Salmon with Reversible Sterility: AKA Terminator

Every year hundreds of thousands of farmed Atlantic salmon escape into the wild.[81] The escape of salmon and the possible interbreeding with wild salmon threatens to pollute the wild gene pool and spread disease.[82] One focus of gene editing is the development of salmon that are engineered to be sterile so that escapees can't interbreed with wild salmon. In addition to biocontainment, engineered sterility offers, in theory, the additional benefit of protecting the company's proprietary fish stock.[83] A team of researchers in Norway is using gene editing (CRISPR-Cas9) to knock out the "*dead-end*" gene in salmon, yielding salmon embryos that lack germ cells and are hence sterile. By injecting the genetically sterile embryos with messenger RNA technology, the scientists have successfully restored the fish's fertility – allowing for the development of fertile broodstock that will produce sterile offspring for hatcheries. The research opens the door to "a possibility for large-scale production of germ-cell free Atlantic salmon offspring through the genetically sterile broodstock, which can pass the sterility trait on to the next generation."[84] For ETC Group, and anyone familiar with the history of Terminator seed technology, the prospect of commercializing gene-edited salmon with engineered sterility genes is a nightmare scenario: the engineered sterility is reversible and cannot function as a reliable biocontainment tool.[85] The gene-editing research on salmon sterility in Norway is still in early stages and has not yet undergone ecological impact assessment, regulatory review or public debate. The aquaculture genetics industry is – thus far – skittish about publicly endorsing controversial genetic engineering technologies.[86]

Industrial fish farms already employ a vast array of high-tech, data-intensive technologies at all levels of breeding, production and processing, including artificial intelligence and surveillance for biosecurity and tracing. For example, one of the world's largest salmon producers, Cermaq, is pioneering its iFarm in Norway that uses real-time facial recognition technology that reportedly allows identification of each individual salmon and ensures that the fish are healthy.[87] The technology is also designed to cut costs by monitoring sea lice.

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