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# A proposal for the addressing the needs of the pediatric pulmonary work force

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## 1. Introduction: In the future, Pediatric Pulmonologists will need more training in science, not less

Unprecedented opportunities and daunting challenges are anticipated that will determine the future of pediatric pulmonary medicine. Many issues exist regarding workforce shortages, developing and retaining successful clinician-scientists in academics, developing and applying novel therapeutic strategies and others. To address these issues and to optimize pediatric pulmonary training, a group of faculty from various institutions met in 2019 and proposed specific, long-term solutions to the emerging problems in the field. Input on these ideas was then solicited more broadly from faculty with relevant expertise and from recent trainees. The proposal presented here is a synthesis of these ideas.

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Pediatric pulmonology was among the first pediatric specialties to be grounded deliberately in science, requiring its fellows to demonstrate expertise in scientific inquiry (1). In the future, we will need more training in science, not less. Specifically, the scope of scientific inquiry will need to be broader to match the rapidly advancing research technology and its application. The proposal outlined below is designed both to help optimize the practices of current providers and to prepare the next generation to be leaders in pediatric care in the future. We are optimistic that this can be accomplished.

Our broad objectives are 1) to meet the pediatric subspecialty workforce demand by increasing interest and participation in pediatric pulmonary training; 2) to modernize training to ensure that future pediatric pulmonologists are prepared clinically and scientifically for the future of the field; 3) to train pediatric pulmonologists who add value in the future of pediatric healthcare, complemented by advanced practice providers (APPs) and artificial intelligence (AI) systems that are well-informed to optimize quality healthcare delivery; and 4) to decrease the cost and improve the quality of care provided to children with respiratory diseases.

Note that not all aspects are endorsed by all contributors. The proposal is meant simply to be a blueprint for discussion, experimentation and improvement, after the fashion advocated by Eric Reis in *The Lean Startup* (2). For example, this iterative process could be undertaken in the context of T32 programs. If successful, it could serve more broadly as a guide to modernize the field. It is intended to generate further discussion from academic programs across the United States.

## 2. Background

A number of specific problems have emerged with our current systems for training and for practice (Table 1). The first five of these are somewhat urgent and will be the focus here, though the other two are addressed as well. While the data regarding these problems have been carefully and thoughtfully documented over the course of the last decade (3–12), we briefly summarize here the issues we will address.

### 1. Physician shortage

The number of physicians selecting a career in pediatric pulmonology is low, and in many regions fails to meet the current clinical and academic demand. One problem may be the low salaries during fellowship, making debt repayment challenging. Another may be the need to create a pipeline of students interested in pediatric pulmonary research. A third is a vicious cycle of attrition. Specifically, pediatric pulmonologists are in short supply and are therefore over-worked; their actual expertise is often under-utilized. They do not have sufficient opportunities to interact with and to inspire trainees to enter the field; or to be at the leading edge of discovery. They must often defer important care to generalists who are at times less familiar with the basics of the field and with the recent advances. Trainee interest in the field suffers, worsening the physician shortage. The cycle repeats and worsens. In the current manuscript, we propose concrete solutions to all three of these problem.

### 2. We are not optimally preparing either faculty or trainees for the modern pace and breadth of scientific discovery

A much broader scope of research training is now needed than what is traditionally taught during fellowship. Traditional pediatric pulmonary research labs doing cell and molecular biology are now only a piece of a much larger puzzle that includes data sciences, 'omics' and personalized clinical trials (Table 2). Trainees need to learn to manage, understand and apply a massive and growing amount of new scientific knowledge (13). In the 1980's, the traditional pace of knowledge accumulation accelerated rapidly, from doubling every century to doubling every year (14). In the near future, estimates are that knowledge will double every 12 hours. If our specialty is prepared for this "knowledge tsunami" we will succeed in this radically changed landscape. It is upon us, and we need to plan. There is unprecedented opportunity, both to understand less common pulmonary disorders and to personalize therapies for more common ones. The pediatric pulmonologist of the (near) future will need to have traditional clinical skills, but will also need to understand data science from diverse sources; pathways to new drug and device development; and preclinical testing, including the nuances of designing and executing successful investigator-initiated trials. Thus, pediatric pulmonologists in training will need ***more, not less, training in science***. Increasing partnerships with APP's, and use of AI tools to handle the routine care, will allow physicians to spend more time focused on synthesizing new knowledge and applying it to personalized medicine. Right now, physicians in general are very poorly prepared; we are barely talking about how to do this.

### 3. Multiple factors discourage pediatric specialists from remaining in academics

Academic centers are not yet optimally leveraging cutting-edge discoveries and innovation. Clinical care services in a region are replicative, inefficient and expensive, and expertise is diluted. The current model is wasteful not ideal for patients. It prepares us poorly for the future. With increasing transparency relative to outcomes and value, patients and payers will be better able to make informed choices in the near future. A system with increased efficiency that delivers better value, more translational science and more efficient application of evidence-based medicine (EBM) can allow more optimal use of physician time and expertise. The pediatric pulmonary physician-scientist will also be able to use the full spectrum of scientific knowledge - from big data to personalized trials - to identify disease pathophysiology and to personalize care when needed. She or he will be part of networks of academic investigators and innovators that are ready to solve problems in a new era of medical science. However, this approach of the future is not yet a reality in most academic medical centers. As a first step, most programs will need to teach more science, discovery, innovation and translation.

### 4. More systematic training in sub-subspecialization is needed

Pediatric pulmonology is becoming more and more sub-subspecialized, with different individual physicians taking on roles managing CF, primary ciliary dyskinesia (PCD), neuromuscular disease and chronic respiratory insufficiency, interstitial lung disease (ILD), aerodigestive disorders, severe asthma, bronchopulmonary dysplasia (BPD), lung transplantation, pulmonary hypertension and others. However, pediatric pulmonology training does not ordinarily offer focused training in these areas. Sub-subspecialty training is currently a mixture of on-the-job training and research experience. Given the variability of these specialized clinical programs at academic medical centers, the exposure to such subspecialties is limited. Here, we envision subspecialty care as a system of efficient, consolidated care networks based in large, academic programs, with focused training for physicians. APP's will see the average new referral for new-onset cough and wheeze and do much of the routine care, under the supervision of general pulmonologists; while sub-subspecialists will work in each niche, in touch on a daily basis with the regional research infrastructure. Not every academic center will necessarily have every niche, for economy of scale, but there will be collaborative networks formed. However, this approach is still embryonic.

### 5. In most training programs, support for junior faculty after training does not last long enough to facilitate the establishment of a successful research career

Although more successful than those not trained in NHLBI-sponsored pediatric pulmonary T32 training programs, successful transition to K award funding is infrequent; and to R award funding is less frequent still. The reason is that trainees can still become over-involved in activities (for physicians, spending most of their time seeing routine patients and paying time taxes [15]) before they can get their research programs, publications, patents and start-ups on a firm footing (10–12). This problem is a major contributor to the shortage of physician-scientists (12).

## 3. Opportunities

While our field faces challenges, recent advances in science provide a broad range of opportunities. These contribute to our optimism about the future of the field. Examples are provided in Table 2.

## 4. Proposed solutions

### a. Optimize practices for the future

One example of how a pediatric pulmonology practice can be built and structured to take advantage of the opportunities listed in Table 2 is outlined provided in Appendix 1. Fundamentally, this sort of approach requires that we work together regionally as subspecialists to practice and to train. We need to push back against strategies that can add cost and dilute expertise. For example,

- Provide focused continuing education for existing faculty structured around training goals spelled out in Table 3, below.
- Work regionally at the grass roots level across institutional divides. Team up.
- Enlist and inform patients so that they understand real outcomes, not marketing slogans.
- Enlist and inform payers: having duplicate services across a region can dilute expertise, worsen outcomes and increase cost.

- Advocate for NIH and NSF to incentivize regional collaboration in practice and research to de-incentivize duplication, while recognizing the difficulty in doing so.
- Advocate for state governments to incentivize collaborations between regional institutions to achieve greater efficiencies.
- Cut costs and improve outcomes with the help of APP's in pulmonary divisions to provide state-of-the art EBM-based management of routine inpatients and outpatients. APPs will be less expensive than pulmonologists, and can provide routine services as well as pulmonologists trained primarily clinically.
- Demonstrate that expert, highly-trained pulmonary sub-subspecialty care provides better outcomes.
- Develop effective business models. In general, this will require divisional business leaders who work for division heads and have the latitude to think creatively about optimizing financial metrics.
- Iteratively and creatively improve our practices for the customer with pilot programs (such as Appendix 1; ref 2).

### b. Optimize work-force training for the future

**- Develop a financial base for training—**Funding for training initiatives can be raised from philanthropy – especially children's research foundations - and from industry, advocacy groups and the NIH. The Physician Scientist Development Program (PSDP) is an example of a program that can be useful. The issues outline here can be summarized for donors and grant funders, with specific requests made around preparing for the future. Specifics of financing training resources available will vary with time, grant support and institution..

**- Optimize pre-fellowship outreach to future trainees—**Recruiting pediatric pulmonary physician-scientists of the future will require inspiring and motivating learners at all levels (10–12). This is being addressed, in part, by NIH-funded research opportunities that include undergraduate training (e.g. T35) and residency training (e.g. R38). These provide necessary support and experiences of trainees that will favorably impact career choices. Pediatric pulmonologists will need to make the case for the priority of our specialty to undergraduates, medical students and residents. The CF "success story" needs to be told, highlighting the roles of physician-scientists and clinical researchers, and emphasizing women physicians and those from diverse backgrounds. Programs which host trainees at scientific conferences will need to be expanded, as these are often cited as transformative for participants. In addition, visibility of pediatric pulmonary specialists as role models for rewarding careers to students and residents is essential.

### - Improve training components

### i. A new approach for training pediatric pulmonary fellows

***Year 1.*** ***Clinical training will be the focus:*** For some specific programs and/or fellows, year 1 training can be mixed with year 2 training. The goal, though, is to remove inefficiencies in clinical training by consolidating training as much as possible. A foundational experience for clinical training of a pediatric pulmonary fellow can usually be accomplished in a year, as long as she or he has subsequent, ongoing exposure to continuity and to more unusual patients in a large program or consortium of programs. This will enable training for many fellows to be completed in three years, though many will want to go on to a fourth year for additional research expertise. Two total years of training will not be adequate in this model, because it would not allow adequate time for training in pulmonary science, experience with unusual conditions, or longitudinal continuity of care. An example of how the clinical training rotations and clinics could be accomplished efficiently is provided in Appendix 2.

***Didactic training:*** First, one month of training would be provided in pediatric pulmonary basic science, including development, anatomy, physiology, cell biology, genetics, etc. This would ideally be module-based computer training with faculty preceptors contributing from across the country, so the information quality would be uniform and so that repeated lectures do not need to be given to small numbers of trainees. This training would include initial training in requirements such as ethics, grant-writing, and statistics. After this month, the fellow can start being on call at night, being in continuity clinics and being in subspecialty clinics. Lead programs can model collaborative teleconferences and didactic lectures in which the most expert faculty in each subject, drawn from a number of academic institutions, provide teaching to post-graduate MD and PhD trainees in Pediatric Pulmonary from a number of different institutions. To participate, programs will need to demonstrate that they are collaborative, particularly regionally. This will improve the uniform quality of the material taught, and will lighten the burden of the teaching faculty at each institution. In the long run, this model could be expanded the academic institutions nationally and even internationally.

Second, a month devoted to (1) learning principles of learning evidence based medicine (EBM) as the standard of care for common pulmonary conditions is vital, and may be achieved with the use of the same modules or teleconferences provided to APPs (below), followed by (2) a week of hands-on training with tracheostomies and ventilators, followed (for physicians) by (3) a week in the bronchoscopy simulator learning for flexible bronchoscopy, laryngoscopy, tracheoscopy, and -in the future - interventional bronchoscopy; with standardized videos of pathology that could be shared between training programs. This time period would also include (4) a week of reading pulmonary function tests (PFT's), beginning with simple spirometry and advancing to complex plethysmography and exercise physiology, using samples in a standard module created from contributions for faculty in collaborating centers, or even across North America.

***Clinical training requirements:*** For the most part, these clinical requirements would be accomplished in the first year and will be tracked by an App or the online educational network. A suggested outline is provided in Appendix 2. The fellow would be required to maintain a log of research questions and ideas while on clinical service. This can be App-based.

***Year 2.*** ***Training in pulmonary science:*** The pediatric pulmonology fellow's training in science needs to be dramatically expanded from the paradigm of simply working in a cell biology lab for a while. The past approach does not provide the spectrum of scientific education that will be needed to be successful (to add value) clinically; nor does it usually lead to a successful academic career as a physician-scientist. Most of the clinical training can be accomplished in a year, but scientific training needs to increase, not decrease.

Clinically, the fellow will likely continue in twice-monthly half-day continuity clinics. If there are any of the specialty clinics or bronchoscopies that need to be made up from year one, these can be made up in year 2. The fellow would be on service for a very limited time in year 2. Overall, there would be a total of about 40 primarily clinical days in year 2.

***The focus of year 2 will be to learn modern research techniques: discovery and innovation:*** This learning will require collaboration and coordination with other departments and schools such as genetics, proteomics, bioinformatics, pharmacology, biomedical engineering, the tech transfer; and law schools, the business schools and contract research organizations. Fellows could go to other consortium/collaborative institutions for a week or more to gain experience if it is not available on site, or visit these sites in regular webinars.

Most importantly, the fellow will learn the whole spectrum of scientific inquiry relevant to pulmonary discovery. She or he will do modular learning with pre-and post-training exams on each of the areas of research listed in Table 3. The fellow will attend at least three didactic session on each (either on site or remotely). Understanding how these processes operate will be as important in the future as understanding basic physiology and technical skills.

The fellow will participate in at least three sessions analyzing exomic or whole genome sequencing data using appropriate software, helping to identify relevant target genes.

The fellow will also typically apply for research grant support, which can include loan repayment support.

Finally, depending on specific needs and interest, the fellow will spend at least 4 weeks more intensively in at least three of the following research environments. This will require careful structuring by the program administrator.

This part of the year will take 6–9 months, and can be done at the same time as the fellow's individual research project.

***Choosing a research project:*** Successful research projects that lead to successful careers as physician-scientists are most commonly those that are primarily thought up by the investigator. Thus, the fellow will spend two weeks doing extensive research on PubMed, ClinVar, United States Patent and Trademark office (USPTO), ClinicalTrials.gov and other databases regarding the research questions that have come to her or him during year one. These will be research questions that could be recorded in the App, or in other sites. If there are no realistic research questions that have come to mind, the research physician-scientists on faculty will help. The fellow will formulate an achievable research project with the program director, and the program director will help the fellow choose a strong, independently-funded and inspirational mentor appropriate for the topic. The mentor needs to have published several manuscripts and/or patents per year, and to have been senior author on at least one high-profile paper in the previous four years. There can be associate mentor(s) forming a multidisciplinary team (see below).

***Career development coaching:*** During this year, the fellow should also receive one-on-one coaching from the program director and mentors that carefully and deliberately addresses the career development objectives outlined in Appendix 3. Several additional resources are now available, including the Physician-Scientist Support Foundation (www.thepssf.org) (12)

### Year 3. The fellow will complete training and transition to successful faculty work as a general pulmonary or sub-subspecialty physician-scientist

***Compensation:*** The pay will be regular third year fellow salary plus a bonus for fellows planning to stay on faculty to do research.

This year will have several purposes:

1. To address any clinical deficits or incomplete items needed for the program director to be certain the candidate can practice adequately. This will include completing anything needed on the first year checklist.
2. To receive formal sub-subspecialty training in an area of interest, including spending time at partner programs for benchmarking and didactic training. For trainees going in to general pulmonary, one of the roles could be as medical director of the APP general pulmonology program.
3. To cover the clinical service as a fellow for either 4 or 8 weeks (depending on whether or not the fellow is writing a research grant/going into discovery and innovation).
4. To continue to attend at least twice monthly case conferences, presenting at least four. These will ensure the fellow has good experience with unusual, once/year type cases.
5. To complete her or his research, writing at least one paper and, if on a research track, writing an F grant (or equivalent, such as CF Foundation, American Thoracic Society (ATS), and industry). A loan repayment program (LRP) grant could also be written.
6. For those on a discovery and innovation track, to begin the first draft of a K-level award application.
7. To continue career development mentoring (see appendix 3).

**8.** Note that, for fellows desiring extra degree-level training (master's degree programs, for example) the second, third and/or fourth year can be intensively focused on this course and thesis work. This will interface well with the other objectives of years 3 and 4.

***Years 4–5*** ***(optional):*** For those on a discovery and innovation track, this will be an instructor-level position with 70% protected time to write papers, patents and grants; or to finish obtaining a master's degree, such as an MPH. Funding will come from the grants written in the second year, from resources from the children's hospital foundations and industry partners.

***Compensation*** will be that of an instructor or assistant professor, as institutionally appropriate.

Clinically, the physician-scientists will see patients in sub-subspecialty clinic and take call.

Most of the time will be spent with her/his mentor writing papers, patents and grants. At least one K-level grant will be submitted in the first six months; and a revised application will be prepared (if need be) in the following six months.

**2. Pediatric Respiratory Medicine Post-doctoral PhD trainees:** PhD scientists will become more and more important to the clinical mission for the reasons outlined above, and every effort should be made to supplement PhD income (through incentives, industry, startups, etc.). Post-graduate (and perhaps pre-graduate) PhD trainees can be in any field across the spectrum described in Year 2 MD training above. It is anticipated that specific academic institutions will have specific strengths, which are complementary to other regional institutions. The research training will be similar to that of second, third and fourth year clinical fellows as described above. These scientists will be included in T32 training programs and will become key members of each of the centers' or consortiums' team for discovery and innovation. Traditionally, there has been a significant pay gap between MD's and PhD. This culture will be slow to change.

**3. Pediatric pulmonary certification for APP's:** APP's will receive one year advanced provider training in pediatric pulmonology, with a certifying exam at the end. The salary of a fellow, with standard APP salary thereafter will apply.

The year will begin with a month of modules on general pulmonary techniques, including reading PFT's, doing allergy testing, providing spacer teaching, learning types of asthma and CF and BPD medications.

Next will be EBM-based medicine training modules detailing standard of care for non-severe asthma, CF, BPD, recurring infection (including PCD) and pulmonary hypertension. These will be identical to those in the second month for the MD fellows.

The APP will then train for ten months in general pulmonary clinic, and in covering the inpatient service. Ultimately, and APP may provide coverage of the pulmonary service during night shifts, for example.

The program will coordinate with the nursing school (or physician assistant [PA] school if the provider is a PA) to provide certification of expertise in Pediatric Pulmonary Care, as is done for Pediatric Hematology and Oncology, for example.

***Proposed implementation process of this proposal for pilot program(s):*** We recognize the many financial, logistical and practical challenges to overcome in implementing program changes such as the ones described in this proposal. However, a path to success might include the following steps:

1. Discuss the proposal with funders at lead institutions, philanthropic organizations, companies and the NIH. Develop a long-term business plan.
2. Write at least one multi-institutional T32 using this structure as a basis for training; pilot the program.
3. Publish the proposal (current document) to get input more broadly from Division Heads, Training Program Directors and recent American Board of Pediatrics [ABP] diplomates.
4. Develop regional training and subspecialty committees to promote complementary practices and training with balanced market share.
5. Lobby patients, payers and legislatures that a new, collaborative and innovative model is needed for the future, one that will save money and improve outcomes.
6. Lobby health systems to be more collaborative so that they will be well-positioned for the future.
7. Form national committees to create modules, ideally by filming and refining lectures at individual institutions, at the ATS, and at fellows’ boot camp.
8. Develop the training App.
9. Refine the program using lessons learned from the pilot program (2).
10. Once a base of experience has been built, meet again with financial stakeholders as described in point #1.
11. Plan a phase-in for the approach in consultation with other stakeholders such as the American Board of Pediatrics (ABP), American Academy of Pediatrics and the Society for Pediatric Research. For example, interaction with ABP might include updated questions on the in-training exam; and adjusted MOC credits so they are not just about EBM/QI, but all aspects of scientific discovery, innovation and personalized medicine; while at the same time controlling the MOC time burden.

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## Appendix 1.: A vision for how Pediatric Pulmonary practices could be structured in the future

In the current model, the general pulmonologist sees some CF patients and just about everything else in a general pulmonary clinic, with some attendings tending to see more of one disease than another, and efforts made to have APP's either manage details of difficult populations (Aerodigestive, PAH, etc.) or see routine patients. PhD's in the division study a particular aspect of airway biology, such as CF or ALI, and train fellows; but the interface between MD's and PhD's is typically weak. This type of model does not really leverage the strengths of the academic medical center, leaving it vulnerable to for-profit practices that want to take away some of the academic center's best providers and payer mix (16). We offer here one proposal to begin to address these problems.

The ideal program would be a large, free-standing academic program - or a regional consortium of smaller programs - with roughly the following composition:

1. Strong scientific links to academic departments or networks, including genetics/ epigenetics, a proteomic center, microbiome science, bioinformatics, cell and molecular biology, animal models, high-throughput drug screening, a biomedical engineering (BME )program, advanced imaging, commercialization assistance, at least one CRO, and a clinical trials core. These resources would be coordinated by a physician-scientist in the Pediatric Pulmonary faculty, and the scientists would meet regularly to discuss new opportunities in personalized care.

2. The ideal provider structure or consortium structure (if several academic centers work together in a region) per ~ 3–5 million population (1–3 major centers or consortia per state on average; less populous states would have one center or consortium per 3–4 states).

   10–12 pediatric pulmonologists with formal training in specific sub-sub specialties and/or who are physician-scientists and physician-educators. The following is a general template, with structures varying according to need and expertise.

   - Division head(s); more than one if it is a consortium with regional centers
   - General pulmonologist(s), physician-educators and physician administrators, managing APP's and training
   - Aerodigestive provider who may also become an interventional bronchoscopist
   - ILD/rare lung disease/genetics specialist, who may also do PCD and/or lung transplant
   - Trach/vent- BPD specialist, who may also run the neuromuscular program

- Severe asthma specialist in partnership with an academic allergist; preferably networked with state and local programs
- PAH specialist, working with a cardiologist, who may also specialize in pulmonary hemorrhage syndromes
- A PCD specialist; who may also be the ILD provider
- At least two CF specialists, who may also run clinical trials
- Chest wall, Sleep, Transplant
- At least one physician-scientist will manage the scientific interface

Additionally:

- 6 pediatric pulmonary trained APP's to run and bill for general pulmonary clinics and the inpatient service (helping to ensure quality and consistency), including a night shift APP
- RN's/case managers to manage details of subspecialty programs such as severe asthma, PAH, PCD, aerodigestive, etc.
- RT and social work support
- A database manager who tracks outcomes
- An innovative business manager who works for the division head, not for the practice plan.
- A strong telemedicine presence, particularly for follow-up visits in areas remote from the academic medical center. The importance of this component has recently been underscored by the COVID-19 pandemic (17).
- A grants/contracts specialist
- Clinical trials specialists and personnel

**3.** Close affiliation with other academic programs, including adult pulmonology, A/I/Rheumatology, a sleep and Pediatric ENT, GI, Heme-Onc, Pediatric Surgery, Orthopedics and Cardiology programs

**4.** A new model for billing. Advertise improved outcomes and cost savings to patients and payers. Though quite counter to current competitive market-share models, administrators would need to be incentivized to remove barriers to collaboration and allow academic centers to partner together. The disadvantage would be theoretical loss of competition-based improvements in service. But programs have institutional pride; competition affects fees charged for medical services surprisingly little; and the long-term goal often articulated for medical reimbursement is that it should be quality- and outcome-driven. A collaborative effort without redundancy will generally improve quality, as the cases will go to the center with the most expertise. This should ultimately improve reimbursement for each program housed primarily at one institution.

Note that the consortium model will require a new approach from administrators, chairs, USNWR, NIH training grant programs, Foundations (like PCD, CFF, etc.) and insurers. All of these possibilities have been initiated in one way or another, except with US News and World Report (USNWR). For example, if one of two medium-sized programs in a state wants to improve its USNWR score by starting a PCD program, but there is another PCD program already nearby in the same state. If the two programs are considered one for ranking, they don't have to increase the cost of care by starting a whole new, redundant program with a less-than-expert general pulmonologist at the helm. Each consortium member just does a share of the sub-subspecialization. If USNWR won't accept this model, then the Pediatric Pulmonary community might hypothetically consider developing its own rating system, maybe named for and supported by a famous philanthropist, for example: "The ___ Children's Respiratory Quality Report".

Measured outcomes will be patient and provider satisfaction, quality of care metrics, cost of care metrics, new disease entities identified, new treatments developed, new grants and new companies.

If pilot programs are successful, the data will be presented, and other training programs can adopt the model. Smaller programs can form training consortia. Improved market share, grant income and return on investment from intellectual property will encourage academic medical centers to invest in the proposed salary structure. Improved translational research outcomes will encourage NIH to invest in the salary structure. If there are areas in which the pilot programs are unsuccessful or do not meet customer needs, they will be improved (2).

## Appendix 2.: An example of how most clinical training could be accomplished in a year

The first year fellow would:

Attend at least 24 CF half-day clinics, and follow at least 30 CF inpatients on inpatient service (on service or consult)

Attend at least 12 half-day clinics in which severe asthma is managed, and follow at least 30 asthma inpatients (on service or, preferably, on consults)

Attend at least 12 technology-dependent or trach-vent clinics, including muscular dystrophy clinic and BPD clinic, and follow at least 30 inpatients ventilated for respiratory failure (including at least 10 each BPD and neuromuscular disease) on service or on consult.

Attend at least 12 half-day clinics for each of the following: ILD, Aerodigestive and PCD.

Attend at least 12 additional half-day clinics in subspecialties such as pulmonary hypertension, sickle cell, vascular malformations (HHT), alveolar hemorrhage and lung transplant, depending on the focus of the expertise in the program. Or network of programs.

Note that many programs will have combined clinics for efficiency, including “general pulmonary clinic” in which many of these subspecialty clinics well be combined. For example, severe asthma may be combined with PCD, or ILD may be combined with PCD. As long as the fellow gets exposure to these entities, she or he could attend 96 half-day clinics with combinations of entities.

Attend at least 24 half-day continuity clinics in which fellows will see routine referrals and follow those that need follow-up. In the post-COVID 19 era, telemedicine will probably be a significant part of this experience.

In total, this is 60 full days of clinic. If the clinics are chosen deliberately, less time will be wasted on redundancy and nonsevere disease.

The fellow would be required to attend and/or present at 24 divisional case conferences, journal clubs or morbidity/mortality conferences. This would include at least four presentations prepared by the fellow. For regional consortia, these can be networked on line.

The fellow would be required to have performed a satisfactory number of bronchoscopies to the satisfaction of the training director.

The fellow would be required to spend 20 weeks on inpatient service in the first year.

The fellow would be required to maintain a record of research ideas and of procedures on an App.

In total, this is approximately 11 months of work, though the clinical training could be accelerated and accomplished a bit sooner.

## Appendix 3.: Career development

This will occur throughout the training, but especially in year two. There will be material on skills for career development, resilience, choosing a mentor, avoiding burnout and minimizing time taxes (uncontested mandates adding ever-increasing administrative burdens to the physician-scientist; 15). Specifically, these Career Development topics will include things like:

- How to select a mentor.
- How to develop as a physician-scientist.
- How to organize thoughts/ideas.
- How to give effective presentations.
- How to plan a career deliberately.
- How to advocate for one’s self.
- How to address conflict.
- How do you deal with rejection and build resilience.
- How to have difficult conversations.

- How to build a research team.
- How to be successful as a woman or under-represented minority in science.
- How to apply for a job.
- How to negotiate a contract.
- How to push back against time taxes (15).

## References


1. Chernick V, Mellins RB Pediatric pulmonary: a developmental history in North America. Pediatr Res. 2004; 55(3):514–20 [PubMed: 14711898]
2. Reis E The lean startup: How today's entrepreneurs use continuous innovation to create radically successful businesses New York: Penguin Random House, 2011
3. Ferkol T, Zeitlin P, Abman S, Blaisdell CJ, O'Brodovich H. NHLBI training workshop report: the vanishing pediatric pulmonary investigator and recommendations for recovery. Lung. 2009;187(6):367–74 [PubMed: 19806399]
4. Collaco JM, Abman S. Evolving Challenges in Pediatric Pulmonary Medicine. New Opportunities to Reinvigorate the Field. American Journal of Respiratory and Critical Care Medicine. 2018; (198(6):724–279 [PubMed: 29648880]
5. Hayes D Jr. Pediatric pulmonary workforce: an aging dilemma. Chest. 2014;146(3):e119–e120 [PubMed: 25180745]
6. Cornfield DN. Society for Pediatric Research 2010 Presidential Address: Academic Pediatrics and the Narrative of Discovery. Pediatr Res. 2011;70(3):320–4 [PubMed: 21822098]
7. Weiss P, Mauer E, Gerber LM, Boyer D, Abramson EL. Funding sources and effects of limited funding in pediatric pulmonary fellowship programs. Pediatr Pulmonol. 2019 Oct. Epub ahead of print
8. Rubenstien RC, Kreindler JL. On preventing the extinction of the physician-scientist in pediatric pulmonary. Front Pediatr. 2014; 2:4 [PubMed: 24479109]
9. Hayes D Jr, Kopp BT, Kirkby S, Allen ED, McCoy KS. Attrition in Pediatric Pulmonary Fellowship. Pediatr Allergy Immunol Pulmonol. 2014; 27 (1): 34–35
10. Alvira CM, Steinhorn RH, Balistreri WF, Fineman JR, Oishi PE, Padbury JF, Kinsella JP, Abman SH. Enhancing the development and retention of physician-scientists in academic pediatrics: strategies for success. J Pediatr 2018; 200:277–84 [PubMed: 30055815]
11. Cornfield DN, Lane R, Abman SH. Creation and retention of the next generation of physician-scientists for child health research. JAMA 2013;309:1781–2 [PubMed: 23632720]
12. Jain MK, Cheung VG, Utz PJ, Kobilka BK, Yamada T, Lefkowitz R. Saving the Endangered Physician-Scientist - A Plan for Accelerating Medical Breakthroughs. N Engl J Med. 2019 381:399–402 [PubMed: 31365796]
13. Lee LY, Loscalzo J. Network medicine in pathobiology. Am J Pathol. 2019: 189:1311–1326 [PubMed: 31014954]
14. Accelerating Acceleration: Towards Tomorrow, Dymaxion Forum, Buckminster Fuller Institute. https://www.bfi.org/dymaxion-forum/2011/12/accelerating-acceleration-towards-tomorrow, viewed 18 February, 2020.
15. Surdam JO, Gaston B, Kalergis H. The burden of time taxes on pulmonary researchers and clinicians. AM J Respir Crit Care Med 191:A5208, 2015.
16. Johnston SC. Academic Medical Centers: Too Large for Their Own Health? JAMA. 2019 7 16;322(3)203–204. PMID: 3120613 [PubMed: 31206135]
17. Brough HA, Kalayci O, Sediva A Untersmayr E, Munblit D, Rodriquez Del Rio P, Vazquez-Ortiz M, Arasi S, Alvaro-Lozano M, Tsabouri S, Galli E, Beken B, Eigenmann PA. Managing childhood allergies and immunodeficiencies during respiratory virus epidemics – the 2020 COVID-19 pandemic. Pediatr Allergy Immunol. 2020 4 22 Epub ahead of print. PMID: 32319129

**Table 1.**

Needs to be addressed

| | |
|---|---|
| 1 | The physician shortage must be addressed |
| 2 | Physicians must have the knowledge base needed to keep up with the rapidly accelerating pace of scientific discovery |
| 3 | Increasingly, patients will need physicians to stay engaged in academics |
| 4 | More formal training in pediatric pulmonology sub-subspecialties is needed |
| 5 | Physician-scientists require support for research after fellowship |
| 6 | Team science needs to be developed and encouraged |
| 7 | Diversity must be increased, and unconscious bias decreased; a workforce is needed on how to accomplish this. |

**Table 2.**

Opportunities provided by academic medicine

| | |
|---|---|
| 1 | Artificial intelligence and machine learning |
| 2 | Rapidly advancing technology |
| 3 | Next generation ‘omics analyses |
| 4 | Advances in bioinformatics to apply big data and to help to manage the knowledge doubling rate |
| 5 | High throughput screening for small molecule discovery |
| 6 | Advances in gene editing and gene therapy |
| 7 | Single cell technologies |
| 8 | Accelerated drug discovery |
| 9 | Regenerative medicine and cell-based therapies |

**Table 3.**

Scientific training for pediatric pulmonology fellows.

| |
|---|
| • Big data collection. Whole genome sequencing (WGS) and/or exomics, transcriptomics/NextGen sequencing, epigenomics, proteomics, microbiomics, metabolomics and other methodologies. |
| • Bioinformatics, including programs for analyzing WGS and other databases; practice analyzing WGS and/or exomic data; AI and deep machine learning |
| • Target validation with cell and molecular biology, gene editing, transgenic animal models, biobanking, histology/microscopy. |
| • Target treatment development, including high-throughput screening, viral and other delivery vectors, stem cell therapy, aerosol science, basics of biomedical engineering principles. |
| • Intellectual property and principles of translation product development. Business modules (could be at the business school and/or law school). |
| • Requirements for preclinical testing (ideally at a contract research organization [CRO]). |
| • Requirements and processes for Phase 1, 2 and 3 clinical trials. |
| • Personalized medicine: applying big data findings to new therapeutic development in the clinic. |
| Other topics can include: |
| • Medical administration, accounting and clinical efficiency. |
| • Building a small business and/or working in industry. |
| • Implementation science and outcomes research. |
| • Environmental science as it relates to lung health. |
| • Epidemiology research. |