The Peanut Foundation
Peanut Genome Initiative – Phase II, 2019-2022
February 7, 2019

Mission of the Foundation

The Peanut Foundation is the research-funding arm of the American Peanut Council. Its mission is to assume a leadership role in promoting, coordinating and funding an organized research and education plan that results in a more resilient and competitive U.S. peanut industry. We are the only funder of peanut production and processing research that represents the entire industry. Our board of directors represents the diversity of the industry including growers, shellers, manufacturers and allied industries. In addition to financially supporting relevant research, we also interact with government and university research institutions as well as other peanut organizations to communicate research needs and leverage additional funding opportunities. The Peanut Foundation focuses on production and processing research and should not be confused with The Peanut Institute which focuses on human nutrition research, although there may be areas of overlapping interests. The Peanut Foundation operates solely off contributions from the peanut industry.

Accomplishments of the Peanut Genome Initiative (Phase I, 2012-2017)

The U.S. peanut industry invested considerable time and money in the now completed Phase I - Peanut Genome Initiative (PGI-Phase I) and is poised to capitalize on that investment.

Phase I successfully accomplished two major objectives: 1) sequencing the genomes of cultivated peanut and its two progenitor wild species (the parents of all of today’s cultivated peanuts), and 2) development of high-quality genomic tools to support broad scale utilization of marker assisted selection (MAS) by peanut breeders. These are crucial achievements have enabled a new era of advancements in peanut productivity, profitability and sustainability.

Due to strong consumer concerns, the peanut industry has been reluctant to pursue any genetic improvements that would result in peanut products made from genetically modified organisms (GMOs). The Peanut Foundation has instead been committed to funding MAS research which required mapping of the peanut genome and the discovery of high-quality markers. Markers are places on the genome that confirm the presence of specific genes influencing relevant traits. Breeders use them to quickly select which breeding lines are worth pursuing and which can be discarded because they do not have the desired traits.

The PGI -Phase I was accomplished within the projected five years and a budget of $6M. All scientists involved in the effort agree that the final product is of extremely high quality. The peanut research community now has the capability to find beneficial genes in cultivated and wild peanuts that can lead to even greater yields, lower production costs, lower losses to disease, improved processing traits,
improved nutrition, improved safety, better flavor and virtually anything that is genetically controlled by the peanut plant.

For decades to come, PGI -Phase I accomplishments will lead to improved sustainability and profitability of every segment of the industry and maintain peanut’s competitiveness among other crop choices that farmers may have. Conventional breeding techniques have greatly improved the peanut cultivars we’ve utilized in recent decades, but the accomplishments of the PGI have opened doors for breeders to control peanut traits in a more precise and less time-consuming manner rather than by random and serendipitous reorganization of genes. These advances have been accomplished without using controversial and expensive GMO techniques.

Examples of MAS technologies that are already extremely useful for peanut breeders include markers for high oleic oil chemistry, early and late leafspot, tomato spotted wilt virus and root-knot nematode resistance. PGI -Phase I research has already led to the release of several new peanut varieties including Georgia 14N (Dr. Branch, UGA, use of the nematode resistance marker), Ole’ (Dr. Chamberlin, USDA, use of the high oleic marker in a Spanish variety), and TifNV-HiO/L (Dr. Holbrook, USDA, use of the nematode resistance and high oleic acid markers). During Phase I, scientists also discovered novel ways to incorporate genes from wild peanut species into modern cultivated peanut, greatly increasing the array of genes available to peanut breeders.

Where do we go from here?

Since completion of the PGI – Phase I, the Foundation has engaged in an extensive effort to listen to the peanut industry regarding their wishes for future research. The feedback was diverse, but we heard the need to focus on using our new genomic tools to address four major issues: disease resistance (initially focusing on leafspot), aflatoxin contamination, drought tolerance and flavor conservation/enhancement. Given what we heard from the industry, The Peanut Foundation proposes the following research plan which addresses these four issues and overarching subject matter (such as germplasm conservation and phenotyping) necessary to accomplish the primary goals. A well thought out plan is necessary to guide us through the complexity of research options which range from low to high probability of success and low to high cost. We think the PGI-Phase II plan is fundamentally sound. It reflects the wishes of the industry and is grounded in realistic goals defined by leading scientists. The plan is flexible and may be modified at any time in order to accommodate new information and funding as it evolves.

Peanut Genome Initiative - Phase II Research Plan (2019-2022)

We intend to continue our focus on marker assisted selection technologies that improve and speed the peanut breeding process and will not invest in GMO research at this time. We do see amazing potential in the recent advances in gene editing. While the USDA has ruled that gene editing does not result in a GMO, the European Union recently ruled that gene editing is a GMO technique. Therefore, given the importance of exports to U.S. peanut growers, shellers and manufacturers, we will not invest in gene editing research that would result in what the EU would consider a GMO peanut. However, we would
consider supporting research where gene editing is used only as a research tool that helps us understand how genes work.

We have invested heavily in the basic research that has given us a high-quality whole genome sequence of cultivated peanut and methodology to select desirable genes from not only domestic peanut but also wild species. While some foundational genome work may still be necessary to reach our goals, we now intend to transition to more application focused research targeting priority issues for our industry.

We intend to seek research proposals that target these new research priorities but will always be looking for other research opportunities that offer potential for a high return on investment.

**Proposed Research Target Areas**

**RESEARCH TARGET AREA NUMBER 1: Disease Resistance (initially focusing on leafspot)**

There are several key peanut diseases important to growers due to losses in yield and grade as well as increased input costs. Relative importance of these diseases varies by growing region, but nationally, leafspot is the most costly. Several gene regions affecting leafspot resistance have been identified in lines that have the wild species *Arachis cardenasi* in their pedigree, but there is also good evidence that different genes controlling resistance are also found in the cultivated *A. hypogaea* collection. Resistance is multigenic and complex, but with good phenotyping data, techniques are available to make significant progress by separating the components of resistance (infection, disease spread, pathogen reproduction, defoliation). The key leafspot resistance regions of the genome correspond to introgressions (genes introduced from a wild species) made many years ago without knowledge of its significance at that time. Several breeders are using markers in attempt to achieve levels of leafspot resistance never seen in previous cultivars. Promising lines are in various stages of backcrossing to achieve genetic stability. Some of these lines are currently being grown at the Foundation-supported winter nursery in Puerto Rico so that two generations per year can be generated. We see significant progress in this area as attainable within 2-4 years, with new cultivars available to growers within six years.

If high levels of late and early leafspot resistance are attained, it is estimated that U.S. growers would save $53,000,000 per year in production costs.

PGI -Phase I research has already identified useful markers for resistance to tomato spotted wilt and recent research is leading scientists to believe that markers for resistance to other diseases such as white mold and Sclerotinia blight are attainable in the near future. These markers will lead to future cultivars which would save significant production costs in geographic regions where these diseases are important.

Current research projects:

Useful leafspot resistance markers are already in use by breeders and we are funding several researchers who are looking to improve existing markers and find new sources of resistance.
**RESEARCH TARGET AREA NUMBER 2: Drought tolerance**

Rainfall is the key factor causing variation in peanut yields worldwide. Even with irrigation, yields can decline and production costs increase during extended hot, dry conditions. Tolerance to drought stress is difficult to measure because it is most likely controlled by many genes affecting numerous physical traits and metabolic pathways in the plant. The ultimate goal is a peanut that is more water efficient and which continues to put energy into making peanuts under less than ideal soil moisture conditions, not just survive a drought without producing peanuts. The Peanut Foundation has already invested in drought stress research and, although we see this as more of a long-term research investment, we believe significant advances in drought tolerance are attainable.

Although this research is difficult and has some risk of limited success, scientists tell us there are genetic traits that can be modified to improve water efficiency in peanut plants. It is estimated that U.S. growers would save over $69,000,000 in production costs and yield losses per year if better tolerance to drought was available in commercial varieties.

Current research projects:

Several Peanut Foundation-funded researchers and breeders are actively researching drought tolerance. Dr. Barry Tillman and other scientists at the University of Florida received a $500,000 NIFA grant of which $250,000 was co-funded by the Foundation. This NIFA grant would not have occurred without Peanut Foundation co-funding. The research protocol is a unique approach to breeding for drought tolerance. Dr. Burow (Texas Tech), Dr. Chen (Auburn) and others are also looking for improved drought tolerance markers.

**RESEARCH TARGET AREA NUMBER 3: Aflatoxin mitigation**

Decades of aflatoxin resistance research has generated valuable knowledge, but aflatoxin contamination continues to be a major cost for the industry. Genomic tools now give us unique methods to attack this serious issue. Like drought tolerance, we should recognize that research on aflatoxin is a longer-term investment. Ultimate advancements in aflatoxin mitigation may be the result of improved resistance by the plant to infection by the causal fungal pathogen (Aspergillus spp.), which may also be linked to improved drought tolerance. One particular peanut line continues to show significantly lower levels of aflatoxin contamination and work is underway to identify the genes controlling key processes affecting the pathogen-host relationship and aflatoxin production pathways. Whatever the mechanism, we feel new genomic tools offer the best hope for success.

Aflatoxin costs vary greatly per year, but on the average, the estimated cost of lost production in the U.S. totals about $25,000,000 per year. There are substantial additional costs to shellers and manufacturers in the form of remilling, blanching, extra freight, more peanuts going to lower value oil stock and possible destruction of contaminated final products.
Current research projects:

Dr. Ozias-Akins (UGA) is leading an effort to evaluate the genetic connections to resistance discovered in a specific germplasm. Again, it is difficult to predict where this line of research will lead, but the genomic tools now available give us new hope that genetic controls to aflatoxin resistance exist and can be used to mitigate ongoing problems for the peanut industry. Dr. Guo (USDA) continues to work with a team to evaluate metabolic pathways in the *Aspergillus* fungus and the host plant (corn and peanut) that are keys to how and why aflatoxin is produced under specific environmental conditions.

**RESEARCH TARGET AREA NUMBER 4: Flavor conservation/enhancement**

Flavor is another complex yet vitally important trait affecting consumer acceptance of our product. Flavor variation among existing cultivars is widely recognized, but not everyone agrees on what constitutes good peanut flavor. It is a function of genetic variation but also extrinsic factors such as storage, handling, roasting method and packaging. Trained taste panels have given us the best insight into the consumers response to flavor characteristics. Flavor data exists from analysis of voluntary entrants to the annual Uniform Peanut Performance Test, but for the most part, flavor has not been a target of breeding programs. We propose to build a database of flavor profiles among a diverse list of peanut germplasm, match that database to the growing database of peanut genotypes for precursors of flavor compounds, and ultimately discover markers that are associated with key flavor characteristics. This research program will be a long-term goal given our limited knowledge of the genetic control of flavor and the influence of pre- and post-harvest environments on flavor traits. While, in the short run, the industry may not be able to breed a peanut that everyone agrees has better flavor, perhaps we can identify key gene variants positively impacting flavor and avoid breeding lines that have inadvertently lost those gene variants.

Current research projects:

A new project lead by Dr. Adhikari (UGA) and Dr. Dean (USDA) is looking at phenotyping 20 commercial varieties for flavor, texture and oil chemistry traits.

**Overarching Research Support Investments Necessary to Solve These Issues**

*PeanutBase* - One of our key guiding principles has always been granting public access to all genomic data generated by Foundation research. Public access avoids licensing and proprietary ownership of traits generated from industry funding. PeanutBase is the web-based information storage system universally used for peanut genomics and genetic mapping data. The system is maintained by USDA and housed at Iowa State University. We will work with USDA to encourage more federal support and will continue to provide much-needed supplemental financial support from the peanut industry.

Current research projects:
Foundation funds currently help Dr. Ethalinda Cannon (Iowa State) and Dr. Steven Cannon (USDA) manage PeanutBase.

**Germplasm conservation, curation and genotyping** – The relatively low level of variation within cultivated peanut limits our ability to find new desirable traits. It’s from this small degree of variability in gene expression that breeders will find the desirable traits that will define future peanut cultivars. Therefore, it is critical to conserve and characterize all existing variability. Fortunately, there is an enormous amount of variability in gene expression within wild peanut species, and genomic tools now give us more access to those genes. So, conservation of wild species has become even more critical to future breeding advancements. We intend to support conservation, curation and genotyping activities and support free exchange of germplasm for scientific purposes.

Current research projects:

Along with the National Peanut Board, we are supporting the transfer of the valuable germplasm from Charles Simpson’s (Texas A&M) career collection to the USDA germplasm collection in Griffin, Georgia. We have funded the formation of a backup collection of wild peanut species at NCSU, led by Dr. Tom Stalker. The Peanut Foundation and the USAID Feed the Future Innovation Lab for Peanut are co-funding a project led by Dr. Peggy Ozias-Akins to genotype several thousand peanut accessions of African origin in the USDA collection, thereby helping expand the known diversity of peanut genes available to breeders.

**Phenotyping to support marker discovery and improvement** – Marker assisted breeding is dependent upon having high quality markers that indicate the presence of specific genes linked to specific traits. Marker discovery requires high quality genotypes of a diverse collection of peanut germplasm, but that data is useless without high quality phenotyping (documentation of the actual physical expression of the genes which are present). Phenotyping requires enormous amounts of time, resources and physical space compared to genotyping and is often the bottleneck to new variety development. We intend to continue support of large scale, multi-trait phenotyping projects. The development of structured populations which segregate traits into stable breeding lines available to breeders was supported by Peanut Foundation funds in the past, but there may be a need for new populations in the future. Development of structured populations will be integrated with the overall phenotyping effort.

Current research projects:

Dr. Holbrook (USDA) is managing a multi-scientist, multi-location and multi-trait phenotyping project and Dr. Guo (USDA) had led an effort to develop structured populations.

**Development of breeder support tools and breeder workshops to communicate new techniques** – The Peanut Foundation recently supported a breeder workshop on the use of markers in breeding and hope
to support more efforts to enable the use of genomic technology. There also is a need to develop new breeder-friendly tools to analyze breeding lines for the presence or absence of known markers and a need to develop populations that facilitate the incorporated of genes from wild species into cultivated peanut. Finally, as more traits are incorporated into peanut cultivars with MAS, there will be a need for development of techniques that help pyramid (stack) desirable traits into single cultivars.

**Scientific Meeting Support** – Free exchange of scientific information is vital to the advancement of research and that exchange can happen at small informal meetings or large formal international conferences. We intend to financially support key scientific peanut research meetings as necessary.

**How do we fund PGI - Phase II research?**

Research funding comes from various public and private sources. The Peanut Foundation will continue to play a leadership role in funding relevant research and communicating critical research needs to other funders. We consider contributions to be investments which will be returned to the industry many times over. The scientific data generated in Phase I is available worldwide. Translation of that information into valuable new peanut cultivars requires an infrastructure of physical and human resources and the United States has the capacity to capitalize on our new genomic tools.

We estimate that it will take a minimum of $600,000 per year to maintain the critical progress on current initiatives and capitalize on new opportunities outlined in this report. The more we invest, the sooner we can expect results. We intend to leverage grower, sheller, manufacturer and allied industry contributions to secure additional investments from other sources. If the financial responsibility is divided among growers, shellers and manufacturers (as was done in PGI -Phase I), each industry segment would need to contribute only $200,000 per year for the next four years. Although a smaller component of the industry, allied industries significantly contributed to the original PGI and we would seek their continued support to help us overcome shortfalls or, hopefully, supplement funding over the $600,000 goal. If successful, this funding level would result in $2,400,000 million over four years from the industry. This total is less than half of the amount spent on Phase I. Supplemental funds from allied industries and leveraged dollars from government (such as the NIFA matching program in which we have already participated) could add to this total.

The Peanut Foundation exists to support research that keeps the U.S. peanut industry competitive and resilient. The amazing history and progress of the U.S. peanut industry is the result of numerous advancements that were made possible by investments in research and science.

Our continuing research will build upon the discoveries and outputs from Phase I of the Peanut Genome Initiative.