# ARCTURUS THERAPEUTICS

Building the Next Generation of RNA Medicines

August 2020

### BUILDING INNOVATIVE RNA MEDICINES

### FORWARD LOOKING STATEMENTS

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# **Company Highlights**



#### **Arcturus is a Clinical-Stage mRNA Vaccines and Medicines Company**

#### **Publicly Traded (Nasdaq: ARCT)**

Headquarters: San Diego, CA

Number of Employees:104

Founded: 2013

#### **Promising Therapeutic Candidates**

- LUNAR-COV19 (COVID-19 Vaccine)
- LUNAR-OTC (Ornithine Transcarbamylase Deficiency)
- LUNAR-CF (Cystic Fibrosis)
- Additional Earlier Stage Programs



#### **Arcturus Technologies Validated by Multiple Strategic Partners**











Catalent.

### Proprietary mRNA Technologies Driving Promising Therapeutic Programs

UILDING INNOVATIVE

Broad and Strong Intellectual Property Portfolio

mRNA & STARR™ mRNA
mRNA Chemistry
mRNA Design & Modifications
mRNA Manufacturing Process
LUNAR® Delivery
Lipid Chemistry
Formulation Design
LUNAR® Drug Product Manufacturing
192 Patents & Patent Applications

Program	Indication		
LUNAR-COV19	COVID-19 Vaccine		
LUNAR-FLU	Flu Vaccine		
LUNAR-OTC	Ornithine Transcarbamylase (OTC) Deficiency		
LUNAR-CF	Cystic Fibrosis		
LUNAR-CV	Cardiovascular Disease		
ADDITIONAL E	ADDITIONAL EARLIER STAGE PROGRAMS		



# **Arcturus Pipeline of mRNA Medicines**

	Product Name	Indication	Route of Administration	Cell Target	Prevalence Worldwide	Anticipated Milestones
VACCINES	LUNAR-COV19 (ARCT-021)	COVID-19	Intramuscular	Myocytes & Dendritic Cells	Global	Phase 1/2 Initial Data Q4 2020
VACCINES	LUNAR-FLU	Influenza	Intramuscular	Myocytes & Dendritic Cells	Global	CTA 2021
HEPATIC	LUNAR-OTC (ARCT-810)	Ornithine Transcarbamylase Deficiency	Intravenous	Periportal Hepatocytes	> 10,000	Phase 1 Initial Data Q4 2020
RESPIRATORY	LUNAR-CF	Cystic Fibrosis	Inhaled	Bronchial Epithelial Cells	> 70,000	DC Selection 2020 IND 2021
TARGETED	LUNAR-CV	Cardiovascular Disease	Intravenous	Hepatocytes	~4,000 (HoFH) 3.5 Mill (HeFH)	CTA 2021

Multiple mRNA Therapeutic Programs in Clinical Development with Milestones in 2020

# BUILDING INNOVATIVE RNA MEDICINES

# **Partnerships Maximize Platform**

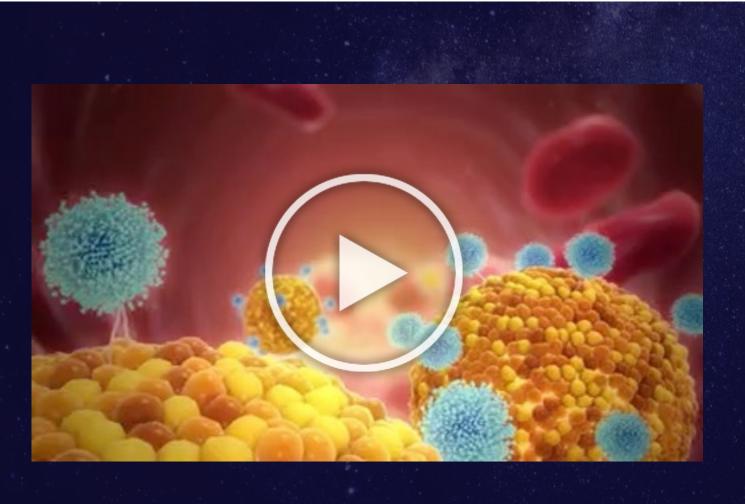
Program	Partner	Indication	
LUNAR-HBV	Johnson Johnson	Hepatitis B Virus (HBV)	
LUNAR-NASH	Takeda	Nonalcoholic Steatohepatitis (NASH)	
LUNAR-GSD3	ultrageny	Glycogen Storage Disease Type III	
LUNAR-RARE	ultrageny	Undisclosed Rare Disease	
LUNAR-RPL	Undisclosed Large Pharma	Vaccines	
LUNAR-AH Undisclosed Animal Health Pharma		Vaccines	

**Greater than \$1 Billion in Potential Milestones & Royalties** 

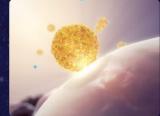
# **LUNAR®** Delivery Technology

Biodegradable, highly optimized for each cell type





**LUNAR Associates** with Cell Membrane



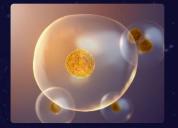
Enters Cell Via Endocytosis





Rapid Biodegradation of Vehicle

Lipid Particle in Endosome



Increased Acidity as Endosome Ages

RNA in Cytosol



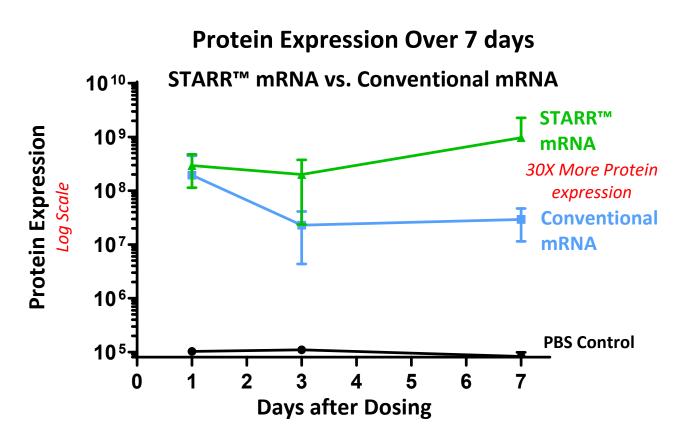
RNA Processing and Translation

# BUILDING INNOVATIVE RNA MEDICINES

### **STARR™ mRNA** Superior to Conventional mRNA

Self-Transcribing and Replicating mRNA (STARR) delivered with LUNAR® provides higher protein expression and potentially longer-lasting duration of protein expression in mouse

### **STARR™** Technology **30-Fold Higher Protein Expression STARR™ PBS** Conventional **Technology** Control **mRNA**



STARR™ mRNA technology together with LUNAR® delivery may enable single vaccine administration at very low dose



# **LUNAR-COV19 (ARCT-021) COVID-19 Vaccine Candidate**

### **Arcturus COVID-19 Vaccine Candidate has Significant Advantages**



- Duke-NUS Partnership Duke NUS Medical School
- mRNA Vaccine: Simple, No Adjuvants, No Viruses
- STARR™ mRNA: Produces 30X More Protein than Conventional mRNA
- LUNAR® Technology: Non-viral Delivery System



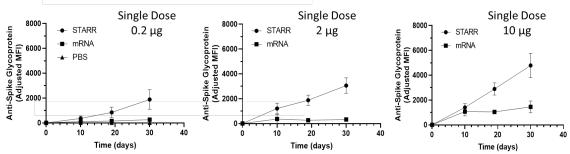
- Promising Preclinical Data: Neutralizing Antibodies & Cell-mediated Immunity
- Potential Single-Shot: Simpler Logistics for Vaccinating Large Populations
- Very Low Dose: Enables Rapid Global Scale-up
- Readily Manufactured: Arcturus Processes + Strategic Partnership Catalent.

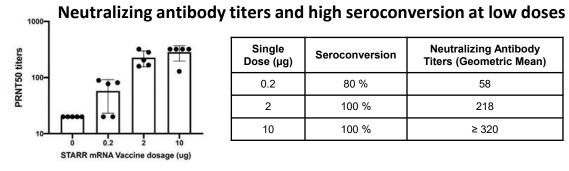
### Preclinical Data: Broad and Robust Immune Response



### **Humoral Immunity**

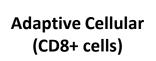
#### STARR™ induces more robust titers compared to conventional mRNA

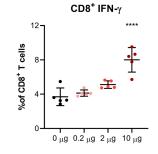




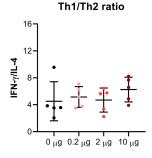
Single Dose (µg)	Seroconversion	Neutralizing Antibody Titers (Geometric Mean)
0.2	80 %	58
2	100 %	218
10	100 %	≥ 320

### **Cellular Immunity**





Balanced (Th1/Th2) immune response



- Single administration with a very low dose of Arcturus COVID vaccine results in potent immune reaction
- STARR™ mRNA generates neutralizing antibodies (anti-SARS-CoV-2 Spike Glycoprotein IgG) and a cellular T-cell mediated immune response at a much lower dose level compared to conventional mRNA



### Clinical Plan to Rapidly Advance LUNAR-COV19

- Approved to Proceed with Phase 1/2 Clinical Trial by Singapore Health Sciences Authority (HSA); Human dosing initiated (ref: clinicaltrials.gov)
- Up to 108 healthy volunteer adults to evaluate safety and immune response
- Trial design includes the elderly, and allows for rapid selection of dose to take forward into large registrational studies with lyophilized drug product
- With the Company's manufacturing partners, Arcturus is positioned to manufacture millions of doses in 2020 and potentially hundreds of millions of doses annually thereafter
- Arcturus retains global rights to LUNAR-COV19



# LUNAR-OTC (ARCT-810) Ornithine Transcarbamylase (OTC) Deficiency

# **OTC Deficiency Market Opportunity**





#### Ornithine Transcarbamylase (OTC) Deficiency: The most common urea cycle disorder

- The urea cycle converts neurotoxic ammonia to water-soluble urea that can be excreted in urine
- Deficiency in OTC causes elevated blood ammonia, which can lead to neurological damage, coma, and death
- 10,000 worldwide prevalence



#### **Unmet Medical Need**

- Present standard of care involves a strict diet (low protein, high fluid intake) plus ammonia scavengers (sodium phenylbutyrate)
- Present standard of care does not effectively prevent life-threatening spikes of ammonia
- Severe OTC Deficiency patients are typically referred for liver transplant, currently the only cure



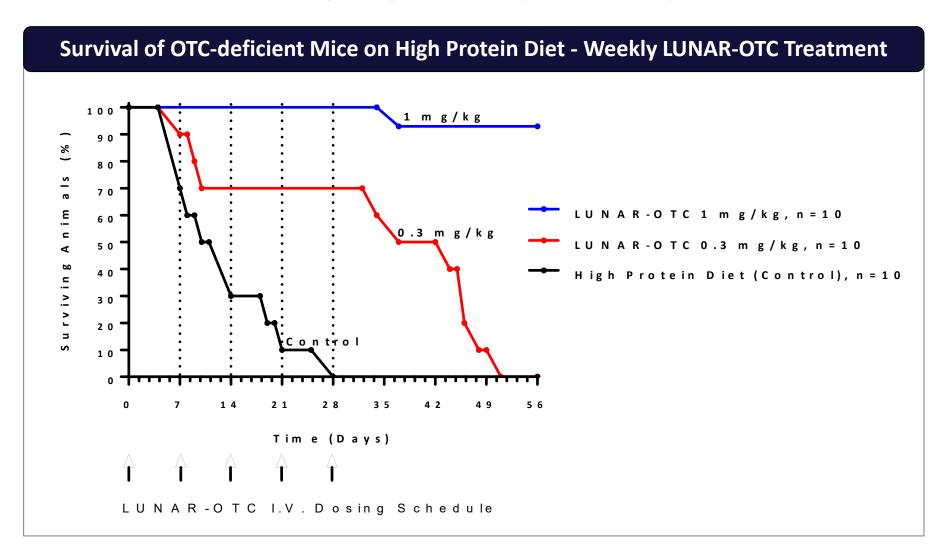
#### **LUNAR-OTC Aims to Restore Enzyme Function**

 Expression of OTC enzyme in liver has potential to restore normal urea cycle activity to detoxify ammonia, preventing neurological damage and removing need for liver transplantation

### **LUNAR-OTC**



Disease Normalization Following Single and Repeat Dosing in OTC Mouse Model

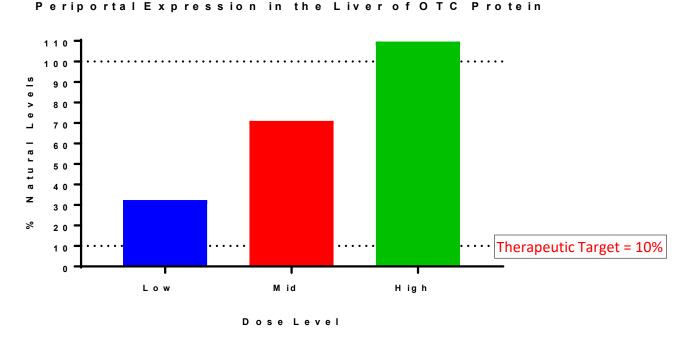


### **LUNAR-OTC**



Exceeds Therapeutic Target of 10% Enzyme Replacement at all Doses in OTC-Deficient Mouse Model

- OTCD impacts ureagenesis (ammonia detoxification)
- The main site of ureagenesis is the periportal region of the liver\*
- Establishing 10% of natural enzyme levels is expected to be therapeutically significant



\*Li, L. et al. PGC-1α Promotes Ureagenesis in Mouse Periportal Hepatocytes through SIRT3 and SIRT5 in Response to Glucagon. Scientific Reports. 6:24156 | DOI: 10.1038/srep24156, April 2016 \*Lamers, W.H., Hakvoort, T.B.M., and Köhler, E.S. 'Molecular Pathology of Liver Diseases' in Monga S.P.S. (ed.), MOLECULAR PATHOLOGY LIBRARY SERIES, Springer Publishing, New York, pp. 125-132 | DOI: 10.1007/978-1-4419-7107-4

LUNAR-OTC treatment increases OTC expression in mouse periportal hepatocytes (main site of ureagenesis)

### **ARCT-810 Phase 1/1b Study Ongoing**



#### **Two Single Ascending Dose Studies**

- New Zealand Phase 1 clinical trial began in early June in up to 30 healthy volunteers
  - 3 of 5 cohorts dosed
  - No significant AEs, lab value abnormalities or infusion related reactions despite no steroid premedication
  - On track to complete Q4 2020
- U.S. Phase 1b clinical trial in up to 12 stable OTC-deficient patients
  - Patient study up to 3 dose levels
  - All doses are within the anticipated range for therapeutic biological effect
  - On track to dose by Q4 2020
  - Timing of initial data dependent on COVID19 status

**Primary Goal**: Identify safest doses to take forward into multiple dose clinical trials

**Primary Endpoints**: Safety and tolerability

**Exploratory Endpoints:** Biomarkers include ureagenesis, plasma ammonia levels, plasma OTC enzyme activity, and urine orotic acid levels



## LUNAR-CF Cystic Fibrosis

# **Cystic Fibrosis Market Opportunity**





#### **Cystic Fibrosis: The most common rare disease in the United States**

- Caused by genetic mutations in the CFTR gene, resulting in aberrant flux of ions in and out of cells, causing thick mucus buildup in lung airways
- Chronic airway obstruction leads to infection and inflammation, which causes permanent tissue scarring and respiratory failure
- 70,000 worldwide prevalence



#### **Unmet Medical Need**

- No CFTR functional corrector is approved for treatment of all patients
- Present standard of care does not effectively prevent long-term effects of mucus accumulation.
   CF patients with late-stage loss of respiratory function require lung transplant



#### **LUNAR-CF Aims to Restore CFTR Function**

- An mRNA replacement therapy has the potential to deliver a new copy of CFTR into the lungs of CF patients, independent of any genotype
- A functional CFTR protein can restore chloride channel efflux in the airways, reducing mucus accumulation, tissue scarring and minimizing the progressive respiratory dysfunction observed in CF patients

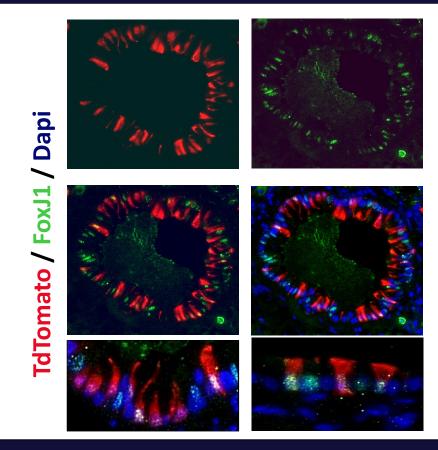
### Delivery of LUNAR®-mRNA to Rodent Airways



**Nebulization: Upper/Lower Airways** 

**LUNAR® + Luciferase mRNA** 

LUNAR® Targets Mice Epithelial Airways (TdTomato),
Including Ciliated Cells (TdTomato/FoxJ1)



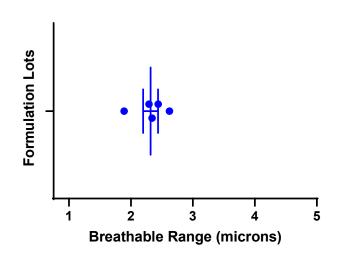
### LUNAR®, an aerosolized delivery platform for lung

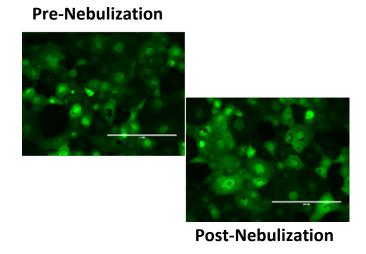


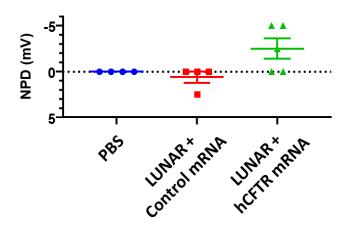
Aerosolized LUNAR® Particles are Breathable

Aerosolized LUNAR® -mRNA (EGFP) maintains activity

LUNAR®-mRNA (hCFTR) is biologically active *in vivo* (NPD, Mouse)







Aerosolized LUNAR® droplets are in the optimal breathable range (1-5 microns)

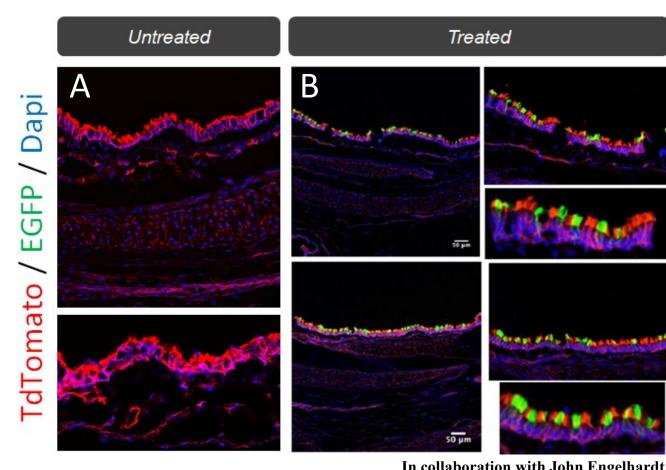
Aerosolized LUNAR® maintains activity as measured by EGFP protein expression & Nasal Potential Difference (NPD)

### Delivery of LUNAR®-mRNA into Epithelial Airways in Ferret

RNA MEDICINES

EGFP conversion in tracheal epithelial airways observed in the ROSA26TG Ferret model

- Ferrets are an excellent species for modeling certain human lung diseases\*
- Novel LUNAR® formulations of CRE mRNA were tested in a transgenic **ROSA26TG ferret model**
- **Activation of EGFP expression** indicates that LUNAR® targets epithelial airways
- **Anticipated next steps: Development Candidate Selection 2020 & IND Filing** 2021



In collaboration with John Engelhardt



### **LUNAR-CV**

Targeted Messenger RNA Therapeutic Cardiovascular Disease; LDL-Cholesterol Reduction

## **HoFH Market Opportunity**





#### **Homozygous Familial Hypercholesterolemia (HoFH):**

- Severely elevated LDL Cholesterol (LDL-C) levels increases risk for cardiovascular disease
- In ~90% of HoFH patients, the LDL receptor (LDL-R) is deficient or absent that leads to low or no LDL-C uptake and subsequent degradation in the liver
- ~4000 HoFH patients and 3.5 million heterozygous FH (HeFH) patients in G7



#### **Unmet Medical Need**

- Current cholesterol-lowering medications do not sufficiently lower LDL levels in HoFH
- Most individuals with HoFH experience severe coronary artery disease by their mid-20s and apheresis is recommended by 5 years-old
- High rate of coronary bypass surgery or death by the teenage years in HoFH



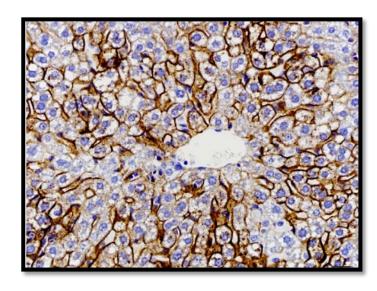
#### **LUNAR-CV** Aims to lower LDL-Cholesterol to Normal Levels

- Restoration of LDL-Receptor function with mRNA therapy in the liver has potential to lower plasma LDL-Cholesterol levels, preventing cardiovascular disease, removing need for apheresis
- Potential to treat HeFH patients who do not respond effectively to existing therapies

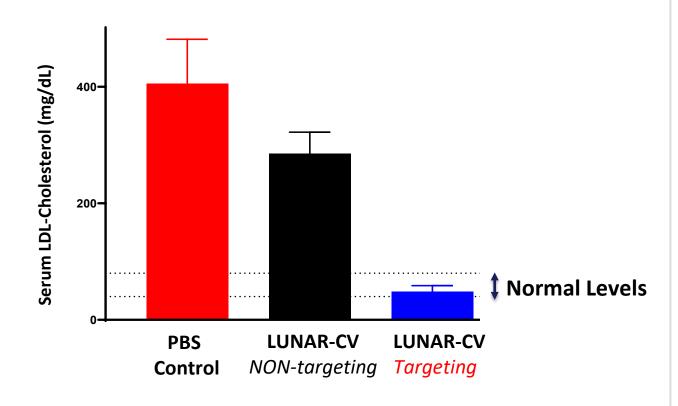
# LUNAR-CV, Targeted mRNA Therapeutic



Targets Hepatocytes in LDL Receptor Knock-out Mouse Model Result: LDL-Cholesterol is bound and cleared from the plasma



in vivo Proof-of-Concept:Hepatocytes Expressing LDL Receptors in LDL-R KO Mouse Model



LUNAR-CV Utilizes Arcturus Targeting LUNAR® Delivery Technology LUNAR-CV Treatment Results in LDL-Cholesterol Levels Being Restored to Normal



# **Moving Forward**

### **Anticipated Milestones and Cash Position**



LUNAR-COV19 (	ARCT-021)
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Phase 1/2 Initial Data Q4 2020

#### **LUNAR-FLU**

Clinical Trial Application Filing 2021

#### **LUNAR-OTC (ARCT-810)**

Phase 1 Initial Results Q4 2020

#### **LUNAR-CF**

Development Candidate Selection 2020
IND Application Filing 2021

#### **LUNAR-CV**

Clinical Trial Application Filing 2021

#### **Cash Position**

\$136.1 million as of June 30, 2020

\$186.3 million added in Q3 2020 from Public Offering

Sufficient to support operations for more than two years

#### ARCTURUS THERAPEUTICS

#### **Management Team**



Joseph E. Payne, MSc President & CEO



CSO & COO

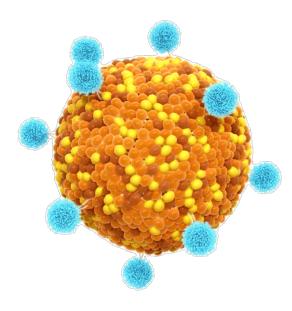


Pad Chivukula, Ph.D. Andrew Sassine, MBA CFO



Steve Hughes, M.D. Chief Development Officer







# MERCK







#### **Board of Directors**



Peter Farrell, Ph.D. Chairman of the Board



Karah Parschauer, JD Director of the Board



Edward W. Holmes, M.D. Director of the Board



James Barlow, MA Director of the Board



Magda Marquet, Ph.D. Director of the Board



Joseph E. Payne, MSc Director of the Board President & CEO



Director of the Board, CFO



Andrew Sassine, MBA Emil D. Kakkis, M.D., Ph.D. Board Advisor





















### **Appendix**

### **LUNAR-COV19 Preclinical Seroconversion Data**



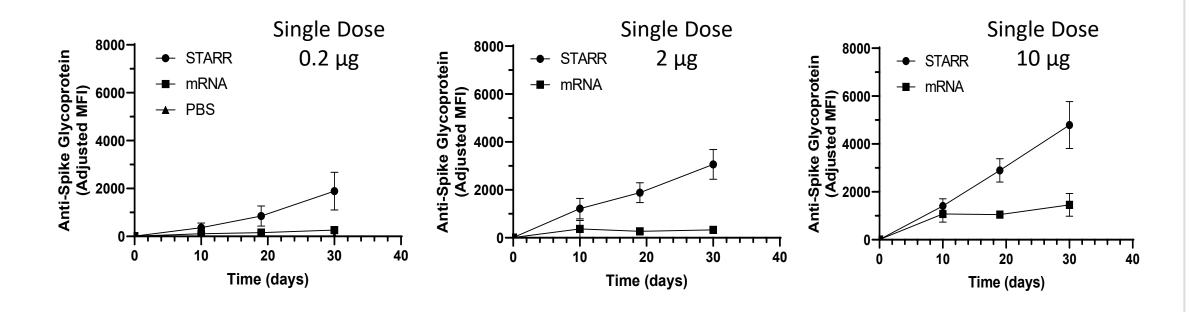
#### Seroconversion Rate (% of Animals) – STARR™ mRNA vs. Conventional mRNA

Single	LUNAR® Delivery			
Single	STARR™ r	nRNA (%)	Convention	al mRNA (%)
Dose (μg)	Day 10	Day 19	Day 10	Day 19
0.2	40	60	20	20
2	80	100	20	0
10	100	100	40	80

100% of mouse seroconverted by day 19 at a single low dose (2 μg)

## BUILDING INNOVATIVE RNA MEDICINES

### **Higher and More Robust Antibody Titers**

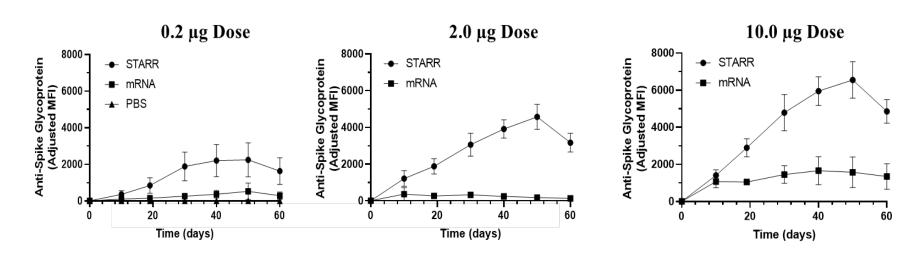


- **Higher titers** (anti-SARS-CoV-2 Spike Glycoprotein IgG) elicited by STARR™ mRNA
- **Titers continue to increase** with STARR™ mRNA; plateau is reached with conventional mRNA
- Dose dependent increase in IgG titers



### **Anti-Spike Protein Levels Continue to Increase Over 50 Days**

#### **Single Administration of LUNAR-COV19**



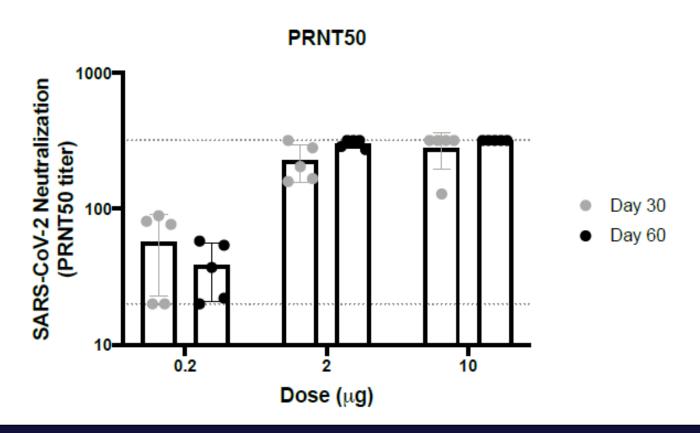
- **Higher titers** (anti-SARS-CoV-2 Spike Glycoprotein IgG) elicited by STARR™ mRNA
- Titers continue to increase over 50 days with STARR™ mRNA; plateau reached with conventional mRNA
- Dose dependent increase in IgG titers; Luminex bead assay, 1/2000 serum dilution





### **Neutralizing Antibodies Continue to Increase After 60 Days**

Single Administration (small dose, 2ug) of LUNAR-COV19



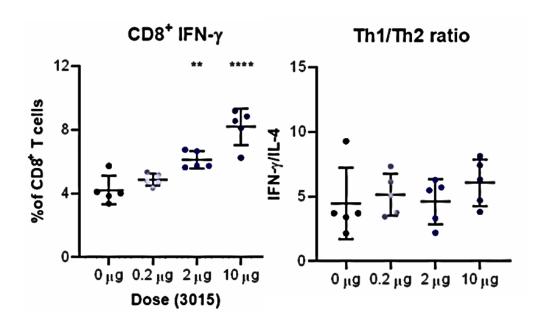
#### Virus neutralization assay:

Serum dilutions are incubated with SARS-CoV-2 virus, then added to cells. The cells die forming plaques, which are counted. The serum dilution that reduces the number of plaques by 50% is recorded (PRNT50). Maximum serum dilution tested was 1/320

After single dose (2 ug) of LUNAR-COV19, neutralizing antibodies continue to increase for 60 days (>300 titer)

### Arcturus Vaccine elicits a Balanced Cell Mediated Immune Response





RNA Dose (µg)	% IFN-g + CD8 <sup>+</sup> T Cells	CD4+ Th1/Th2 (IFN-g/IL4)
0.0	4.0	4.6
0.2	4.5	5.3
2.0	6.0	5.0
10.0	8.0	6.0

#### **Results Summary**

- RNA dose dependent increase in IFN-g positive CD8+ T-cells
- Th1 biased CD4<sup>+</sup> response and lack of change in Th1/Th2 ratio with increased RNA dose indicate balanced cell mediated immune response

# BUILDING INNOVATIVE RNA MEDICINES

### **LUNAR-COV19 Data Summary**

- Very low dose: Strong neutralizing antibody response with just a single dose of 0.2 10 µg
   STARR™ RNA
- Strong humoral response continuous increase in neutralizing antibodies beyond Day 30
- Strong T-cell response: dose responsive increase in IFN-g positive CD8+ T-cells
- Potential single shot simplifies vaccination campaigns
- Safety: balanced cellular immune response favorable profile to mitigate against immune pathology and Vaccine Induced Enhancement
- Superior immunogenic profile of STARR™ compared to conventional mRNA
- Adjuvant-free, Preservative-free, Antibiotic-free reduces public concerns

# **Arcturus Safety Profile**



#### **External Validation**

• Multiple strategic partnerships over many years confirms the positive potential safety profile of Arcturus LUNAR® and mRNA

#### Arcturus is committed to developing safe mRNA products

15 studies over several years with strategic partners

#### **Top Safety Concern for RNA Medicines is Delivery**

**Arcturus LUNAR® Delivery Technology is well tolerated in non-human primates (NHPs)** 



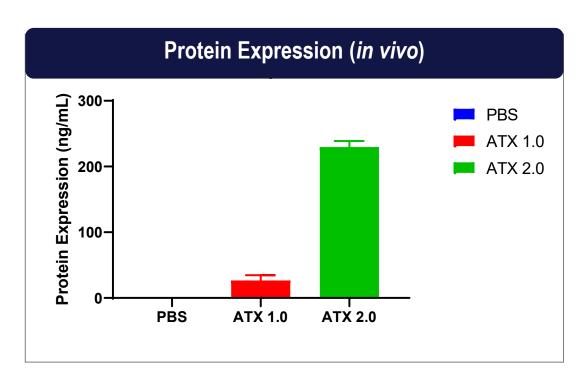
- √ @ 15 mg/kg single dose of non-coding siRNA
- ✓ @ 3 mg/kg x eight (8) weekly doses of non-coding siRNA (total of 24 mg/kg over 2 months)

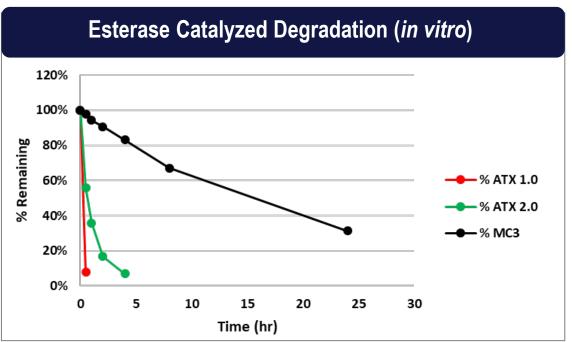
#### Arcturus mRNA chemistry shows promising efficacy and tolerability data

Efficacy of OTC mRNA in mouse model @ 0.1 – 1 mg/kg

# ATX Lipids are Effective and Biodegradable



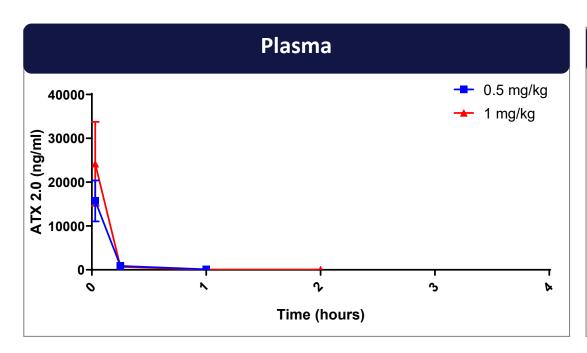


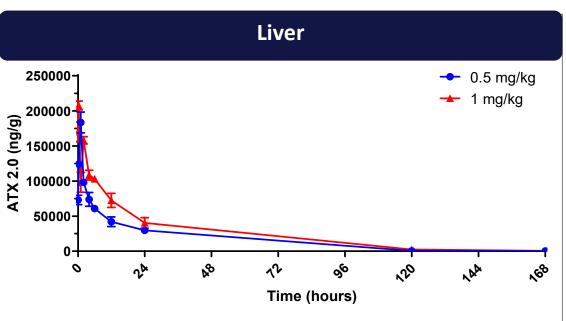


**Next Generation ATX Lipids Retain Degradability & Improve Delivery Efficiency** 

## BUILDING INNOVATIVE RNA MEDICINES

### ATX 2.0 Lipid is Biodegradable and Clears in vivo





- ATX Lipid (the major component in LUNAR® technology) is degraded in vivo
- ATX 2.0 Lipid Half-Life in the Liver is Approximately 20 hours

# Drug Substance: mRNA Design



**Arcturus' proprietary mRNA optimization platform** 

Sustained hEPO activity in NHPs upon repeat dosing

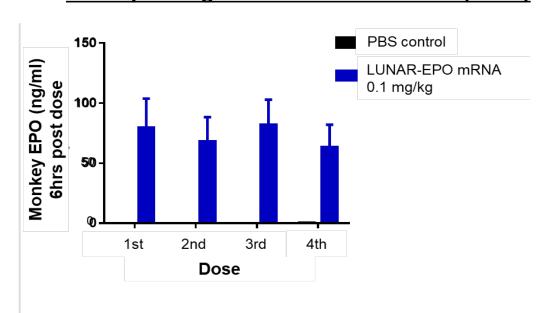
#### **Optimize Improve Protein Expression** mRNA sequence **Duration**

Chemistry **Process** 

**Functional Activity** 



#### Weekly Dosing in Non-Human Primates (NHPs)



**Proprietary mRNA Optimization Platform Demonstrates Sustained Activity Upon Repeat Dosing in NHPs** 

### Drug Substance (mRNA) Manufacturing



DNA Template Production

IVT and Capping Reaction

**Purification Process** 

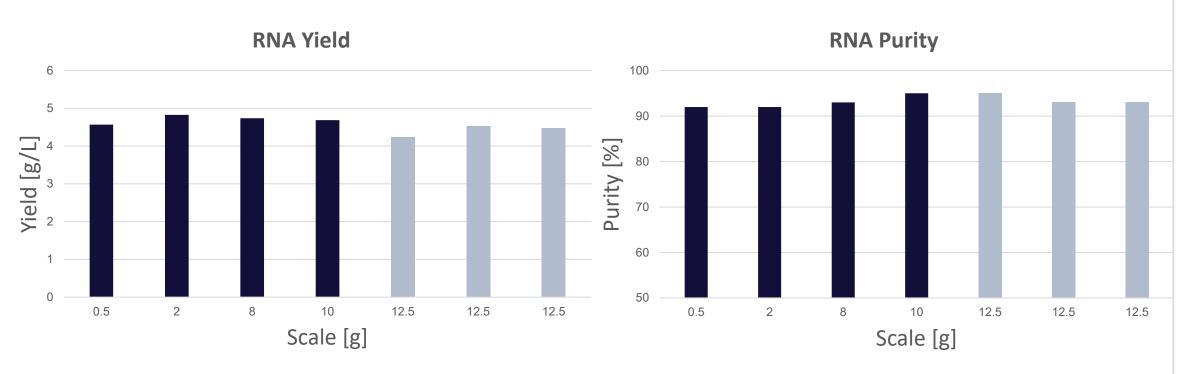
Buffer Exchange & Concentration

Features	Benefits
Optimized IVT Method	Reduced Cost; Higher Purity
Improved Capping Reaction	Reduced Cost of Goods
<b>Proprietary Purification Process</b>	Higher Purity in a Shorter Time
Efficient	Entire Process Less Than One Week
Scalable to > 1Kg	Access Large Patient Populations
Adaptable	Can Utilize a Variety of Modifications

Arcturus Internal non-GMP mRNA Production Capabilities: Up to 30 g in Less Than One Week

### Drug Substance (mRNA) Manufacturing





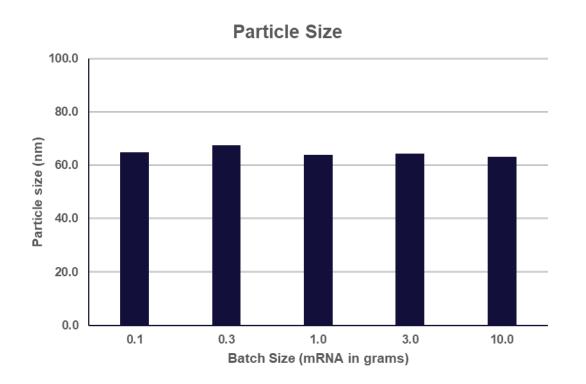
Non-GMP Lots Produced at Arcturus

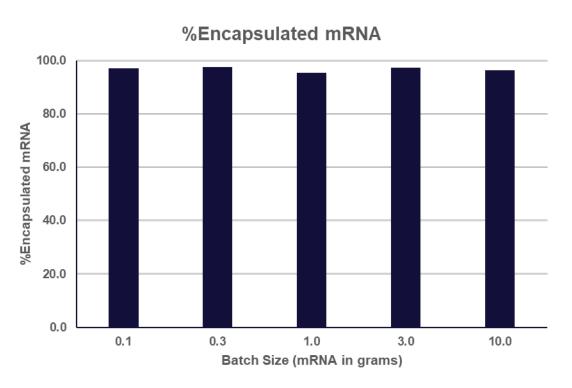
GMP Lots Produced at CMO as part of recent GMP campaign

Three 12.5 g lots produced in recent GMP campaign are of equivalent quality and yield

### Drug Product (LUNAR® + mRNA) Manufacturing







- Manufacturing of Drug Product Demonstrated up to Multigram Scale with Yields > 85%
- GMP Batch of LUNAR®-OTC (ARCT-810) Drug Product Manufactured and Released